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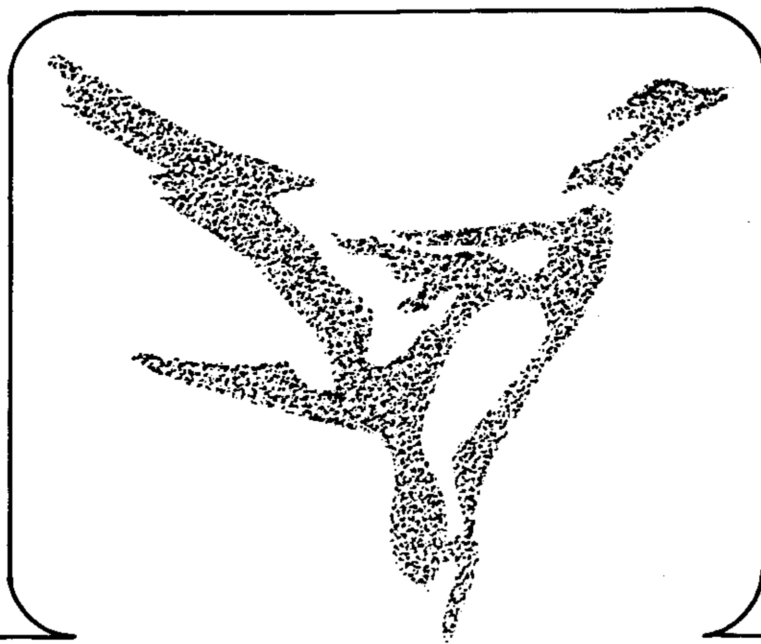
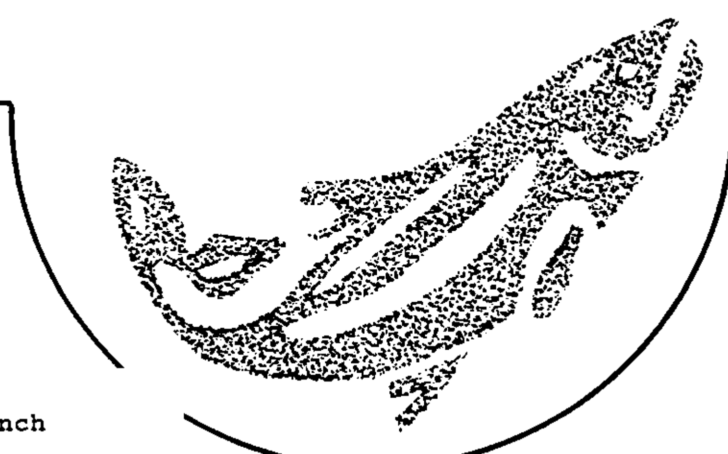
Lower Snake River
Fish and Wildlife Compensation

Status Of The Warmwater Fishery And The Potential Of Improving Warmwater Fish Habitat In The Lower Snake Reservoirs

January 1983





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A comprehensive survey of fish and anglers was conducted on the lower Snake River reservoirs, Washington during 1979 and 1980. Intensive sampling was conducted on Little Goose Reservoir with less effort on the remaining three reservoirs. Angler use was estimated to be about 46,000 hours in 1979 and 80,000 hours in 1980 in Little Goose Reservoir. Angler use was similar for Lower Granite, Little Goose, and Ice Harbor while Lower Monumental received lower use. Yield to the angler in Little Goose Reservoir was estimated to range from 1.5 to 2.7 kg/ha.

20.

Thirty-one species representing nine families and consisting of over 52,000 age I and older fish were collected. Information on mortality, movements, spawning, and food habits was generated on selected game and forage fishes. Larval and young-of-year fishes were sampled and habitat use and relative abundance approximated that of the adult fish.

Limnological characteristics of the reservoirs were evaluated. The occurrence of water temperatures that exceeded 22 C and dissolved oxygen levels below 4 mg/l suggested that these reservoirs should be managed for warm and cool water resident fishes and not resident salmonid fishes.

Executive Summary

of the Final Report

Status of the Warmwater Fishery and the Potential of Improving Warmwater Fish Habitat in the Lower Snake Reservoirs

by

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U.S. Army Corps of Engineers
Contract No. DACW68-79-C0057

January 1983

The purpose of this report is to summarize the Final Report, "Status of the Warmwater Fishery and the Potential of Improving Warmwater Fish Habitat in the Lower Snake Reservoirs," for the contract between the U.S. Army Corps of Engineers and the University of Idaho. The objective of this project was to "assess the status of the warmwater fishery and to determine the potential of improving warmwater fish habitat in lower Snake River reservoirs for the Snake River Compensation Plan." Specific subobjectives of the project were:

1. To assess angler attitudes and quantify angler use and catch in lower Snake River reservoirs;
2. To assess species composition, relative abundance, fish species associations, habitat preferences, and movement of fishes in lower Snake River reservoirs;
3. To evaluate food habits, age structure, and growth of selected warmwater fishes in lower Snake River reservoirs;
4. To evaluate reproductive cycles and spawning habitat preferences of selected warmwater fishes in lower Snake River reservoirs; and,
5. To correlate fish behavior with limnological characteristics of lower Snake River reservoirs.

INTRODUCTION

Settlement of the Snake River Basin has brought numerous changes to the area. Fish populations generally declined as a result of man's activities within the Basin. One of the major deleterious impacts to the native fish fauna was associated with dam construction. Dams altered the physical-chemical properties of the natural riverine systems which altered the biotic communities. One major change in the biotic community has been a shift from cold water resident and anadromous fishes to resident exotic warmwater fish complexes. As additional dams were constructed in the Basin, the anadromous stocks declined despite extensive mitigation efforts by resource management agencies. Also, the sports fishery within the Basin began to shift to resident warmwater fishes. This change was especially true in the lower Snake River. These biotic changes to warmwater fisheries in the lower Snake River caused concern among biologists. Major concerns were related to the interactions of resident species and anadromous salmonids, acceptance of the warmwater fishery by sports fishermen, and the composition of the warmwater fish stocks. As a result of these concerns, this study was initiated in February 1979.

STUDY AREA

The study area extended from Ice Harbor Dam near Pasco, Washington, upstream to Lewiston, Idaho. Four dams constructed on the lower Snake River impound water a distance of approximately 211 km (137 miles). The resulting reservoirs (downstream to upstream), Ice Harbor, Lower Monumental, Little Goose, and Lower Granite, generally are similar in morphometry and physical characteristics. As can be seen, Lower Granite is the longest reservoir, while Lower Monumental is the smallest. Mean depth is similar among Lower Granite, Little Goose, and Lower Monumental (about 17 m), while Ice Harbor averages about 3 m shallower (Fig. 1).

Because of the large size of the lower Snake River reservoirs and their similarities, we developed a habitat classification scheme for fish sampling. Major habitat types sampled on the lower Snake River reservoirs varied from tailwaters, shoal, gulch, deepwater, and embayments (Fig. 1). These habitats sampled for fish were as follows: Lower Granite - gulch, deepwater, shoal; Little Goose - tailwater, shoal, deepwater, gulch, and embayment; Lower Monumental - shoal and embayment; and, Ice Harbor - tailwater, embayment, shoal.

We selected Little Goose Reservoir (Lake Bryan) for intensive study because of accessibility and proximity, suspected heavy angler use, and the similarity of aquatic habitats to those found in other lower Snake River reservoirs. The habitat types sampled in Little Goose are shown in Figure 1.

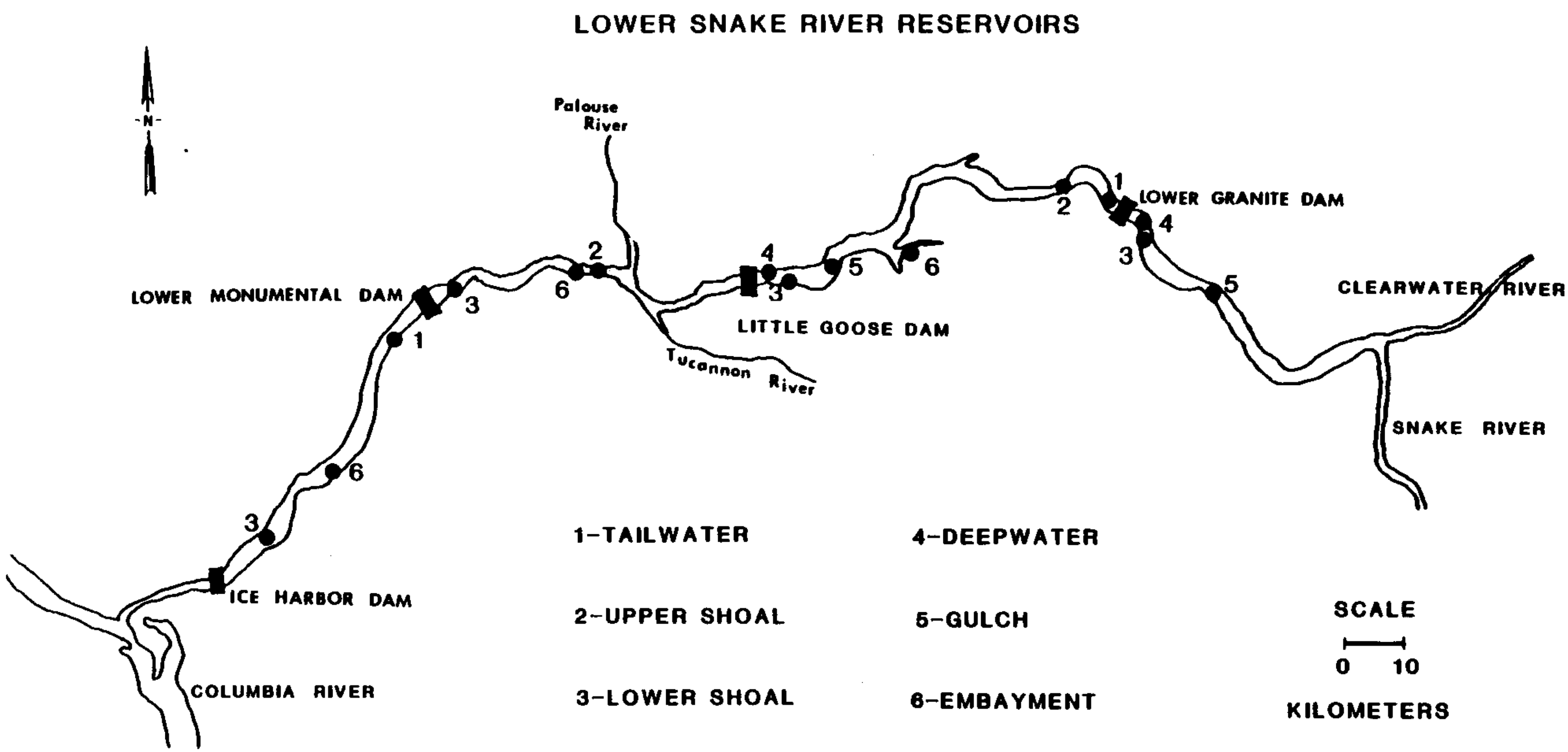

Figure 1. Reservoirs on the Lower Snake River and location of various habitat types sampled for fishes.

Subobjective 1

To assess angler attitudes and quantify angler use and catch in lower Snake River reservoirs.

METHODS

Aerial surveys of the lower Snake reservoirs (Fig. 1) were conducted on one weekend day from March through November, 1979 and 1980. Time (a.m. or p.m.) and direction (upriver or downriver) of weekend aerial surveys were randomly selected. Aerial survey data were used to determine relative seasonal boat and angler use at the four reservoirs.

Angler surveys on Little Goose Reservoir were conducted during April through November, 1979 and March through November, 1980. To facilitate angler enumeration, Little Goose Reservoir was divided into four sampling zones: Boyer Park - Illia Landing; Willow Landing - Penawawa; Central Ferry - Port of Garfield; and, Little Goose Landing. During 1979, ground surveys on Little Goose Reservoir were conducted using stratified cluster sampling. Clusters were half-day periods with one zone being sampled during a given half-day. Sampling schedules were developed each month by randomly selecting half-days to be sampled and then assigning zones to the half-days using a random numbers table. Ground surveys in 1979 were usually conducted on two weekdays and two weekend-holiday days each week. Half-day clusters were 6 to 8 hours (depending on seasonal changes in daylight hours); survey clerks made instantaneous counts of anglers and boats every hour during the cluster. In 1980, a stratified random sampling design was used. Number of samples per zone, to achieve a bound (similar to a confidence interval) on the error of estimation of +/- 50% of the estimated use at the stratum level (various sampling zones), was estimated from the 1979 data. Based on 1979 trends, Boyer Park - Illia Landing, Willow Landing - Penawawa, and Central Ferry - Port of Garfield zones were divided into two seasonal strata in 1980: March-April and July-November; and, May-June. Little Goose Landing, however, was stratified into March-July and October and November, and August-September. On randomly selected days, clerks made instantaneous counts at all zones scheduled to be surveyed that day. Surveys took up to 4 hours to complete and usually were conducted during times representing average daily use. Also, periodic air and boat surveys were conducted in Little Goose Reservoir in 1980 to provide estimates of use at areas that could not be sampled by automobile survey.

Angler interviews were conducted in 1979 and 1980 to obtain information on angling party characteristics, quality of the fishery, yield and composition of the catch. Data collected during interviews included anglers' residence; number of anglers in party; hours fished and whether trip was completed or not; type of fishing (boat or shore); species sought; number and kind of fishes caught; total length of fish caught; and, a quality rating of the fishery.

RESULTS and DISCUSSION

Results of aerial surveys indicated that Little Goose, Lower Granite, and Ice Harbor reservoirs received similar angler use. Lower Monumental Reservoir received the least angler use, while Ice Harbor Reservoir received the most pleasure boat use in 1979 and 1980. Heaviest boat use on Ice Harbor probably was related to the proximity of the large population center in the Tri-Cities area. Also, low angler use on Lower Monumental Reservoir may have been related to the more limited access than on other lower Snake reservoirs.

Anglers fished an estimated 45,752 hours on Little Goose Reservoir from April - November, 1979 and 79,605 hours from March - November, 1980. Fishing boat and pleasure boat use on Little Goose Reservoir were estimated to be 8,864 hours and 17,202 hours, respectively, in 1979. During 1980, 14,734 fishing boat hours and 20,923 pleasure boat hours were estimated for Little Goose Reservoir.

Of the 45,752 angler hours estimated for Little Goose Reservoir in 1979, 56% was by shore anglers and the remainder by boat anglers. The Central Ferry - Port of Garfield zone received the most angler use in 1979 (16,533 hours) followed by the Boyer Park - Illia Landing zone (13,907 hours), the Little Goose Landing zone (10,092 hours), and the Willow Landing - Penawawa zone (5,222 hours). Trends in boat use were similar to those for angler use in 1979. The Central Ferry - Port of Garfield zone received the most boat use, followed by Boyer Park - Illia Landing, Little Goose Landing, and Willow Landing - Penawawa zones.

Of the 79,605 hours of angler use estimated for Little Goose Reservoir in 1980, 60% was by shore anglers and the remainder by boat anglers. The Central Ferry - Port of Garfield (24,990 hours) and Boyer Park - Illia Landing (23,896 hours) received the most angler use followed by Little Goose Landing zone (11,061 hours) and Willow Landing - Penawawa zone (4,950 hours). An additional 14,708 hours of angler use were estimated for areas of Little Goose Reservoir that could not be counted during the 1980 automobile surveys. The Central Ferry - Port of Garfield zone received the most fishing boat use (3,778 hours) while the Boyer Park - Illia Landing zone received the most pleasure boat use (8,604 hours) in 1980. Our estimates of fishing pressure on Little Goose Reservoir were similar to those for other reservoirs in the Snake River system but low compared to reservoirs in more populated areas of the United States.

A majority of parties interviewed (60-90% at the Boyer Park zone, 40-70% at the Central Ferry and Willow Landing zones, and 80-100% at the Little Goose Landing zone) travelled less than 100 km to use Little Goose Reservoir. At the Boyer Park zone, during 1979 and 1980, a majority of the parties interviewed were from the Moscow-Pullman area, whereas a majority of parties interviewed at the Central Ferry and Little Goose Landing zones were from Walla Walla.

Boat angling parties were slightly larger and, on the average, fished longer than shore anglers on Little Goose Reservoir during 1979 and 1980. Mean duration of fishing trips was longest for shore anglers seeking white sturgeon (11.3 hours) and for boat and shore anglers seeking channel catfish (3.2 to 8.0 hours).

During 1979, 61.7% of the boat angling parties and 50.4% of the shore angling parties interviewed were successful (caught at least one fish), whereas 78.7% of the boat angling parties and 71.4% of the shore angling parties were successful in 1980. Boat anglers had mean catch and harvest rates for all species of 0.49 fish/angler hour and 146 g/angler hour in 1979, and 0.55 fish/angler hour and 135 g/angler hour in 1980. Shore anglers interviewed in 1979 had mean catch and harvest rates of 0.63 fish/angler hour and 130 g/angler hour. During 1980, shore angler catch and harvest rates were 0.48 fish/angler hour and 134 g/angler hour. These success rates compare favorably with other warm water fisheries throughout the United States and are high compared to other reservoirs in the northwest.

Although angler success rates were relatively high and more than 50% of the parties were successful, most anglers rated the quality of the fishery on Little Goose Reservoir as fair or poor. Approximately 60% of the anglers interviewed (n = 431) rated the fishery as fair or poor.

Estimated total catch, harvest, and yield from Little Goose Reservoir varied between 1979 and 1980. An estimated 23,961 fish (5.9 fish/ha), weighing 5,938.7 kg (1.5 kg/ha) were removed from Little Goose Reservoir during April through November, 1979. Catch and harvest by boat anglers in 1979 were composed mainly of smallmouth bass, while shore anglers creeled mainly crappies, smallmouth bass, and yellow perch. During March through November, 1980, anglers removed an estimated 40,915 fish (10.1 fish/ha) weighing 11,019.5 kg (2.7 kg/ha). Catch and harvest composition in 1980 were similar to that in 1979. Our estimates of yield for Little Goose Reservoir were low when compared to that for reservoirs throughout the United States.

Subobjective 2

To assess species composition, relative abundance, fish species associations, habitat preferences, and movement of fishes in lower Snake River reservoirs.

METHODS

Fish collections on lower Snake reservoirs were initiated in April, 1979 and continued through November, 1980. Sampling was conducted seasonally in Lower Granite, Lower Monumental, and Ice Harbor reservoirs. Monthly sampling was conducted at six stations representing major habitat types on Little Goose Reservoir (Fig. 1). Night-time electrofishing, horizontal and vertical experimental gill nets, hoop trap nets, and beach seine were employed to sample fish populations. Littoral habitat was sampled with all gear types except vertical gill nets, whereas limnetic habitat was sampled with vertical gill nets. Our estimates of relative abundance were made using catches from effective gear types and a ranking procedure. Overall, fish abundance was determined in Little Goose Reservoir utilizing annual abundance estimates and weighted by shoreline distance of major habitat types.

Annual survival and population estimates were computed for selected game species in Little Goose Reservoir. Survival was estimated using catch curves. Population estimates were made using multiple census techniques. From the population estimates, density and standing crops were calculated.

General movement patterns of resident fishes in Little Goose Reservoir were determined from the recapture of tagged fish. Fish recaptured by scientific sampling gear and angling provided movement information within and among sampling zones.

Habitat preferences of resident fishes in lower Snake reservoirs were assessed by calculating percent of the catch of each species collected at each station.

Fish species associations were assessed on Little Goose Reservoir by calculating Pearson product-moment correlations between sample frequencies for each species. Sample frequencies were obtained from relative abundance calculations.

RESULTS and DISCUSSION

Thirty-one species representing nine families and consisting of over 52,000 age I and older fish were collected in the lower Snake reservoirs (Table 1). Thirty species representing 78% of these fish were collected in Little Goose Reservoir. Our collections indicated that individuals of introduced species were more abundant in embayment habitats, while individuals of native species were more abundant at stations along the main river channel. Smallmouth bass, pumpkinseed, and white crappie were more abundant in up-river reservoirs; channel catfish and carp were more abundant in down-river reservoirs.

Seasonal abundance of fishes differed among sampling stations. For example, abundance of channel catfish and northern squawfish was highest during spring at the tailwater station in Little Goose Reservoir (below Lower Granite Dam) and at the upper shoal station during spring and summer.

Because of the weighting by shoreline distance, overall fish abundance was related to the abundance of fish in the deepwater habitat. Bridgelip sucker was the most abundant species followed by redside shiner, largescale sucker, smallmouth bass, and northern squawfish. These five species represented

Table 1 List of fishes (age I and older) collected with gill nets, trap nets, beach seine, and electrofishing gear in lower Snake reservoirs from April, 1979 through November, 1980.

Family	Scientific Name	Common Name	Reservoirs: Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Acipenseridae	*Acipenser transmontanus*	white sturgeon	0	235	3	2	240
Clupeidae	*Alosa sapidissima*	American shad	0	5	3	0	8
Salmonidae	*Oncorhynchus nerka*	sockeye salmon	0	1	0	0	1
	Oncorhynchus tshawytscha	chinook salmon	4	75	3	2	84
	Prosopium williamsoni	mountain whitefish	2	39	2	10	53
	Salmo gairdneri	rainbow trout	4	172	22	6	204
	Salmo trutta	brown trout	0	1	0	0	1
Cyprinidae	*Acrocheilus alutaceus*	chiselmouth	310	1456	408	99	2273
	Cyprinus carpio	carp	120	1057	187	256	1620
	Mylocheilus caurinus	peamouth	2	76	25	23	126
	Ptychocheilus oregonensis	northern squawfish	354	2510	823	347	4034
	Rhinichthys osculus	speckled dace	0	4	0	0	4
	Richardsonius balteatus	redside shiner	246	3847	219	553	4865
Catostomidae	*Catostomus columbianus*	bridgelip sucker	274	3803	490	402	4969
	Catostomus macrocheilus	largescale sucker	1255	7972	849	1257	11333
Ictaluridae	*Ictalurus natalis*	yellow bullhead	15	240	22	1	278
	Ictalurus nebulosus	brown bullhead	36	629	31	20	716
	Ictalurus punctatus	channel catfish	7	1152	118	218	1495
	Noturus gyrinus	tadpole madtom	0	72	1	1	74
	Pylodictis olivaris	flathead catfish	0	0	0	2	2
Centrarchidae	*Lepomis gibbosus*	pumpkinseed	16	1926	145	70	2157
	Lepomis gulosus	warmouth	0	13	0	0	13
	Lepomis macrochirus	bluegill	12	1218	5	21	1256
	Micropterus dolomieui	smallmouth bass	218	2104	301	106	2729
	Micropterus salmoides	largemouth bass	0	61	0	31	92
	Pomoxis annularis	white crappie	68	7011	440	118	7637
	Pomoxis nigromaculatus	black crappie	79	1672	129	141	2021
Percidae	*Perca flavescens*	yellow perch	68	3046	396	145	3655
Cottidae	*Cottus sp.*[a]	sculpin	0	201	80	38	319
			3090	40598	4702	3869	52259

[a] Includes prickly sculpin (*Cottus asper*), Piute sculpin (*Cottus beldingi*), and mottled sculpin (*Cottus bairdi*).

80% of all fish captured in Little Goose Reservoir. White crappie, yellow perch, carp, chiselmouth, and sculpin followed in abundance.

The recapture of tagged fish enabled us to estimate population sizes, density, standing crops, and annual survival. Population estimates, density, and standing crops were estimated at the lower embayment station. Largescale sucker ($\hat{N}$ = 9241), white crappie ($\hat{N}$ = 8483), black crappie ($\hat{N}$ = 1154), and pumpkinseed ($\hat{N}$ = 708) were the four most abundant species. Standing crop (33.8 kg/ha) and density (200/ha) of white crappie were the highest of all species, while those for pumpkinseed were the lowest (0.64 kg/ha and 17/ha). Annual survival estimates ranged from 28 (smallmouth bass) to 53% (bluegill). Survival estimates for black and white crappies (about 36%), pumpkinseed (S = 0.47), and yellow perch (S = 0.40) were within this range.

Habitat preferences of most resident fishes in lower Snake River reservoirs were similar among seasons with each habitat type generally having a characteristic species complement. Native species occurred primarily in habitats along the main river channel, and the majority of introduced species occurred in embayment habitat. Introduced species, found primarily in the embayment habitat included pumpkinseed, warmouth, bluegill, largemouth bass, white crappie, black crappie, brown bullhead, and tadpole madtom. White sturgeon were collected primarily at the tailwater station. Carp, bridgelip sucker, largescale sucker, smallmouth bass, and sculpin were captured throughout Little Goose Reservoir and, therefore, displayed no habitat preference. Habitat preferences in other lower Snake reservoirs were similar to those observed in Little Goose Reservoir.

Movement of resident fishes, based on recapture of tagged fish in Little Goose Reservoir, was variable among species and location in the reservoir. Individuals of bridgelip and largescale suckers, channel catfish, and white and black crappies travelled distances greater than 15 km. The least amount of movement among reservoir zones was observed in smallmouth bass and brown bullhead. Bass and bullhead travelled mean distances less than 6 km. Tagged white sturgeon were consistently caught at the same location within the upper and lower reservoir zones and, therefore, exhibited little movement. A few fish tagged in one reservoir were recaptured in another reservoir.

We found 39 significant correlations between species. Most correlations were obtained for species occupying similar habitats. Species associations generally were highest between species either occurring within embayment habitat or for species preferring the lotic conditions of the tailwater and upper shoal stations.

Subobjective 3

To evaluate food habits, age structure, and growth of selected warmwater fishes in lower Snake River reservoirs.

METHODS

Fish were collected from April 1979 to November 1980 on lower Snake reservoirs to determine seasonal food habits of smallmouth bass, black crappie, white crappie, redside shiner, northern squawfish, channel catfish, and largescale and bridgelip suckers. Sampling was concentrated on Little Goose Reservoir in tailwater, shoal, embayment, deepwater, and gulch habitats (Fig. 1). Stomachs for food habit analysis were obtained from fish collected by trapnets, gill nets, and electrofishing (Subobjective 2).

Contents of stomachs were examined in the laboratory. Food organisms were sorted, identified, and enumerated. Volumetric displacement (V) was determined in water and frequency of occurrence (F) and numbers (N) recorded. The importance of each food item was determined by the Index of Relative Importance (IRI = (N+V) x F).

To assess the incidence of predation by smallmouth bass, channel catfish and northern squawfish on chinook salmon and steelhead trout smolts, fish sampling was concentrated in the tailwater and upper shoal below Lower Granite Dam during April and May, 1980 (Fig. 1).

Age and growth determinations were made on scales or spines from fishes collected from April to November 1979 and 1980. In the laboratory, scales were washed and impressions made on cellulose acetate slides, spines and fin rays were sectioned, using a jeweler's handsaw, polished, and then mounted on glass slides with permamount. Scales or spines were aged using a scale projector and measurements were taken from the scale image for growth calculations. Each scale or spine sample was interpreted twice. Back-calculated lengths at each year of age were calculated from a model of the body-scale relationship. Growth models were computed using the back-calculated lengths at each annulus.

Weight and length data were used to compute condition factors and allometric growth equations.

RESULTS and DISCUSSION

Crayfish, aquatic insects, zooplankton, and fish were the more important food items of fishes in Little Goose Reservoir. For example, crayfish, fish, and terrestrial and aquatic insects were the more important food items of smallmouth bass. White and black crappies consumed primarily cladocerans, fish, and aquatic insects. Cladocerans were the single most important food item of both black and white crappies. Channel catfish stomachs contained mainly fish, aquatic insects, crayfish, wheat, and cladocerans. Cladocerans, aquatic insects, and terrestrial insects were the more important food items in the diet of redside shiners. Northern squawfish consumed mainly fish, cladocerans, crayfish, aquatic insects, terrestrial insects, and wheat. Fish were of highest relative importance in the squawfish diet during the spring at the tailwater, lower reservoir, and shoal areas. Largescale and bridgelip suckers consumed mainly plant material. Diatoms, detritus, blue-green algae, and filamentous algae were the more important food items of suckers in Little Goose Reservoir.

Stomachs of channel catfish, northern squawfish, and smallmouth bass, examined during the salmonid smolt migration through Little Goose Reservoir, all contained smolts. Few smolts were consumed by smallmouth bass as the incidence of predation was less than 2%. Low water temperatures and the large size of salmonid smolts relative to the average prey size, probably were factors associated with the low incidence of predation by smallmouth bass. However, the frequency of occurrence of smolts in stomachs of channel catfish and northern squawfish was considerably higher. The occurrence of salmonids in channel catfish stomachs (n = 83) varied between tailwater and shoal areas and species of smolts. At the tailwater, chinook salmon, steelhead trout, and unidentified salmonid smolts were found in 54, 38, and 16% of catfish stomachs which contained food. At the shoal area, chinook, steelhead, and unidentified smolts occurred in 40, 40, and 8.7% of catfish stomachs, respectively. Also, of those channel catfish stomachs which contained salmon, an average of 3.2 and 4.3 smolts were consumed at the tailwater and shoal areas. An average of 3.0 and 3.3 steelhead trout smolts were found in channel catfish from tailwater and shoal areas. For northern squawfish (n = 21), the frequency of occurrence of smolts was 42.9% at the tailwater. Salmonid smolts were the most abundant food item in the diet of northern squawfish in April and May, 1980.

The high incidence of smolts in the stomachs of channel catfish and northern squawfish and the apparent migration of these species to the tailwater (Subobjective 1) of Lower Granite Dam should be of concern. These data suggest that smolt mortality by predation could be substantial. Our sampling, however, did not indicate whether these species were feeding on dead, moribund, or healthy smolts. The nature of this predation must be researched under simulated conditions before a definitive position can be made on whether resident species are having a deleterious affect on smolt survival.

Age composition and growth increments were variable among the resident species examined in the lower Snake reservoirs. Growth of fishes generally was similar in Little Goose Reservoir to that in other lower Snake reservoirs. For example, smallmouth bass averaged 71 mm at age I to 497 mm at age XIII. Smallmouth bass grew an average 71 to 54 mm a year during the first 5 years and approximately 25 mm thereafter. Size at various ages and growth increments of smallmouth generally were smaller than those of bass of the same age found in other waters in the United States. Comparison of our data with that in the literature indicates growth of smallmouth bass increased in older fish as a result of impoundment. Growth of white and black crappies was similar; back-calculated lengths ranged from 72 mm at age I to 334 mm at age VIII. Crappies grew an average of 85 to 61 mm per year during their first 3 years and from 45 to 11 mm thereafter. We found that growth increments of white crappie in lower Snake reservoirs generally were larger or comparable to those in other waters at similar latitudes. Growth of bluegill and pumpkinseed was slow and annual increments ranged from 51 to 33 mm during the first 3 years compared to 30 to 17 mm thereafter. Although growth was slow in these species, it was comparable to growth from waters at similar latitudes. Mean back-calculated lengths of channel catfish ranged from 66 mm at age I to 665 mm at age XVI. Channel catfish grew an average 80 to 56 mm during the first 6 years and 41 to 10 mm thereafter. Also, we found growth of channel catfish to be significantly slower in Ice Harbor reservoir in comparison to that in Lower Monumental and Little Goose reservoirs. Growth increments and the size at annulus formation of channel catfish were similar to that for several waters of midwestern United States. Growth of largemouth bass, northern squawfish, redside shiners, and yellow perch also was examined and found to be similar to that reported in the literature. Growth of white sturgeon was variable among age classes; individuals captured from Little Goose Reservoir ranged in age from IV to XII years. The majority of sturgeon examined were age VII and ranged in length from 523 to 810 mm. Our estimates of mean total length of white sturgeon from Little Goose Reservoir were considerably higher than those reported for white sturgeon in the mid-Snake River. Growth of young-of-year American shad and chinook salmon in Little Goose Reservoir was exponential. Young-of-year American shad (0.6 mm/day) grew at a faster rate than chinook salmon (0.4 mm/day) for their short residence (4 months) in Little Goose Reservoir.

Allometric growth and condition factors of resident fishes from the lower Snake reservoirs generally were similar to those reported for other parts of the U.S. For example, condition factors of smallmouth bass and pumpkinseed were similar to those reported in the literature. On the other hand, condition factors of crappies and channel catfish from lower Snake reservoirs generally were higher than those previously reported.

Subobjective 4

To evaluate reproductive cycles and spawning habitat preferences of selected warmwater fishes in lower Snake River reservoirs.

METHODS

To evaluate the reproductive cycles and timing of spawning, individuals of 12 species of resident fish taken from the field collections (Subobjective 2) were dissected. Gonads were weighed (0.10 g) and macroscopically examined to assess the state of maturity. Gonad size was expressed as a percent of body weight or the gonosomatic index (GSI).

To locate spawning areas and obtain additional information on timing of reproduction of selected fishes in Little Goose Reservoir, suspected spawning areas were examined underwater by snorkeling and SCUBA diving. Biologist divers swam systematically parallel to shore and recorded signs of spawning activity. Also, observers waded the shoreline and visually examined the shoreline when water levels were low and water transparency was high. Diameter of spawning nests, water temperature, and dissolved oxygen were measured and substrate type and size recorded.

To assess the effects of fluctuating water levels on fishes which spawn in shallow water in the lower Snake reservoirs, the elevation of spawning sites were determined by comparison with hourly water elevation records.

To further refine timing of spawning and assess the relative importance of various habitats for spawning and rearing, larval and young-of-year (YOY) fishes were sampled biweekly from April through November, 1980, at embayment, gulch, and shoal areas in upper and lower reservoir zones of Little Goose

Reservoir and the tailwater of Lower Granite Dam (Fig. 1). Larval fishes were sampled by towing three sets each of two conical plankton nets on opposite sides of the boat at a speed of 1.3 m/second. Stepwise oblique tows were conducted at night at 1 m increments from the surface to a maximum depth of 3 m. Standard tows were 3 minutes at each depth. YOY fishes were sampled using a 30.5 x 2.4 m seine, constructed of 6.35 mm knotless nylon mesh with a 2.4 x 2.4 x 2.4 m bag. YOY fish sampling was conducted seasonally at three stations in Lower Granite, Lower Monumental and Ice Harbor reservoirs and biweekly at seven stations in Little Goose. Sampling consisted of taking three hauls per station; one unit of effort per sampling period consisted of the sum of three standardized hauls at each sampling station. Correlations were computed between YOY and larval fish abundance and limnological factors.

RESULTS and DISCUSSION

All species examined for reproductive information initiated reproductive development in the fall and spawned from early spring through late summer. In general, native fishes spawned earlier in the year and introduced game fishes spawned later. Based on examination of the gonads, periods of spawning activity for the species examined were: northern squawfish - initiated spawning in June and probably continued into early August; redside shiners - first spawning was in July and fish with ripe gonads were collected into early August; bridgelip suckers - probably spawned in April and May; largescale suckers - spawning occurred in May and June; brown bullhead - spawned late June, July, and early August; channel catfish - spawning probably occurred in July and August; pumpkinseed - initiated spawning in late June and continued into early August; bluegill - spawning occurred through July and early August;

smallmouth bass - probably spawned from late May, June, and into July; white crappie - spawned from June into August; black crappie - spawning occurred in June and July; and, yellow perch - ripe ova and the appearance of embryos suggested most spawning occurred in April and May.

A total of 256 spawning nests were located in Little Goose Reservoir during 1979 and 1980. Approximately 50% (n = 116) were smallmouth bass and 50% (n = 129) were sunfish (Lepomis). Distribution of smallmouth bass nests was similar among habitats and between upper and lower reservoir zones. Shoal areas were more commonly used for spawning in the upper reservoir, while gulch and embayment areas were used in the lower reservoir. Most of the sunfish nests were located in the lower reservoir; gulch, embayment, and shoal areas accounted for most of the sunfish spawning activity.

The vertical distribution of spawning activity for smallmouth bass and sunfish generally was similar between 1979 and 1980. Approximately 54% of the smallmouth bass spawning nests in 1979 and 25% in 1980 were located below minimum pool elevation (192.94 m or 633.0 feet) in Little Goose Reservoir. Approximately 28% of the sunfish nests were located below minimum pool elevation. Depth of spawning data suggested that increased spawning success could occur with operational modifications in present generating modes.

The catch composition of larval and YOY fishes generally was similar in Little Goose Reservoir. Eight fish families were represented in the collections; members of the family Cyprinidae (Minnow family) accounted for 64 and 53% of all larval and YOY fishes sampled, respectively. The highest densities of larval and YOY fishes were found in gulch and embayment habitats. Abundance of larval fishes was highest during July ($\overline{X}$ = 430/1000 m^3). Most larval game fishes were collected during July and August. Larval cyprinid fishes were most abundant at upper reservoir sampling stations, while larval game fishes were most abundant at the embayment stations. Catches of YOY fishes peaked in August; catches were consistently high at the lower embayment station. YOY chinook salmon were abundant in March through July, whereas YOY American shad were commonly caught from August to November.

Species associations and correlations with limnological parameters reflected habitat suitability for the various species and/or similarity in responses to environmental factors. Larval catches of shad, catfish, sunfish, and crappies were positively correlated with water temperature which indicated their increased abundance in warmer backwater areas of Little Goose Reservoir. A number of correlations between YOY fish abundance and limnological factors were significant, but the strength of the associations were low. For example, YOY chinook salmon ($r = 0.27$), chiselmouth ($r = 0.40$), northern squawfish ($r = 0.22$), and smallmouth bass ($r = 0.28$) were positively correlated with aquatic macrophyte abundance. However, these analyses indicated that only from 5 to 16% of the variation (r^2) in fish abundance was accounted for by aquatic macrophytes.

Spawning periods and trends in temporal distributions of larval and YOY fishes generally were sequenced. For example, from gonad samples, yellow perch spawned during April and May, larval perch were first collected and most abundant in May, and YOY yellow perch were collected in highest abundance during July. These time progressions were found for most species examined which corroborated our suggested times of spawning for the resident fishes studied.

The abundance of spawning nests and high catches of larval and YOY fishes in backwater areas of Little Goose Reservoir indicate the importance of these areas for spawning and rearing of game species. Taxa of centrarchid fishes are the dominant sport fishes in the lower Snake River reservoirs, and most of these species require high quality shallow water habitats for spawning and rearing. Our data suggest that maintenance of these areas is essential to maintain the quality of the resident sports fishery in the lower Snake reservoirs.

Subobjective 5

To correlate fish behavior with limnological characteristics of lower Snake River reservoirs.

METHODS

We measured water temperature (C), dissolved oxygen (mg/liter), water transparency, water velocity, water depth, aquatic macrophyte distribution, bottom slope, and littoral reach and related these factors to results of our fish sampling. Water temperature and dissolved oxygen profiles were measured at 1 m intervals at all lower Snake reservoirs. On Little Goose Reservoir water transparency was determined by secchi disc, and water velocity was measured using an electronic flow meter. Also, echo soundings were made to assess water depth, bottom slope, and littoral reach. Aquatic macrophyte distribution was determined in August, 1980, plotted on a map, and measured by planimetry. Pearson-product-moment correlations were calculated between species sample frequencies (Subobjective 1) and selected limnological parameters.

RESULTS and DISCUSSION

Homothermous conditions prevailed in Little Goose Reservoir from October to June. Thermal layering was evident in June through September except at the tailwater of Lower Granite Dam, which remained homothermous (Fig. 2). Water temperatures were higher in 1979 than in 1980 and exceeded 22 C throughout most of the reservoir by August 1979.

Dissolved oxygen levels were negatively correlated with water temperatures. During 1979 and 1980, oxygen levels remained high through early

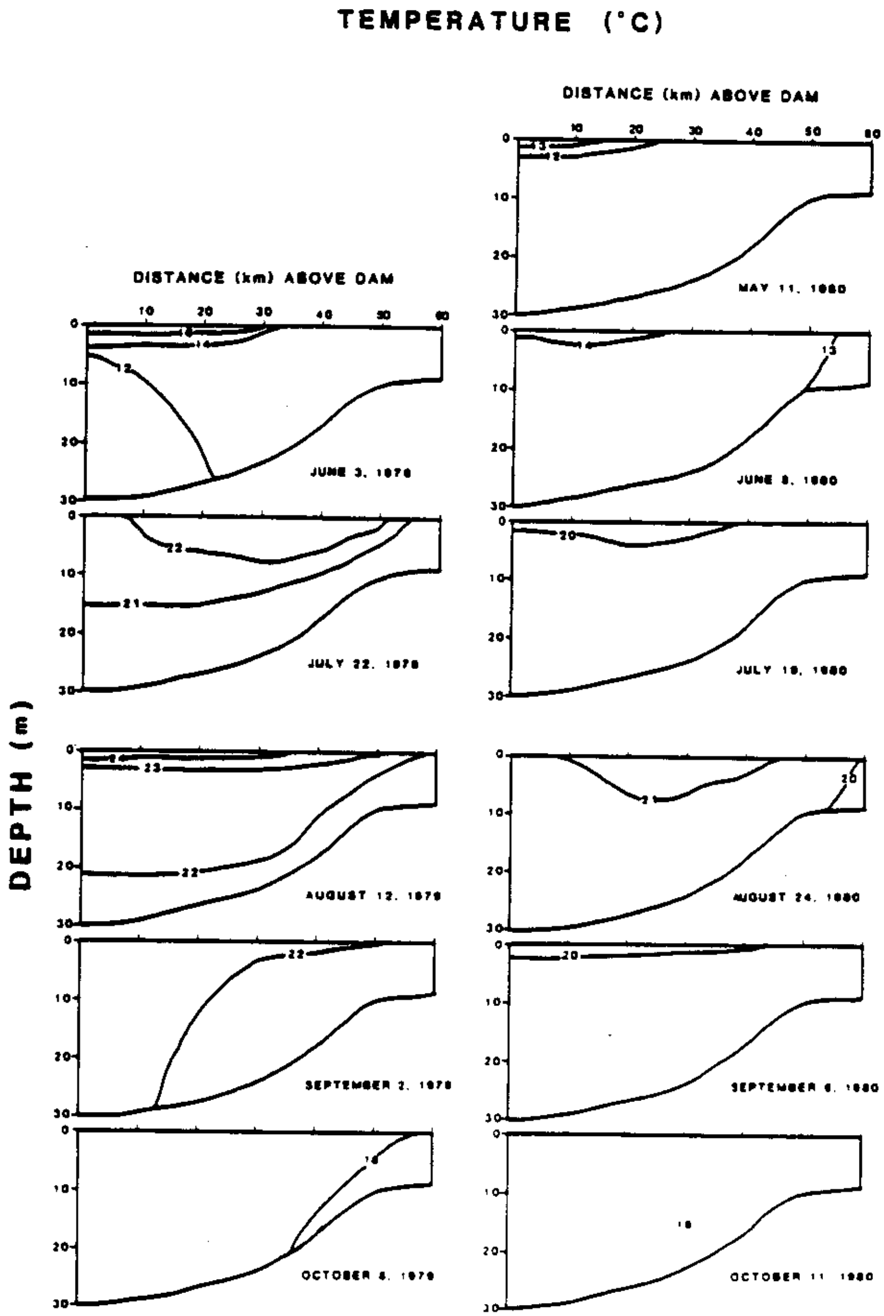

Figure 2. Water temperature (C) isopleths for main channel areas from Little Goose Reservoir, Washington, during 1979 and 1980.

summer but declined by the end of July with lowest levels occurring in deep waters during August 1979 (Fig. 3). Dissolved oxygen levels exhibited replenishment by September 1980 and October 1979.

Water temperatures and dissolved oxygen profiles collected seasonally during 1980 on Lower Granite, Lower Monumental, and Ice Harbor reservoirs revealed similar water temperature and dissolved oxygen conditions to those in Little Goose Reservoir.

Water transparency in Little Goose Reservoir was lowest in the spring (0.7 - 1.1 m) but increased through the summer and fall (1.7 - 4.2 m). Plankton abundance produced wide fluctuations in water transparency and accounted for most decreases in transparency during summer and early fall.

Twenty-seven significant correlations were obtained between six limnological characteristics and sample frequencies of 15 fish species in Little Goose Reservoir. Highest positive correlations were obtained between water velocity and white sturgeon, chiselmouth, northern squawfish, and redside shiners, species commonly collected from lotic areas of the reservoir. Also, species most commonly collected from the lower embayment station (brown bullhead, pumpkinseed, bluegill, and white crappie) were negatively correlated with water velocity. Thus, water velocity was an important limnological factor positively affecting the spatial distribution of some species and negatively influencing the distribution of others. Sample frequencies of nine species were correlated with morphometric characteristics. For example, carp, largescale sucker, brown bullhead, and yellow perch were negatively correlated with water depth, while yellow bullhead and smallmouth bass were positively correlated with water depth. The abundance of few species was significantly correlated with macrophyte distribution, water transparency,

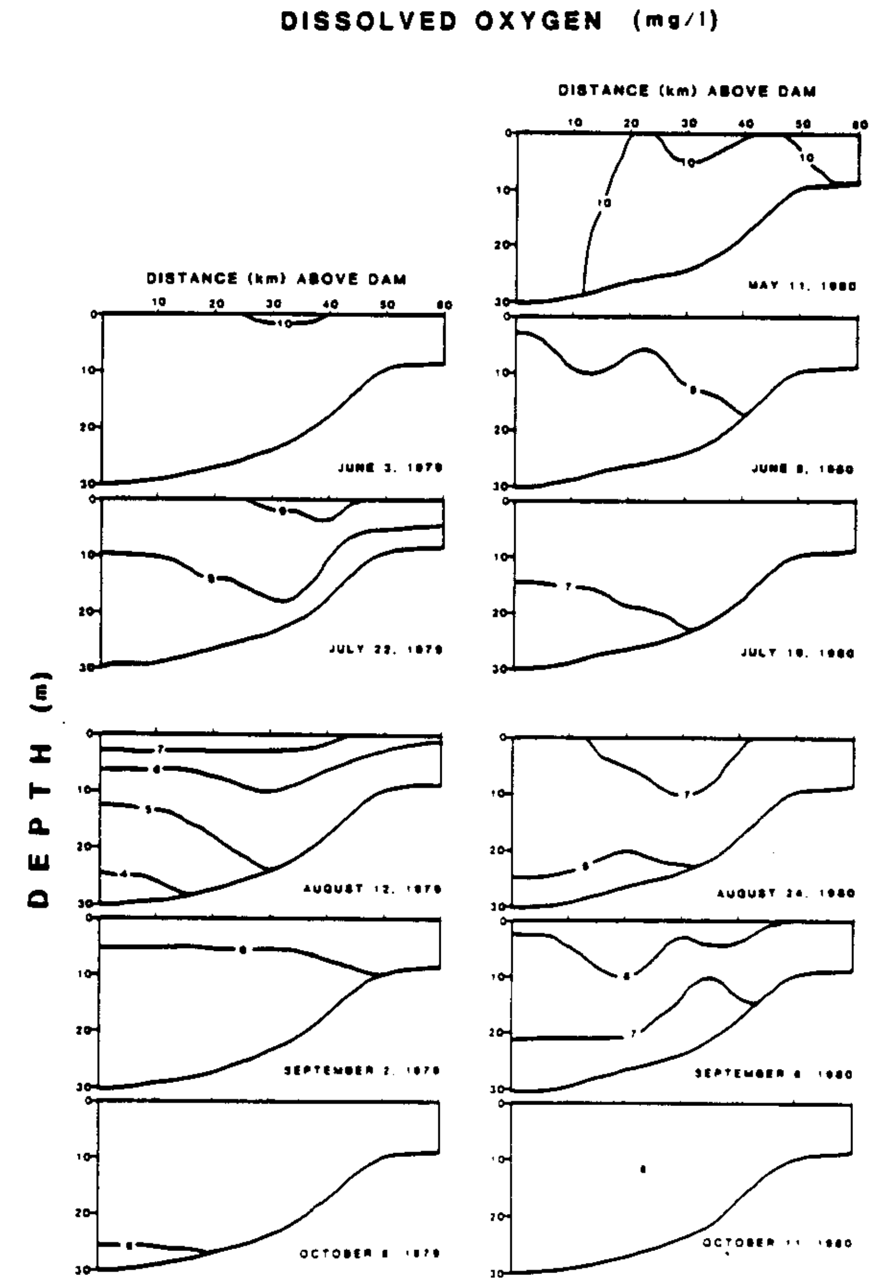

Figure 3. Dissolved oxygen (mg/l) isopleths for main channel areas from Little Goose Reservoir, Washington, during 1979 and 1980.

and water temperature. No significant correlations were obtained between any limnological characteristic and sample frequencies of bridgelip sucker, channel catfish, and black crappie.

Water temperature and dissolved oxygen levels in lower Snake reservoirs indicated more favorable habitat existed for warm/coolwater fishes. High water temperatures and low dissolved oxygen levels during late summer in some years may limit salmonid abundance. In Little Goose Reservoir, late summer water temperatures and dissolved oxygen levels were less critical to salmonids during 1980 than in 1979. In 1979, after very warm air temperatures and lower flows prevailed during the summer, late summer water temperatures averaged more than 22C, and dissolved oxygen levels dropped below 6 mg/liter. These temperatures and oxygen levels border the established limits for salmonid fishes. Therefore, we believe management efforts should focus on resident warm/coolwater fishes.

RECOMMENDATIONS

1) Because of the importance of backwater habitats (embayments, gulches, coves, etc.) in the lower Snake River reservoirs for spawning and rearing of warmwater sport fishes, the quality of these habitats must be maintained. Sediment entering these habitats from surrounding agricultural lands and highway construction and maintenance activities has the potential to degrade these habitats where the abundance of resident fish stocks could be severely impacted. Therefore, if the quality of these habitats cannot be maintained through land management activities, we recommend construction of backwater habitats in suitable main channel areas.

2) Because of high water temperatures and low dissolved oxygen regimens in the lower Snake River reservoirs, fisheries management activities should emphasize warm and cool water resident fishes and not resident salmonid fishes. However, the stocking of catchable sized salmonid fishes should be tried experimentally during the spring and fall when habitat conditions are suitable to assess the feasibility of this management practice.

3) Because much of the sports fishery in the lower Snake River reservoirs is concentrated in backwater areas and a number of these areas exist on the northside of Little Goose and Lower Monumental reservoirs, angling opportunities could be enhanced by increasing land and water access to these habitats. Also, angling opportunities and fishing

success could be increased by installation of floating docks in embayment habitats on lower Snake River reservoirs.

4) Conflicts between anglers and other reservoir user groups could be reduced by restricting to wake speeds in backwater habitats. Because backwater habitats provide the bulk of angling opportunities, speed regulation would aleviate tensions among reservoir users and increase fishing opportunities.

5) At present, fishermen are uninformed about angling opportunities in the lower Snake River reservoirs. Programs should be developed to inform and educate sports fishermen about the species of sport fishes available in the lower Snake River reservoirs and fishing methods required to catch these fish.

6) To maintain adequate recruitment and, thus, the quality of the sports fishery in the lower Snake River reservoirs, water level fluctuations during May, June, and July must be of concern to fishery resource managers. Under present electrical power operating modes, however, our data does not indicate that present water level fluctuations are limiting recruitment and therefore, adversely affecting the quality of the resident sports fishery. Changes in power operation modes, however, could seriously decrease recruitment and adversely affect the quality of the resident sports fishery.

7) Our results suggest that habitat improvement structures (wing dams, rock jetties, artificial reefs, and stake beds) could increase production of resident game fishes in each of the lower Snake River reservoirs. However, the sport fishery benefits and effects on the dynamics of the fish stocks should be experimentally evaluated before a major effort was undertaken.

8) This study provided valuable baseline data on characteristics of the sports fishery and resident species in lower Snake River reservoirs. To more effectively manage these fisheries, more intensive investigations should be conducted on the following:

   a) the dynamics of white sturgeon stocks in each of the lower Snake River reservoirs;

   b) the dynamics and nature of salmonid smolt predation by channel catfish in the tailwaters of lower Snake River reservoirs;

   c) the potential and importance of natural production of chinook salmon in lower Snake River reservoirs;

   d) the benefits of installation of habitat improvement structures (#7) to selected game fishes in lower Snake River reservoirs;

   e) the relationship between water level fluctuations and recruitment of shallow water spawning game fishes; and,

   f) the importance of lower Snake reservoirs for spring and fall rearing of juvenile steelhead trout.

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Acknowledgments

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INTRODUCTION

Settlement in the Snake River Basin initiated numerous changes in the area. As human populations increased in the basin, fish populations generally declined. Irrigation, farming, and power were the major resource developments which contributed to these declines. The greatest impact to the fishery resources of the Snake River, however, has been associated with dam construction. Dams have resulted in changes in the physical-chemical properties of natural riverine systems which in turn have altered the biotic communities. One of the major changes in the fish communities has been a shift from resident and anadromous salmonid fishes to resident exotic warmwater complexes (Bennett et al. 1979).

In the early 1800's, chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Salmo gairdneri) migrated to Shoshone Falls on the Snake River (PNRBC 1971). Construction of Swan Falls Dam in 1901 blocked further upstream migrations of anadromous fish. The operations of upstream dams (i.e., American Falls, Minidoka, Palisades Dams) created unstable reservoir and downstream conditions. Decreased streamflows below these dams elevated river temperatures and created more favorable habitat for nongame species than the original salmonid fish communities. Additional dam construction lower in the basin had more deleterious affects on anadromous salmonids. Dam construction within the middle Snake River, specifically, the Hells Canyon, Oxbow, and Brownlee projects, precluded further upstream migration to anadromous fishes. Prior to dam construction, this area was important for fish passage to upstream spawning habitat and also as spawning and rearing habitat for anadromous fishes. As a result of dam construction, this area is presently used by white sturgeon (Acipenser transmontanus), rainbow trout, and numerous spiny rayed fishes are abundant in this section (Bennett et al. 1979).

Construction of hydroelectric dams further downstream on the lower Snake River has altered approximately 221 km of river to a series of four reservoirs. Alterations of this habitat have been accompanied by changes in composition and relative abundance of fish communities. Prior to dam construction, this area was used by steelhead trout, spring and summer run chinook salmon for passage to upstream spawning areas and downstream to the Pacific Ocean and by fall chinook salmon for spawning and rearing (Raymond 1978). Following dam construction, adult and juvenile anadromous salmonids still migrate through this area although little is known about use and suitability of the reservoir environments for anadromous fish rearing. A number of measures have been taken by the U.S. Army Corps of Engineers in this section of the Snake River to mitigate and enhance anadromous salmonid survival.

Prior to the advent of settlement of the basin, resident fishes in abundance were white sturgeon, suckers, and minnows (Lampman 1946). With settlement, a number of exotic fishes from the east and midwest were introduced. As dams were constructed and the resulting reservoirs impounded, more favorable habitat was created for lacustrine forms. Many of introduced exotic and resident fishes responded to this more favorable lacustrine habitat and increased in number. Further declines in upriver anadromous stocks and the resulting restrictions in upriver fisheries have initiated increased interest in sport fishing for resident species.

Several major areas of concern exist regarding development of the warmwater fisheries in the lower Snake River. Of major concern is the interactions of resident species and anadromous salmonids, acceptance of the warmwater fishery and the community composition of the warmwater fish stocks. As a result of these concerns, this study was initiated in February 1979 to examine the Lower Snake River Reservoir warmwater fishery and its interactions with anadromous salmonid fishes. Specifically, the objective and subobjectives of this study were as follows:

Objective

To assess the status of the warmwater fishery and to determine the potential of improving warmwater fish habitat in lower Snake River reservoirs for the Snake River Compensation Plan.

Subobjectives

1. To assess angler attitudes and quantify angler use and catch in lower Snake River reservoirs;
2. To assess species composition, relative abundance, fish species associations, habitat preferences, and movement of fishes in lower Snake River reservoirs;
3. To evaluate food habits, age structure and growth of selected warmwater fishes in lower Snake River reservoirs;
4. To evaluate reproductive cycles and spawning habitat preferences of selected warmwater fishes in lower Snake River reservoirs; and,
5. To correlate fish behavior with limnological characteristics of lower Snake River reservoirs.

OVERVIEW OF SNAKE BASIN

The Snake River flows approximately 1610 km (1,000 miles) from Jackson Lake, Wyoming before coalescing with the Columbia River, near Pasco, Washington. The Snake River drains all regions of Idaho, except the Panhandle area, eastern Oregon, northern Nevada and Utah, and southeastern Washington. The mean annual flow is approximately 46.4×10^9 m^3 (1638×10^9 cubic feet).

Precipitation within the Snake River Basin is diverse. Mean annual precipitation ranges from 17.8 cm (7 inches) to more than 152 cm (60 inches) per anum. In general, higher elevations receive more precipitation while much of the drainage within southern Idaho, eastern Oregon and southeastern Washington receives less than 25 cm (10 inches) annually. Most of the streamflow in the basin is derived from snowmelt in the mountain area. One-third of the total streamflow is supplied above Weiser, Idaho, another third from the Clearwater River Basin, and the remaining third comes from the Salmon, remaining small tributaries below Weiser, eastern Oregon, and Washington tributaries. Water withdrawals from the Snake River throughout south Idaho, largely from major irrigation diversions, remove more water than normal river gain, resulting in declining river flows (Bennett et al. 1979).

STUDY AREA

Lower Snake Reservoirs

The study area extended from the Ice Harbor Dam near Pasco, Washington upstream to Lewiston, Idaho. This section of the river lies in a canyon in the south-central section of the Columbia River plateau. Four dams constructed on the lower Snake River essentially impound waters for a distance of approximately 221 km (137 miles)(Fig. 1). The resulting reservoirs, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite are generally similar in morphometry

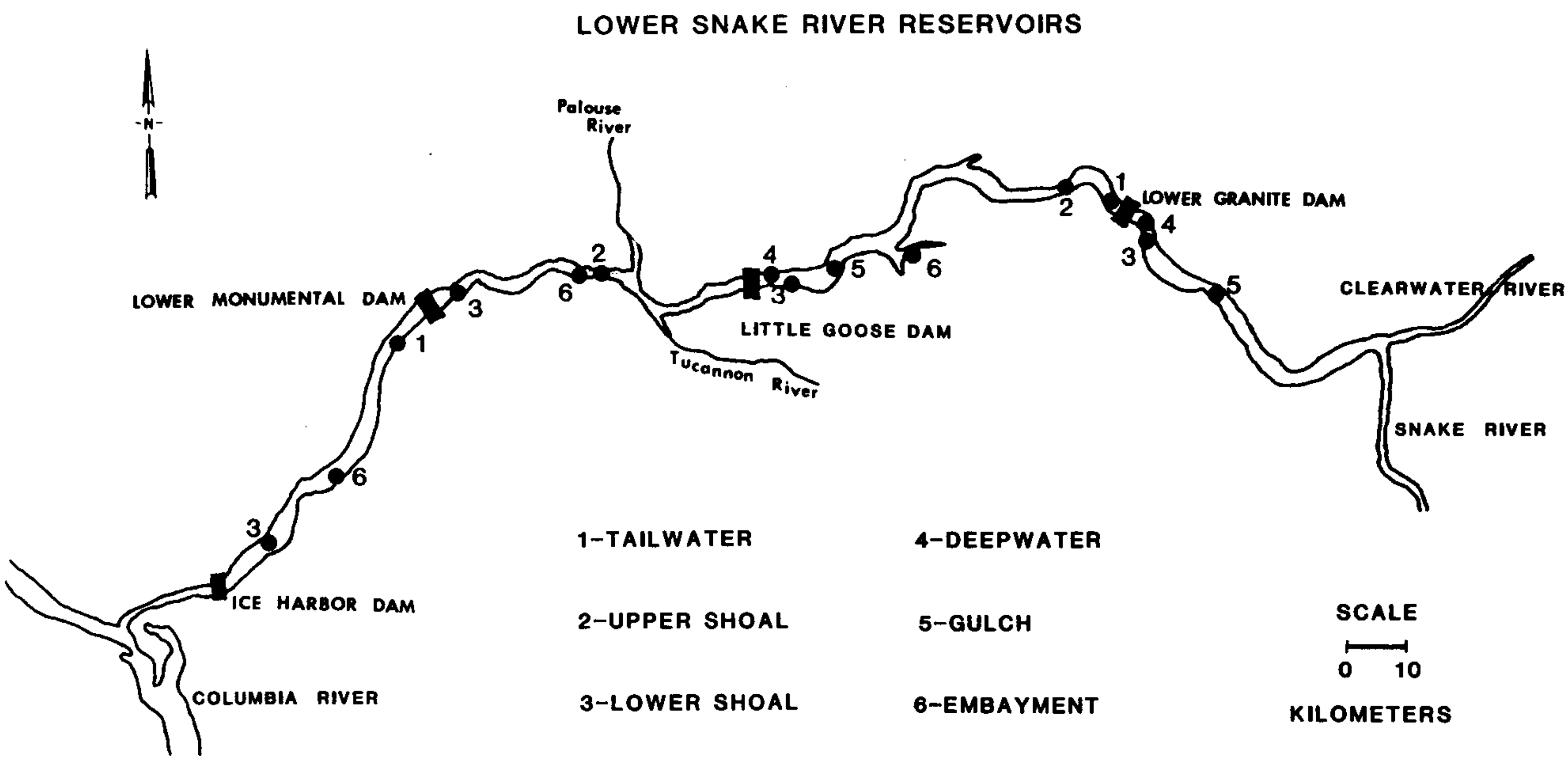

Figure 1. Reservoirs on the Lower Snake River and location of various habitat types sampled for fishes.

and physical characteristics (Table 1). Canyon faces are talus slopes alternated with basalt cliffs, occasional benches and side canyons. Major tributaries within the study area include the Clearwater, Palouse, and Tucannon Rivers (Table 1).

The reservoirs decrease in maximum depth progressing from upstream to downstream while mean depth is similar for Lower Granite, Little Goose and Lower Monumental. Ice Harbor averages about 3 m shallower than the other lower Snake River reservoirs. Lower Granite and Lower Monumental are the narrowest of the four reservoirs (Table 1).

Major uses of the dams and resulting reservoirs are electrical power generation, flood control, cargo transportation, and recreation. Boating activities and fishing are the primary recreational uses.

Because of the large size of the Lower Snake reservoirs (221 km) and similarity of habitats among reservoirs, we developed a habitat classification scheme for fish sampling. Major habitat types sampled on the lower Snake River reservoirs varied from tailwaters, shoal, gulch, deepwater and embayments (Fig. 1). These habitats were sampled for fish at the locations indicated and the habitat types were as follows: Lower Granite - gulch, deepwater, shoal; Little Goose - tailwater, shoal, deepwater, gulch, and embayment; Lower Monumental - shoal and embayment; and, Ice Harbor - tailwater, embayment, shoal.

Little Goose

We selected Little Goose Reservoir (Lake Bryan) for intensive study because of accessibility and proximity, suspected heavy angler use, and variety of aquatic habitats similar to those found in other lower Snake River reservoirs. The habitat types sampled in Little Goose are shown in Figure 1 and the more specific locations and type of sampling effort are shown in Figure 2. For

Table 1. Physical characteristics of lower Snake River reservoirs, Washington and Idaho.

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Normal pool El.-ft. msl (m)	440 (134)	540 (164)	638 (194)	738 (225)
Reservoir length - km (miles)	51.4 (31.9)	46.2 (28.7)	59.9 (37.2)	62.8 (39.0)
Surface area - acres (hectares)	8,375 (3390)	6,590 (2667)	10,025 (4057)	8,900 (3602)
Maximum depth - m (feet) (flat pool)	33.5 (110)	39.6 (130)	41.1 (135)	42.1 (138)
Mean depth - m (feet) (flat pool)	14.5 (48.6)	17.4 (57.2)	17.2 (56.4)	16.6 (54.4)
Maximum width - m (feet)	1,609 (5,280)	1,286 (4,220)	1,432 (4,700)	1,128 (3,700)
Mean width - m (feet)	610 (2,000)	579 (1,900)	518 (1,700)	643 (2,110)
Major tributaries	none	Palouse & Tucannon	none	Clearwater

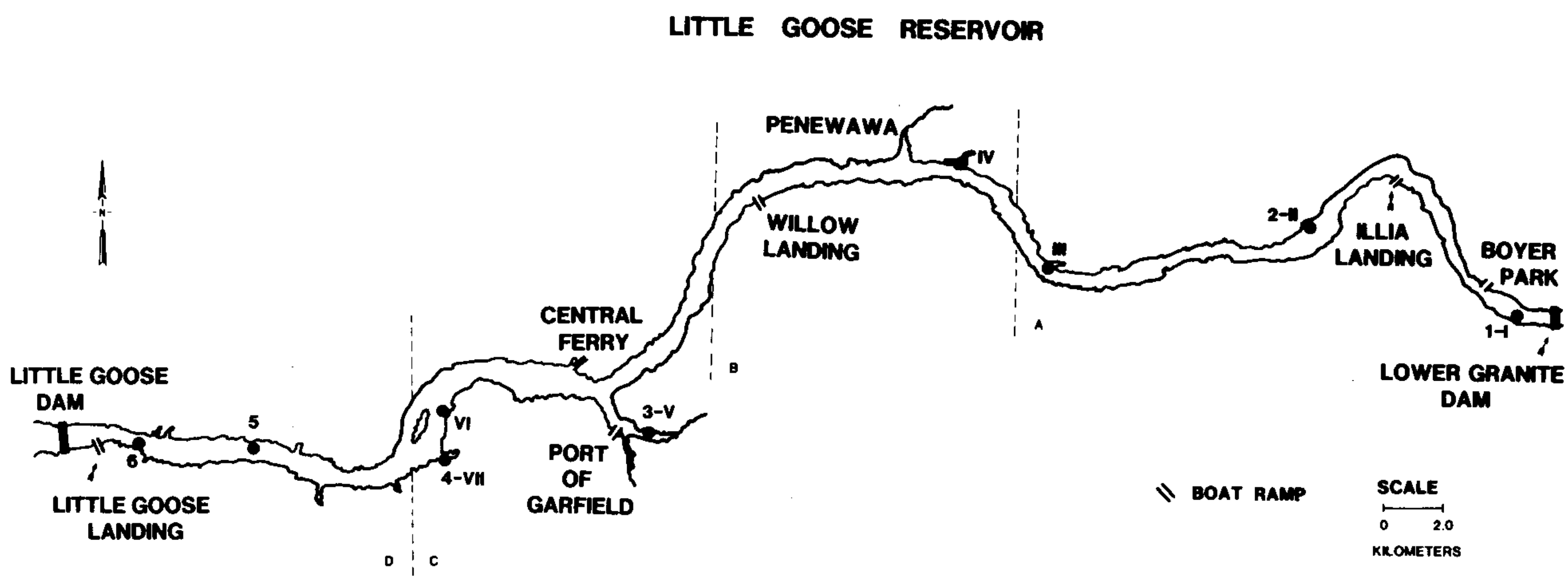

Figure 2. Little Goose Reservoir on the lower Snake River approximately 63 km (39 miles) downstream from Lewiston, Idaho. Major access points and locations of juvenile and adult (Arabic numbers) and larval fish sampling (Roman numerals) are also shown. Letters denote the four reservoir sections used for creel census and upper (sections A and B) and lower (C and D) reservoir zones. Station numbers to note: 1 - I = tailwater; 2 - II = upper shoal; 3 - V = Lower Embayment (Deadman Bay); III = Upper Gulch; IV = Upper Embayment; 4 - VII = Lower Gulch; 5 = Deepwater; and, 6 = Lower Shoal.

fish sampling and comparison, Little Goose Reservoir (Fig. 2) was arbitrarily divided into upper (sections A and B) and lower zones (C and D).

Subobjective 1

To assess angler attitudes and quantify angler use and catch in lower Snake River reservoirs.

Following construction of the lower Snake River reservoirs, little information was available on the recently developing sport fisheries for resident species. Although personnel of the Washington Department of Game conducted sporatic creel checks and angler counts on the reservoirs, quantification of angler use, species sought and caught, and general attitude of the anglers towards the fishery was not available. These data were necessary for the Snake River Compensation Plan.

METHODS

Fishing pressure was estimated using aerial and ground (boat and automobile) surveys. Survey clerks enumerated fishing boats, boat anglers, shore anglers, and pleasure boats. An angler was defined as anyone who was actively fishing when observed (Lambou 1966), and a fishing boat was one containing at least one angler. A pleasure boat was any recreational boat use other than fishing.

Aerial surveys of the Lower Snake Reservoirs (Fig. 1) were conducted during the months of March through November, 1979 and 1980, on one weekend day each month. Time (AM or PM) and direction (upriver or downriver) of weekend aerial surveys were randomly selected; to facilitate enumeration, binoculars were used when necessary. Weekday aerial surveys of the four reservoirs were conducted monthly from June through October, 1979, and March, 1980, in conjunction with U.S. Fish and Wildlife Service waterfowl surveys.

Aerial survey data were used to determine seasonal (Spring: March - May; Summer: June - August; and Fall: September - November) boat and angler use at the four reservoirs. Use among reservoirs and seasons was compared by a 3-dimensional chi-square contingency table for numbers of fishing boats, boat anglers, shore anglers, and pleasure boats. Bonferroni style confidence intervals were used to determine which reservoirs were being preferred or avoided by users (anglers and boaters) during each season (Neu et al. 1974). A proportion of total users (pi) for a given type of use (boat anglers, shore anglers, fishing boats, and pleasure boats) was calculated for each reservoir during each season. Simultaneous Bonferroni style confidence intervals were then calculated for each season and type of use as follows:

$$\hat{p}i-Z_{\alpha/2K}\sqrt{\hat{p}i(1-\hat{p}i)/n} \leq \hat{p}i \leq \hat{p}i+Z_{\alpha/2K}\sqrt{\hat{p}i(1-\hat{p}i)/n}$$

where: $\hat{p}i$ = observed proportion of total use (for a given season and type of use) occurring on reservoir i, i = 1,...,k

$Z_{\alpha/2K}$ = tabular Z value; for α = .10 and k = 4, Z = 2.5857

K = number of reservoirs

n = the total number of users observed on all reservoirs for a given season and type of use

pi = true proportion of use for reservoir i for a given season and type of use

Calculation of Bonferroni style confidence intervals enabled us to determine differential use among lower Snake reservoirs. For example, if the various users were distributed evenly among the four reservoirs, confidence intervals would contain the value of 0.25. However, if a confidence interval did not contain 0.25, then that reservoir received a significantly greater or lesser proportion of the total use for a given season and type of use.

Angler surveys on Little Goose Reservoir were conducted during April through November, 1979, and March through November, 1980. To facilitate sampling, Little Goose Reservoir was divided into four sampling zones: Boyer Park-Illia Landing, Willow Landing Penawawa, Central Ferry-Port of Garfield, and Little Goose Landing (Fig. 2).

During the 1979 season, ground surveys on Little Goose Reservoir were conducted using stratified cluster sampling (Scheaffer et al. 1979). Our clusters were half day periods with one zone being sampled during a given half day. Sampling schedules were developed each month by randomly selecting the half days to be sampled and then assigning zones to the half days using a random numbers table. The probability of selecting a given zone for a given half-day survey was equal to the percentage of total anglers, from the previous month's aerial surveys, that were counted in that zone. Ground surveys in 1979 were usually conducted on two weekdays and two weekend-holiday days each week. Half-day clusters were 6 to 8 hours long (depending on seasonal changes in daylight hours); survey clerks made instantaneous counts of anglers and boats every hour during the cluster. Surveys were stratified by sampling zone, time of day (AM or PM) and by weekdays and weekend-holiday days. Because of observed seasonal use patterns, surveys at the Central Ferry-Port of Garfield zone were further divided into the following seasonal strata: April and July-November; and May - June.

Estimates of use (hours) in 1979 were calculated for boat anglers, shore anglers, fishing boats, and pleasure boats during each time stratum by calculating the mean of all counts in each stratum as follows (Scheaffer et al. 1979):

$$\overline{Y} = \frac{\sum_{i=1}^{n} yi}{\sum_{i=1}^{n} mi}$$

where: $\bar{Y}$ = the mean number of anglers or boats for all observations in the stratum

n = the number of clusters (half days) in the random sample

M = the total number of elements (hours) in the stratum

mi = the number of elements in cluster i, i=1,...,n

yi = the total of all observations (boats or anglers) in the ith cluster

Estimated total hours (T) of use (anglers or boats) were calculated for each stratum by:

$$T = M\bar{y}$$

The variance of the estimated total hours of use was then calculated for each stratum (Scheaffer et al. 1979):

$$V(T) = \frac{N^2}{n}\left(\frac{N-n}{N}\right)\left(\frac{\sum_{i=1}^{n}(yi-\bar{y}mi)^2}{n-1}\right)$$

where: V(T) = the estimated variance of total hours of use for the stratum

N = the total number of clusters (half days) in the stratum

n = the number of clusters (half days) in the random sample

mi = the number of elements (hours) in cluster i, i=1,...,n

yi = the total of all observations (boats of anglers) in the ith cluster

$\bar{y}$ = the mean number of anglers or boats for all observations in the stratum

Once the estimated variance of total hours was calculated, the bound (B) on the error of estimation (approximately equal to 95% confidence interval) was calculated (Scheaffer et al. 1979):

$$B = \pm 2\sqrt{V(T)}$$

Estimates of use for each stratum were combined to estimate total use for each zone and then for the entire reservoir by (Scheaffer et al. 1979):

$$Tst = \sum_{i=1}^{L} Mi\bar{y}i = \sum_{i=1}^{L} Ti$$

where: Tst = estimated total hours of use in the population (season, zone, or entire reservoir)

Mi = the total number of elements (hours) in stratum i i-1,...,L

Ti = estimated hours of use in stratum i i-1,...,L

L = the total number of strata in the population

The estimated variance of total use in 1979 at each zone and for the entire reservoir was calculated by (Scheaffer et al. 1979):

$$V(Tst) = \sum_{i=1}^{L} V(Ti)$$

where: V(Tst) = estimated variance of total hours of use for the population (season, zone or entire reservoir)

V(Ti) = estimated variance of hours of use for stratum i, i=1,...,L

L = the total number of strata in the population

Using the estimated variance of total use, the bound on the error of estimation (B) of total use estimates was calculated:

$$B = \pm 2\sqrt{V(Tst)}$$

Data collected in 1979 were used to develop seasonal strata for a stratified random sampling (Scheaffer et al. 1979) of Little Goose Reservoir during the 1980 sampling season (March - November). Number of samples required per zone, to achieve a bound on the error of estimation of +/- 50% of the estimated use at the stratum level, was also estimated from 1979 data (Scheaffer et al. 1979). Boyer Park-Illia Landing, Willow Landing-Penawawa and Central Ferry-Port of Garfield zones all displayed similar trends in angler use in 1979 with the heaviest use occurring from late April through June (Appendix I). Based on 1979 trends, these three zones were divided into two seasonal strata in 1980: March-April and July-November; and, May-June. The Little Goose Landing Zone displayed different trends in angler use in 1979 with the heaviest angler use occurring during August and September (Appendix I). The Little Goose Landing zone was seasonally stratified; March-July and October-November; and, August-September in 1980. As in 1979, sampling in 1980 was stratified by zone, time of day, and by weekdays and weekend-holiday days. Procedures to conduct the 1980 surveys were identical for all zones; on randomly selected days, clerks made instantaneous counts at all zones scheduled to be surveyed that day. Surveys took up to 4 hours to complete and were usually conducted during times representing average daily use. The order in which various zones were sampled was randomly selected. In addition, periodic air and boat surveys of Little Goose Reservoir were conducted in 1980 to provide estimates of use at areas that could not be sampled by automobile surveys.

Estimates of use (hours) in 1980 were calculated for boat anglers, shore anglers, fishing boats, and pleasure boats during each stratum by (Scheaffer et al. 1979):

$$T = N\bar{y} = N \frac{\sum_{i=1}^{n} yi}{n}$$

where: T = the estimated total hours of use for the stratum

N = the total number of elements (hours) in the stratum

n = the number of instantaneous counts in a random sample

yi = the number of anglers or boats counted in the ith instantaneous count i=1,...,n

$\bar{y}$ = the mean of all instantaneous counts in the stratum

The estimated variance of total use (hours) was calculated for each stratum by (Scheaffer et al. 1979):

$$V(T) = \frac{N^2}{n}\left(\frac{N-n}{N}\right)\frac{\sum_{i-1}^{n}(yi-\bar{y})^2}{n-1}$$

where: V(T) = the estimated variance of total hours of use for the stratum

N = the total number of elements (hours) in the stratum

n = the number of instantaneous counts in a random sample

yi = the number of anglers or boats counted in the ith instantaneous count i=1,...,n

$\bar{y}$ = the mean of all instantaneous counts in the stratum

T = the estimated total hours of use for the stratum

Bounds on the error of estimation (B) were calculated using the estimated variance:

$$B = \pm 2\sqrt{V(T)}$$

Estimates of use for each stratum were combined to estimate total use for each zone and then for the entire reservoir in 1980 by (Scheaffer et al. 1979):

$$Tst = \sum_{i=1}^{L} Ni\bar{y}i = \sum_{i=1}^{L} Ti$$

where: Tst = the estimated total hours of use for the population (season, zone, or entire reservoir)

Ni = the total number of elements (hours) in stratum i, i=1,...,L

$\bar{y}i$ = the mean of all instantaneous counts in stratum i

Ti = the estimated hours of use in stratum i

L = the number of strata in the population

The estimated variance of total use for each zone and for the entire reservoir was calculated by (Scheaffer et al. 1979):

$$V(Tst) = \sum_{i=1}^{L} V(Ti)$$

where: V(Tst) = the estimated variance of total hours of use for the population (season, zone, or entire reservoir)

V(Ti) = the estimated variance of total use for stratum i, i=1,...,L

L = the number of strata in the population

Bounds on the error of estimation (B) were calculated using the estimated variance:

$$B = \pm 2\sqrt{V(Tst)}$$

Data regarding angling party characteristics, quality of the fishery, yield and composition of the catch were obtained through angler interviews in 1979 and 1980. Data collected during interviews included: anglers' residence, number of anglers in party, hours fished and whether trip was or was not completed, type of fishing (boat or shore), species or species group sought, number and kind of fishes caught, and total lengths (mm) of fish caught. Also, anglers were asked to rate the quality of the fishery as excellent, good, fair, or poor. In 1979, anglers were asked if, in their opinion, "the reservoir was overused, received normal use, or was underused by anglers." Because the word "use" could have biological as well as social implications, in 1980 this question was changed to, "would you receive the most enjoyment out of your fishing trip if there were more, fewer, or the same number of anglers using this reservoir?"

Angling party characteristics assessed included angler residence, party size, length of trip, and species sought. Data on angler residence were used to determine distance travelled by a party to use Little Goose Reservoir. Distances travelled were grouped into four classes: 0 to 50 km; 51 to 100 km; 101 to 200 km; and, >200 km. These data were used to calculate the percent of parties interviewed travelling these distances for each season (spring, summer, and fall) in 1979 and 1980. Residence data were used to determine the number of parties visiting Little Goose Reservoir from population centers in the eastern Washington area. Mean party size and mean length of fishing trip (completed trips only) were calculated for boat and shore anglers interviewed during 1979 and 1980. Also, percent of parties interviewed seeking a particular species of fish and percent of total angler hours expended fishing for a given species were calculated. Graphic comparisons of party characteristics and species sought were made among sampling zones, seasons, and between boat and shore anglers.

Angler attitudes, percent of parties successful (those removing at least one fish), catch rates, and harvest rates were used to establish the quality of the sport fishery on Little Goose Reservoir. Data on angler attitudes were analyzed for each access zone, boat and shore anglers, and for successful and unsuccessful parties using chi-square contingency tables. Results of analyses on angler attitudes are expressed as a percentage of parties interviewed who gave a particular response. Percent of parties successful was calculated for all species and for the species sought during 1979 and 1980. Only interviews based on completed trips were used in calculating percent of parties successful. Catch rates (number of fish/angler hour) and harvest rates (biomass/angler hour) were calculated for individual species and for all species. Biomass of creeled fish was estimated from length measurements, obtained during interviews, by grouping fish into size classes and back-calculating weights from length-weight equations obtained from fish collections (Subobjective 2). Only creeled fish were used in calculating catch rates and harvest rates (Lambou 1966). Mean catch rates and harvest rates were calculated each year for boat and shore anglers in each sampling zone by:

$$\overline{x} = \frac{\sum_{i=1}^{n} wixi}{\sum_{i=1}^{n} wi}$$

where: $\overline{x}$ = mean catch rate or harvest rate for the stratum

n = the number of party interviews in the stratum

xi = the catch rate or harvest rate for the ith party

i=1,...,n

wi = weighting factor = the total angler hours expended by the ith party when interviewed

The estimated variance of the mean catch rate or harvest rate was calculated by:

$$V(\bar{x}) = \left(\frac{1}{n}\right) \frac{\sum_{i=1}^{n} wi\ (xi-\bar{x})^2}{\sum_{i=1}^{n} wi}$$

where: $V(\bar{x})$ = estimated variance of the mean catch or harvest rate

n = the number of party interviews in the stratum

xi = the catch or harvest rate for the ith party, i=1,...,n

wi = weighting factor = the total angler hours expended by the ith party when interviewed

$\bar{x}$ = estimated mean catch or harvest rate for the stratum

Using the variance of the means, the bounds (B) on the error of estimation were calculated:

$$B = \pm 2\sqrt{V(\bar{x})}$$

Mean catch and harvest rates for each stratum were combined to estimate catch and harvest rates for each zone and then for the entire reservoir by:

$$\bar{x}st = \frac{1}{\sum_{i=1}^{L} ni} \sum_{i=1}^{L} ni\bar{x}i$$

where: $\bar{x}st$ = the estimated mean catch rate or harvest rate for the population (season, zone, or entire reservoir)

ni = the number of parties interviewed in stratum i, i=1,...,L

$\bar{x}i$ = the mean catch rate or harvest rate for stratum i

The estimated variance of $\bar{x}st$ was calculated by:

$$V(\bar{x}st) = \frac{1}{\left(\sum_{i=1}^{L} ni\right)^2} \sum_{i=1}^{L} ni^2 \, V(\bar{x}i)$$

where: $V(\bar{x}st)$ = the estimated variance of mean catch or harvest rate for the population (season, zone, or entire reservoir)

ni = the number of parties interviewed in stratum i, i=1,...,L

$V(\bar{x}i)$ = the estimated variance of mean catch or harvest rate for stratum i

Bounds on the error of estimation (B) for $\bar{x}st$ were calculated from variance estimates by:

$$B = \pm 2\sqrt{V(\bar{x}st)}$$

Boat and shore angler success rates (catch rates and harvest rates) were compared using a t-test with unequal variances (Ott 1977). Also, success rates were calculated from interviews of parties who said they were seeking a particular species of fish and were compared with success rates of parties not seeking that species by a t-test with unequal variances.

Estimates of use and success rates were combined to estimate total catch (number of fish removed) and total harvest (biomass of fish removed) from Little Goose Reservoir during 1979 and 1980. Catch and harvest estimates were calculated for boat and shore anglers in each sampling zone by:

$$C = T\bar{x}$$

where: C = estimated catch or harvest for the stratum

T = estimated angler hours of use for the stratum

$\bar{x}$ = estimated mean catch rate or harvest rate for the stratum

The estimated variance of total catch and harvest was calculated by:

$$V(C) = V(T\bar{x}) = N^2 [\bar{x}^2 (V(\bar{y})) + \bar{y}^2 (V(\bar{x})) + 2COV\overline{xy}]$$

where: $V(T\bar{x})$ = the estimated variance of total catch or harvest for the stratum

N = the number of elements (hours) in the stratum

$\bar{x}$ = the estimated mean catch rate or harvest rate for the stratum

$\bar{y}$ = the mean of all instantaneous counts in the stratum

$V(\bar{y})$ = the variance of all instantaneous counts in the stratum

$V(\bar{x})$ = the variance of the mean catch rate or harvest rate for the stratum

$COV\overline{xy}$ = covariance term

Bounds on the error of estimation (B) of total catch and harvest were calculated from variance estimates by:

$$B = \pm 2\sqrt{V(T\bar{x}i)}$$

Estimates of catch and harvest for each zone were then combined to estimate total catch and harvest from Little Goose Reservoir in 1979 and 1980 by:

$$Cst = \sum_{i=1}^{L} Ci$$

where: Cst = estimated total catch or harvest for the population (season, zone, or entire reservoir)

L = the number of strata in the population

Ci = the catch or harvest for stratum i, i=1,...,L

Variance of total catch and harvest estimates was calculated by:

$$V(Cst) = \sum_{i-1}^{L} V(T\bar{x}i)$$

where: V(Cst) = the estimated variance of total catch or harvest for the population

L = the number of strata in the population (season, zone, or entire reservoir)

$V(T\bar{x}i)$ = the estimated variance of total catch or harvest for stratum i, i=1,...,L

Bounds on the error of estimation (B) were calculated from variance estimates by:

$$B = \pm 2\sqrt{V(Cst)}$$

Species composition of total catch and harvest was expressed as a percentage of the catch and harvest comprised by a given species. Also, percent composition of total catch and harvest by zones was calculated. Catch and harvest estimates were used to calculate yield from Little Goose Reservoir in 1979 and 1980. Yield was expressed as numbers (catch) and biomass (harvest) of fish removed per unit surface area (#/ha or Kg/ha).

Estimates of white crappie catch in the Central Ferry zone were used, in conjunction with white crappie population estimates (Subobjective 2), to estimate the exploitation rate of white crappie in the Deadman Bay area of Little Goose Reservoir in 1980. A population estimate was calculated for fish greater than 200 mm in total length during the spring of 1980. This estimate was used in calculating exploitation rate as follows:

$$E = \frac{C \quad (A) \quad (B)}{N}$$

where: E = exploitation rate

C = the estimated total catch of white crappie at the Central Ferry zone in 1980

A = the percentage of recorded angler catches of white crappie that were greater than 200 mm in length

B = the percentage of recorded angler catches of white crappie recorded during the season corresponding to the population estimate

N = population estimate for white crappie in Deadman Bay

RESULTS

Aerial Surveys

Significant differences among all combinations of seasons, types of use (total anglers, shore anglers, fishing boats, and pleasure boats) and reservoirs occurred in 1979 and 1980 based on chi square contingency table analyses of aerial survey data. From further analysis of aerial survey data, we found angler use was lowest on Lower Monumental Reservoir and summer pleasure boat use was highest on Ice Harbor Reservoir (Tables 2-4). Data from weekend aerial surveys during 1979 indicated that total anglers and shore anglers on Lower Monumental Reservoir were significantly ($Z=2.5857$, $\alpha = .10$) less than 25% of the totals during the spring and fall seasons (Table 2). During 1980, spring and summer shore angler use and fall fishing boat and boat angler use on Lower Monumental Reservoir were significantly ($Z=2.5857$, $\alpha = .10$) less than 25% of the totals. Weekend pleasure boat use on Ice Harbor Reservoir was significantly ($Z=2.5857$, $\alpha = .10$) higher than 25% of the totals during spring and summer of 1979 and summer of 1980 (Tables 2 and 3).

Estimates of Use on Little Goose Reservoir

Anglers fished an estimated 45,752 hours on Little Goose Reservoir from April - November, 1979 (Fig. 3; Appendix II) and 79,605 hours from March - November, 1980 (Fig. 4; Appendix II). Fishing boat and pleasure boat use on Little Goose Reservoir were estimated to be 8,864 hours and 17,202 hours, respectively, in 1979 (Fig. 5; Appendix II). During 1980, 14,734 fishing boat hours and 20,923 pleasure boat hours were estimated for Little Goose Reservoir (Fig. 6; Appendix II). Estimates of use and bounds on the error of estimation for individual strata are contained in Appendix II.

Table 2. Number of anglers and boats counted during weekend aerial surveys of lower Snake reservoirs from March through November, 1979.

Season[a]	Number of surveys	Use	Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Spring	3	Total anglers	112	134	82[c]	154[b]	482
		Shore anglers	78	88	57[c]	113[b]	336
		Boat anglers	34	46	25	41	146
		Fishing boats	14	19	12	19	64
		Pleasure boats	45[c]	68	46[c]	100[b]	259
Summer	3	Total anglers	51	63	46	40	200
		Shore anglers	21	29	14	26	90
		Boat anglers	30	34	32	14[c]	110
		Fishing boats	15	14	15	6[c]	50
		Pleasure boats	109	138	70[c]	199[b]	516
Fall	3	Total anglers	54[b]	38	17[c]	41	150
		Shore anglers	36[b]	7[c]	4[c]	28	75
		Boat anglers	18	31[b]	13	13	75
		Fishing boats	7	15	5	6	33
		Pleasure boats	28	25	14	14	81

[a]Spring: March - May
Summer: June - August
Fall: September - November

[b]observed value is significantly (α = .10) greater than 25% of the total

[c]observed value is significantly (α = .10) less than 25% of the total

Table 3 . Number of anglers and boats counted during weekend aerial surveys of lower Snake reservoirs from March through November, 1980.

Season[a]	Number of surveys	Use	Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Spring	3	Total anglers	187	167	92	114	560
		Shore anglers	121^{b}	93	38^{c}	55^{c}	307
		Boat anglers	66	74	54	59	253
		Fishing boats	29	33	25	29	116
		Pleasure boats	20	28	14	23	85
Summer	3	Total anglers	141	141	72	145	499
		Shore anglers	95	93	35^{c}	86	309
		Boat anglers	46	48	37	59	190
		Fishing boats	23	20	16	26	85
		Pleasure boats	20^{c}	35^{c}	35^{c}	107^{b}	197
Fall	3	Total anglers	85	77	34	47	243
		Shore anglers	41	21^{c}	27	39	128
		Boat anglers	44^{b}	56^{b}	7^{c}	8^{c}	115
		Fishing boats	27^{b}	26^{b}	4^{c}	3^{c}	60
		Pleasure boats	48^{b}	35	12^{c}	20	115

[a] Spring: March - May
Summer: June - August
Fall: September - November

[b] observed value is significantly (α = .10) greater than 25% of the total

[c] observed value is significantly (α = .10) less than 25% of the total

Table 4 . Number of anglers and boats counted during weekday aerial surveys of lower Snake reservoirs from June through October 1979 and March, 1980.

Season[a]	Number of surveys	Use	Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Summer 1979	3	Total anglers	34	41	26	31	132
		Shore anglers	21	24	11[b]	20	76
		Boat anglers	13	17	15	11	56
		Fishing boats	6	9	6	5	26
		Pleasure boats	7	7	4	5	23
Fall 1979	2	Total anglers	14	13	13	22	62
		Shore anglers	4	3	11	9	27
		Boat anglers	10	10	2[b]	13	35
		Fishing boats	5	3	1[b]	7	16
		Pleasure boats	2	2	4	0[b]	8
Spring 1980	1	Total anglers	19	11	2	3	35
		Shore anglers	11	9	2	3	25
		Boat anglers	8	2	0	0	10
		Fishing boats	4	1	0	0	5
		Pleasure boats	1	0	0	0	1

[a] Spring: March - May
Summer: June - August
Fall: September - November

[b] observed value is significantly (α = .10) less than 25% of total

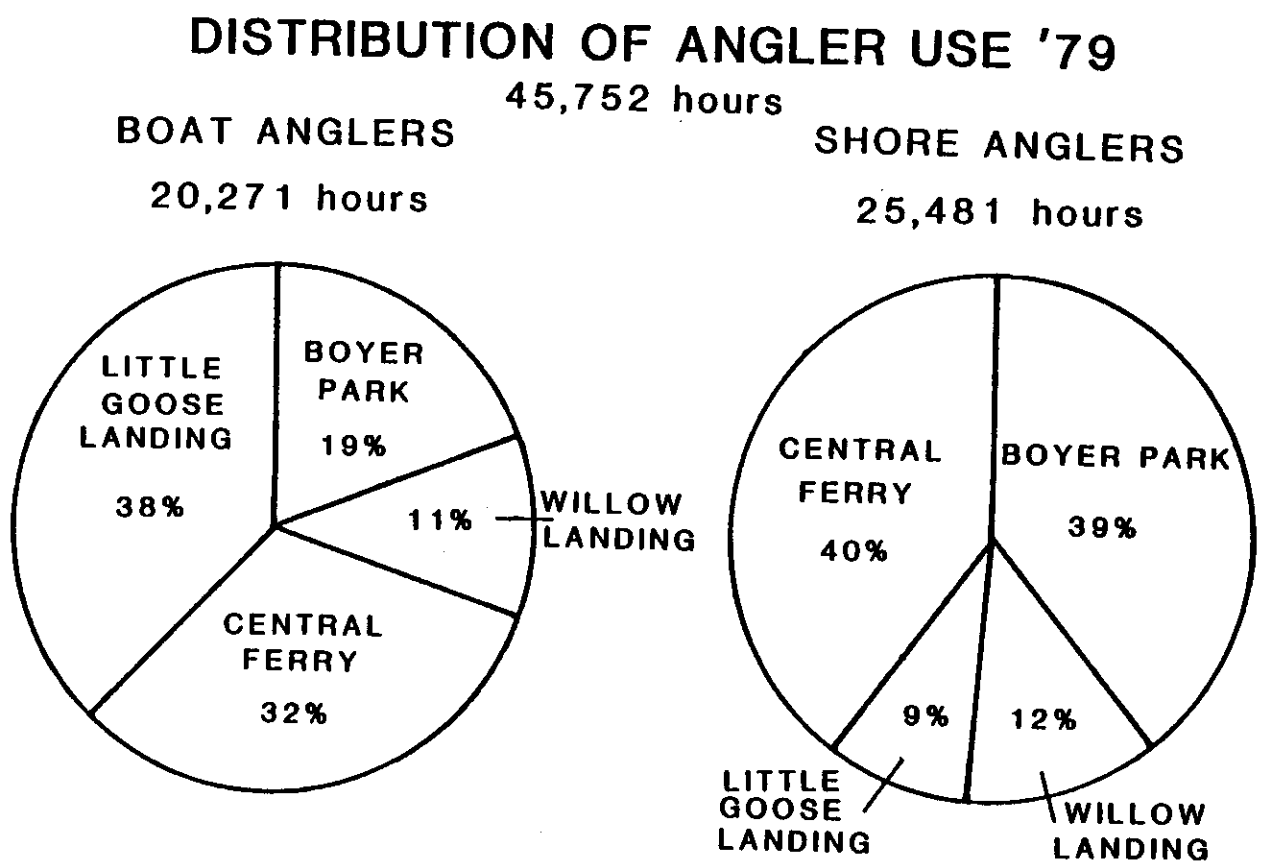

Figure 3. Estimates of total angler use and distribution of boat and shore angler use among zones of Little Goose Reservoir, Washington, during April-November, 1979.

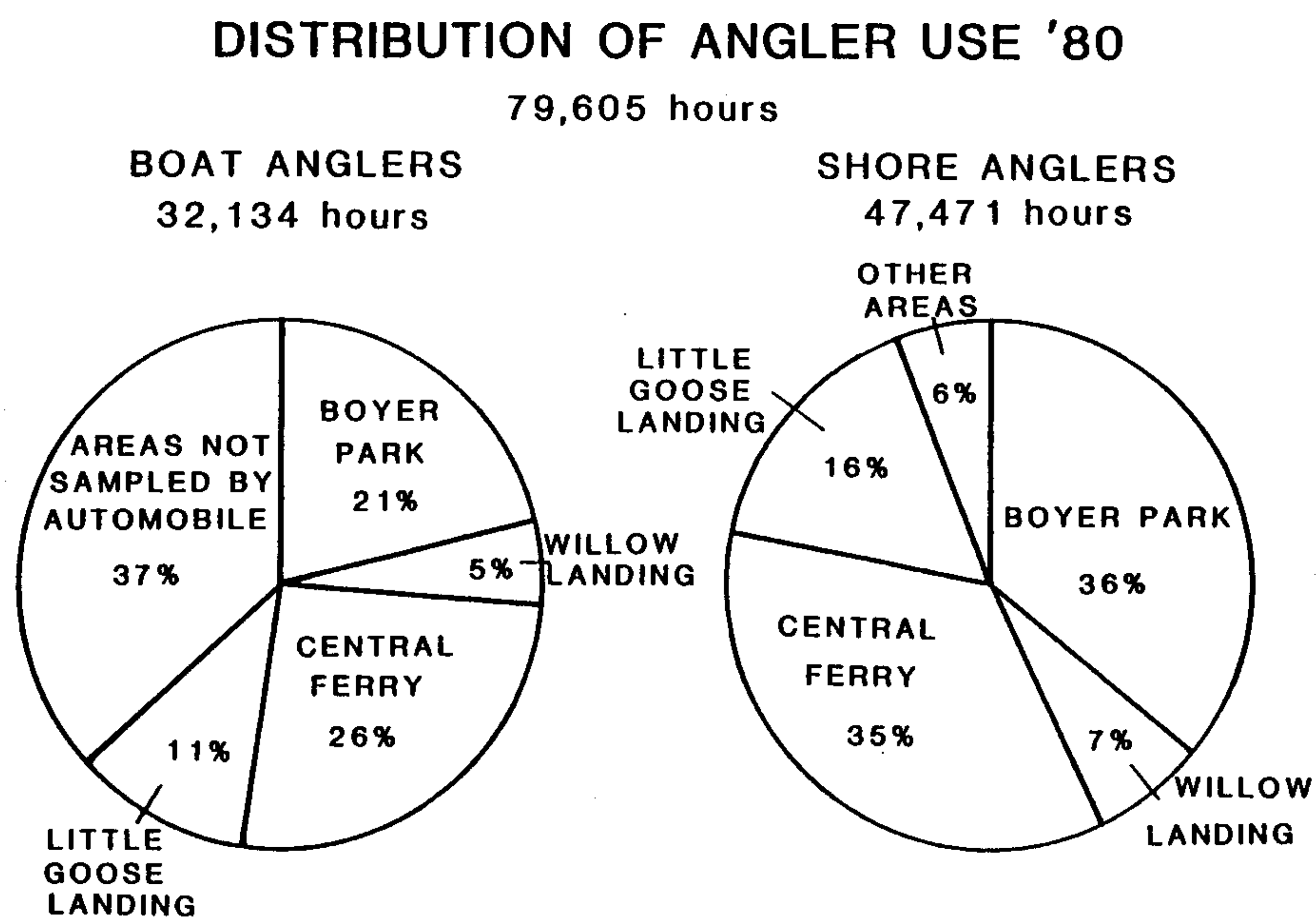

Figure 4. Estimates of total angler use and distribution of boat and shore angler use among zones of Little Goose Reservoir, Washington, during March-November, 1980.

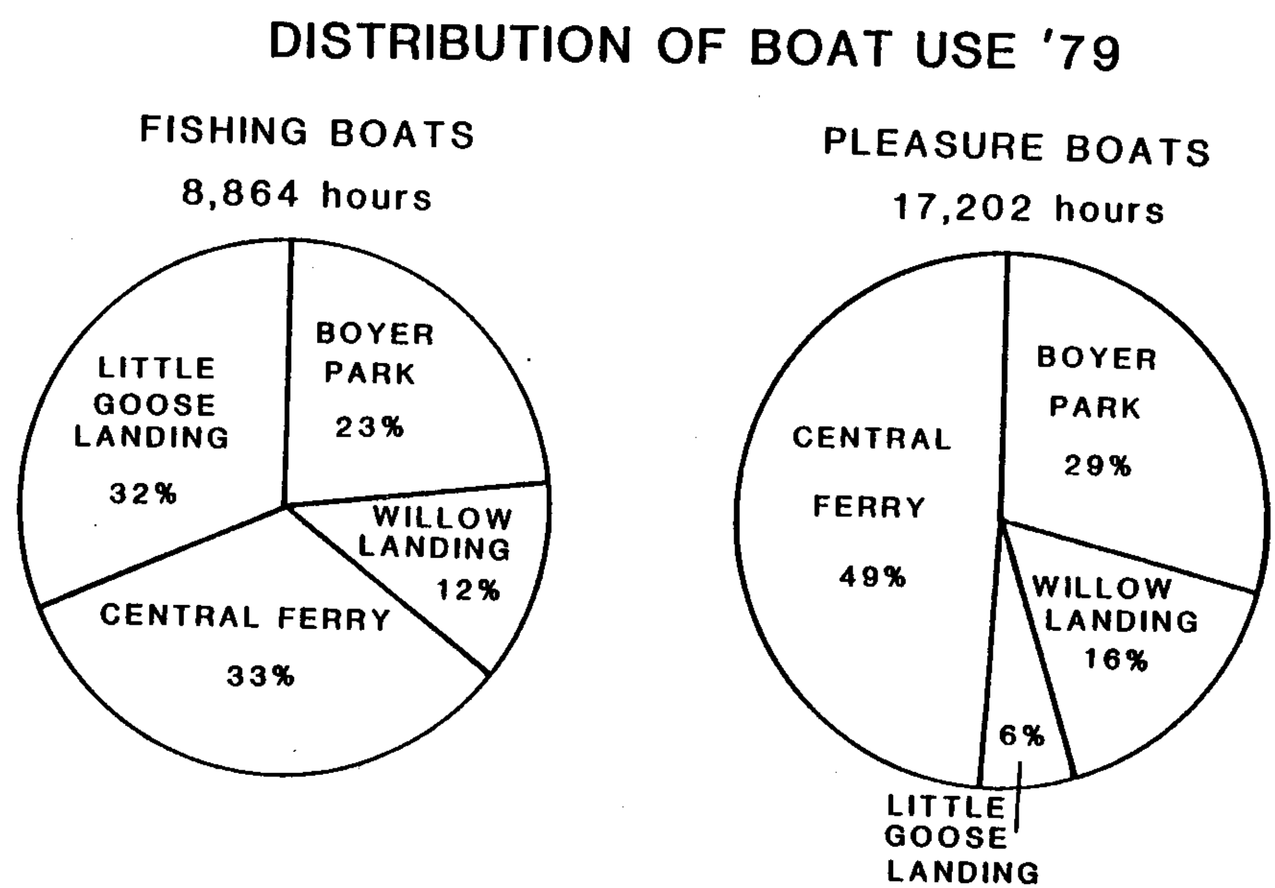

Figure 5. Estimates of fishing boat and pleasure boat use and distribution of boat use among zones of Little Goose Reservoir, Washington, during April-November, 1979.

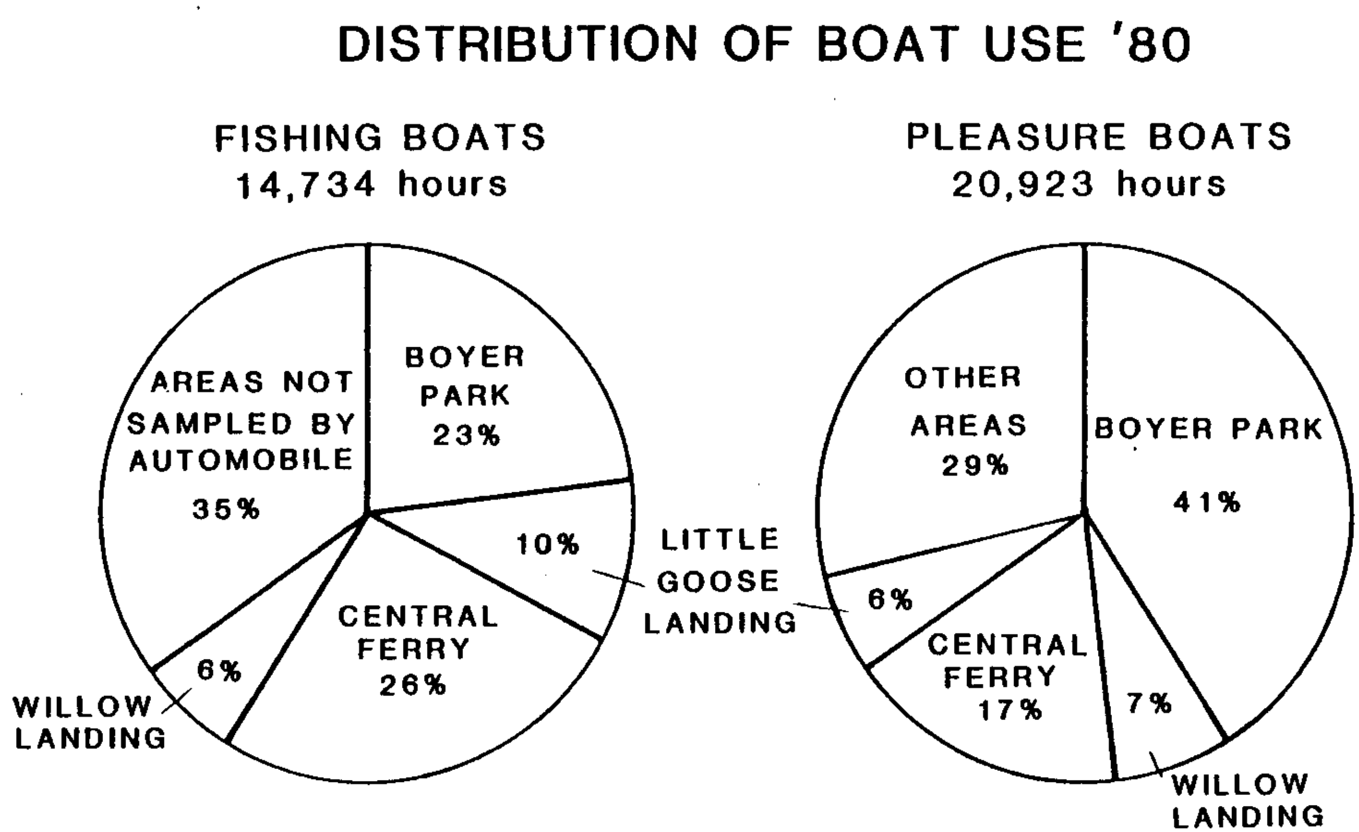

Figure 6. Estimates of fishing boat and pleasure boat use and distribution of boat use among zones of Little Goose Reservoir, Washington, during March-November, 1980.

Of the 45,752 angler hours estimated for Little Goose Reservoir in 1979, 56% was by shore anglers and the remainder by boat anglers. The Central Ferry - Port of Garfield zone received the most angler use in 1979 (16,533 hours; Fig. 3; Appendix II) followed by the Boyer Park - Illia Landing zone (13,907 hours), the Little Goose Landing zone (10,092 hours), and the Willow Landing - Penawawa zone (5,222 hours). Trends in boat use were similar to those for angler use in 1979. The Central Ferry - Port of Garfield zone received the most boat use, followed by Boyer Park - Illia Landing, Little Goose Landing, and Willow Landing - Penawawa zones (Fig. 5; Appendix II).

Of the 79,605 hours of angler use estimated for Little Goose Reservoir in 1980, 60% was by shore anglers and the remainder by boat anglers. The Central Ferry - Port of Garfield (24,990 hours) and Boyer Park - Illia Landing (23,896 hours) zones received the most angler use (Fig. 4; Appendix II) followed by Little Goose Landing Zone (11,061 hours) and Willow Landing - Penawawa zone (4,950 hours). An additional 14,708 hours of angler use were estimated for areas of Little Goose Reservoir that could not be counted during the 1980 automobile surveys (Fig. 4; Appendix II). The Central Ferry - Port of Garfield zone received the most fishing boat use (3,778 hours) while the Boyer Park - Illia Landing zone received the most pleasure boat use (8,604 hours) in 1980 (Fig. 6; Appendix II).

Angling Party Characteristics

Residence data were collected from interviews of 344 angling parties using Little Goose Reservoir in 1979 and 242 angling parties in 1980. The majority of parties interviewed (60 - 90% at the Boyer Park zone, 40 - 70% at the Central Ferry and Willow Landing zones, and 80 - 100% at the Little

Goose Landing zone) travelled 100 km or less to use Little Goose Reservoir (Figs. 7 and 8). The majority of the parties interviewed during 1979 and 1980 at the Boyer Park zone were from the Moscow-Pullman area (Figs. 9 and 10). The majority of parties interviewed at the Central Ferry and Little Goose Landing zones were from Walla Walla (Figs. 9 and 10).

Boat angling parties were slightly larger, and on the average, fished longer than shore anglers on Little Goose Reservoir during 1979 and 1980 (Table 5). Mean duration of fishing trips was greatest for shore anglers seeking white sturgeon and for boat and shore anglers seeking channel catfish (Table 5).

Species commonly sought by anglers on Little Goose Reservoir included bass, crappies, channel catfish, and white sturgeon (Figs. 11 - 14; Table 5). Bass were most commonly sought by boat anglers during 1979 (94%, 52%, and 73% of the boat angler hours at the Boyer Park, Central Ferry, and Little Goose Landing zones, respectively) and 1980 (85%, 40%, and 61% of the boat angler hours at the Boyer Park, Central Ferry, and Little Goose Landing zones, respectively). Shore anglers sought a greater variety of species than boat anglers and displayed differences in species sought among zones (Figs. 12 and 14). Sturgeon were frequently sought by shore anglers at the Boyer Park zone, whereas crappies were frequently sought by shore anglers at the Central Ferry zone. Although variable among zones, as many as 68% of the boat and shore anglers indicated no species preferences.

Angler Success

During 1979, 61.7% of the boat angling parties and 50.4% of the shore angling parties interviewed were successful (caught at least one fish), whereas 78.7% of the boat angling parties and 71.4% of the shore angling

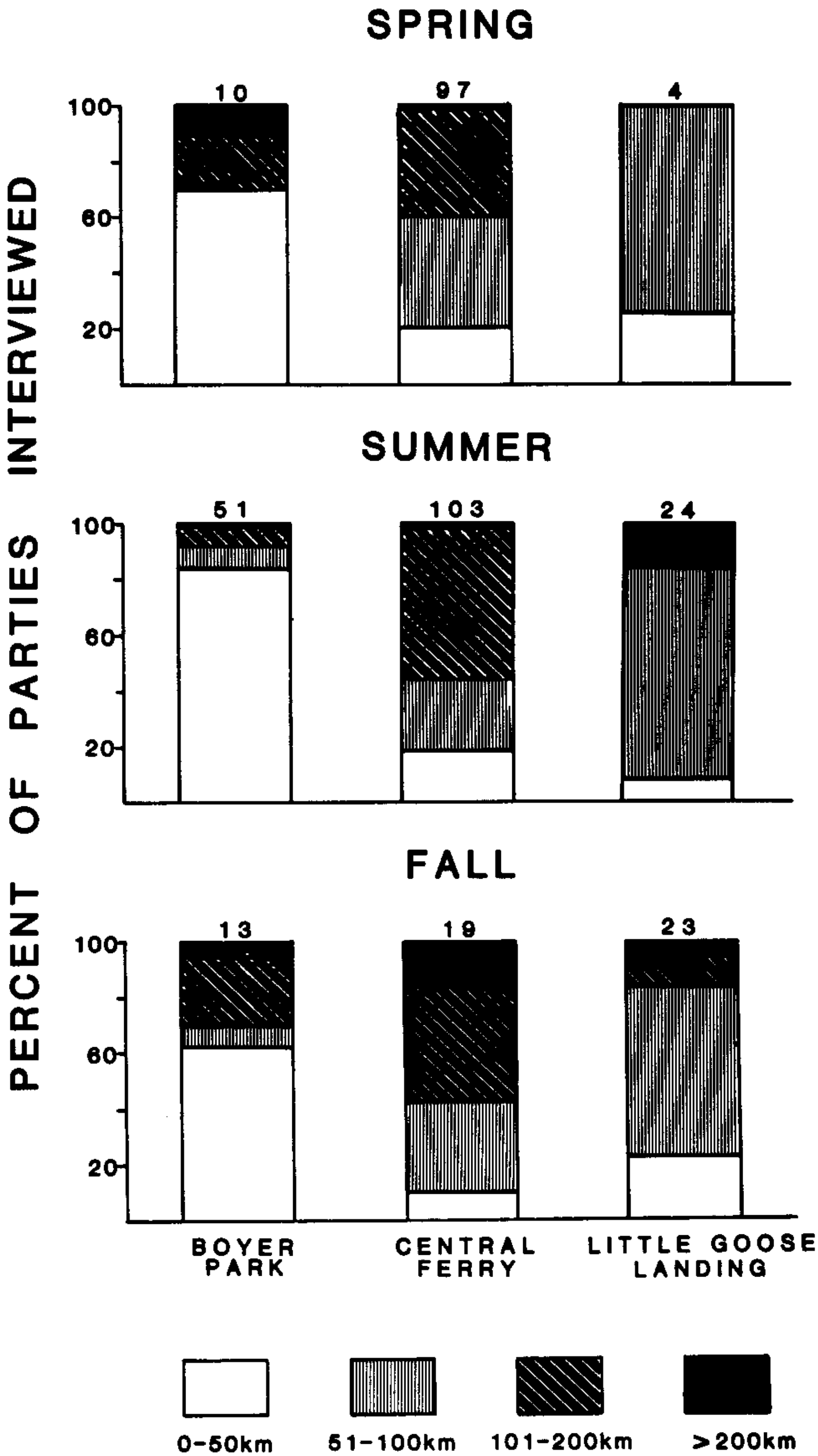

Figure 7. Distances traveled by angling parties using major access areas on Little Goose Reservoir, Washington, 1979. Number of parties interviewed are shown.

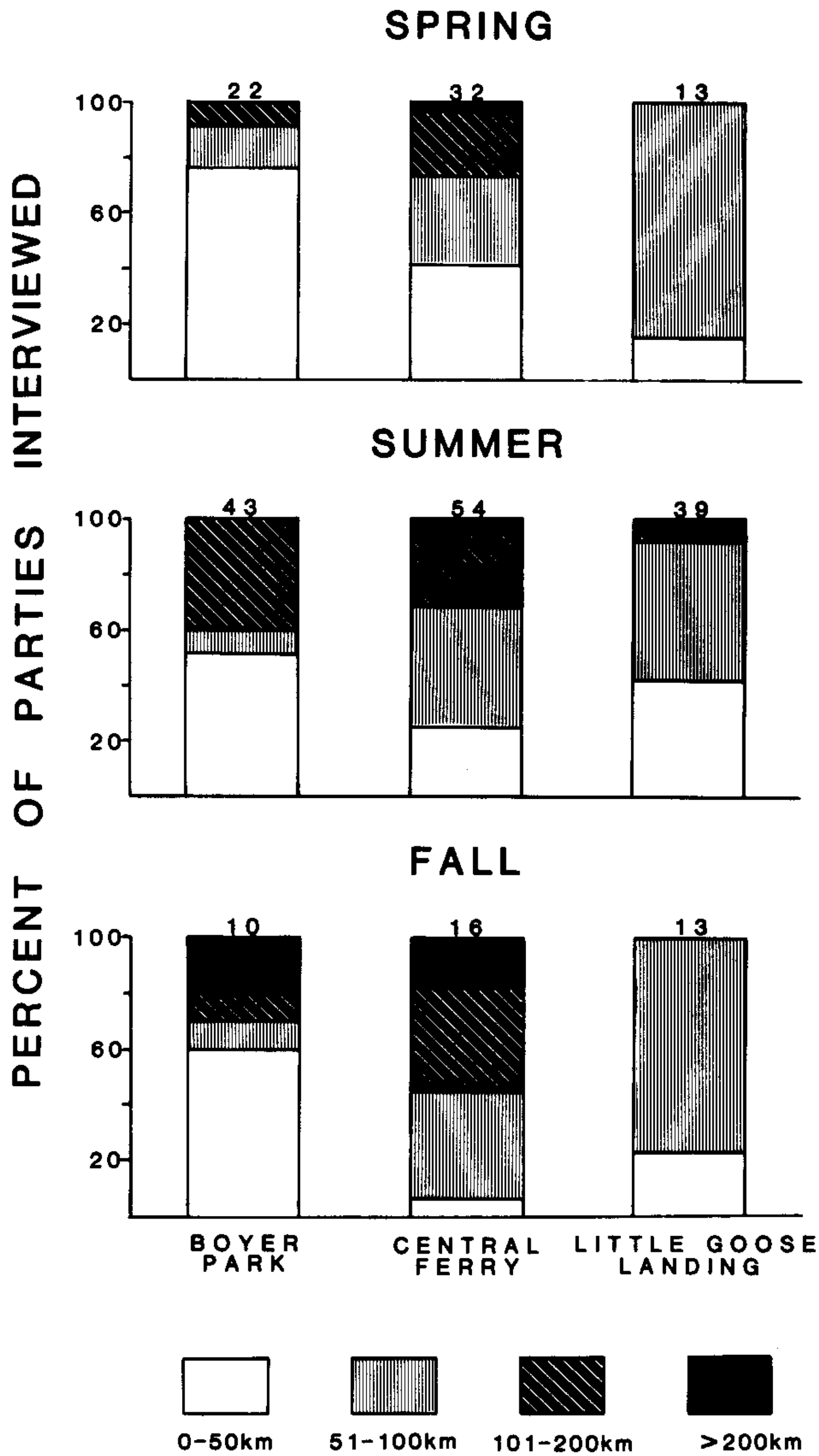

Figure 8. Distances traveled by angling parties using major access areas on Little Goose Reservoir, Washington, 1980. Number of parties interviewed are shown. (Parties interviewed at Willow Landing zone were combined with Central Ferry).

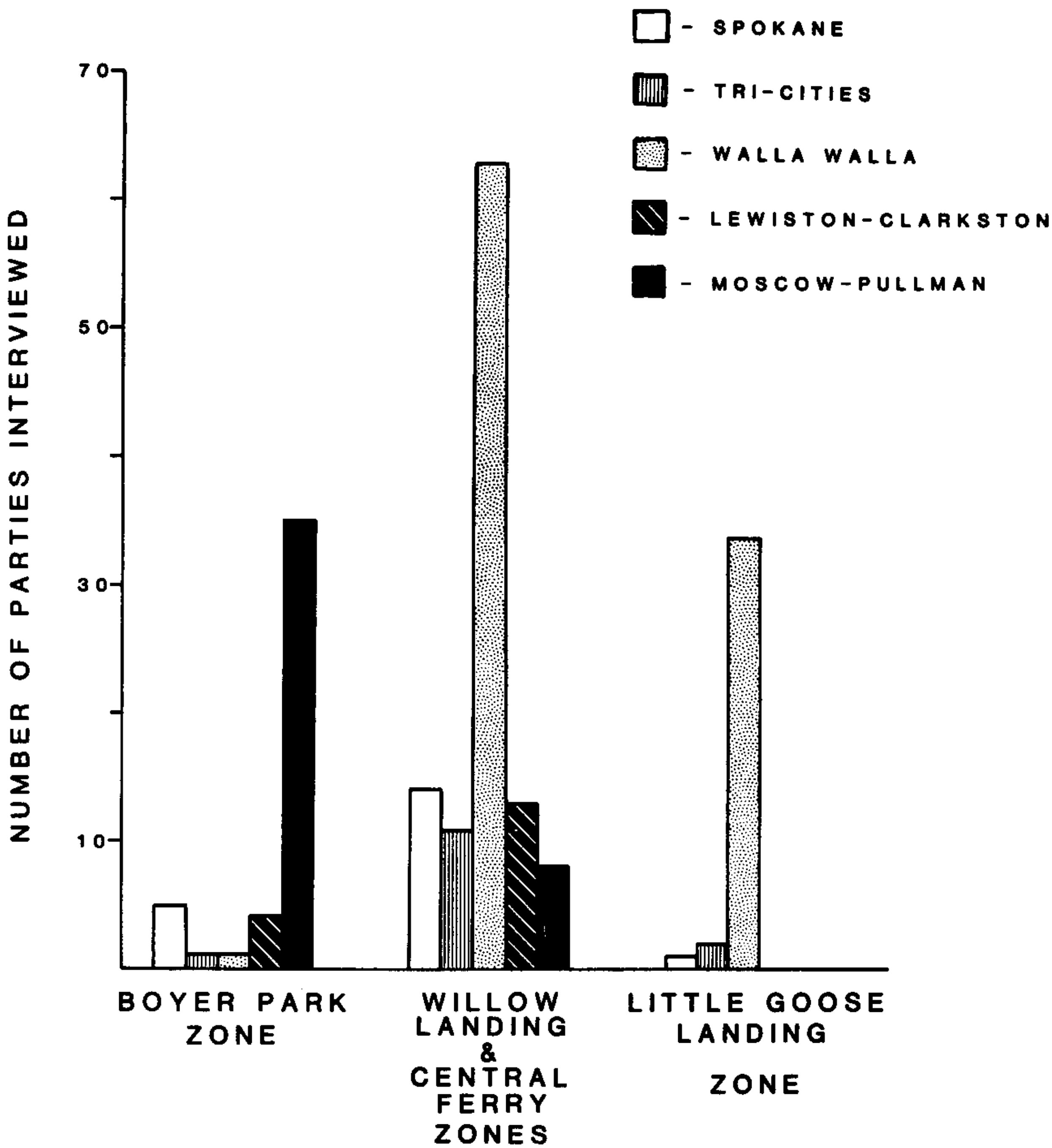

Figure 9. Number of parties interviewed on Little Goose Reservoir, Washington, in 1979 originating from major population centers in eastern Washington.

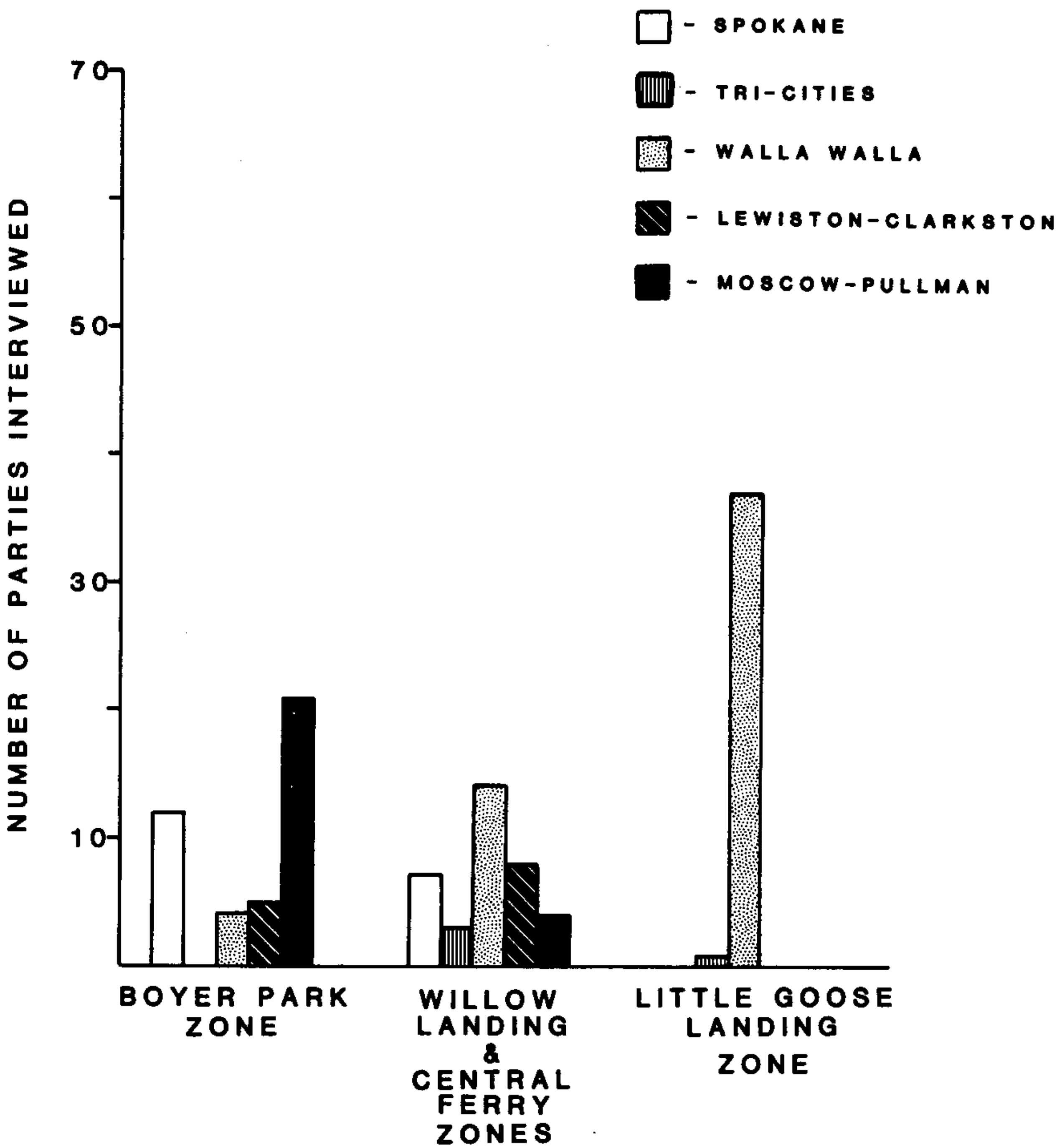

Figure 10. Number of parties interviewed on Little Goose Reservoir, Washington, in 1980 originating from major population centers in eastern Washington.

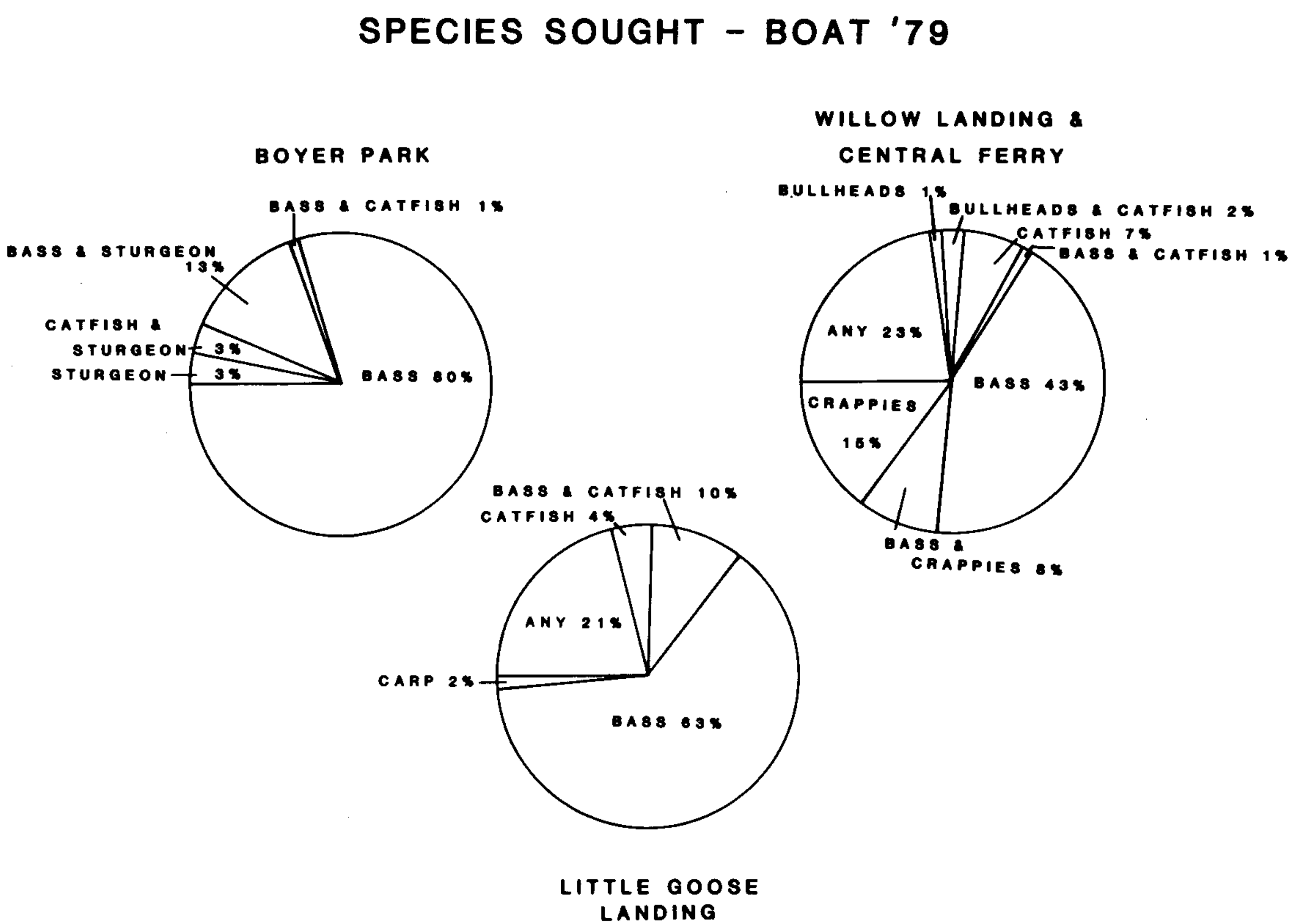

Figure 11. Species sought (percent of angler hours) by boat anglers on Little Goose Reservoir, Washington, from April - November, 1979.

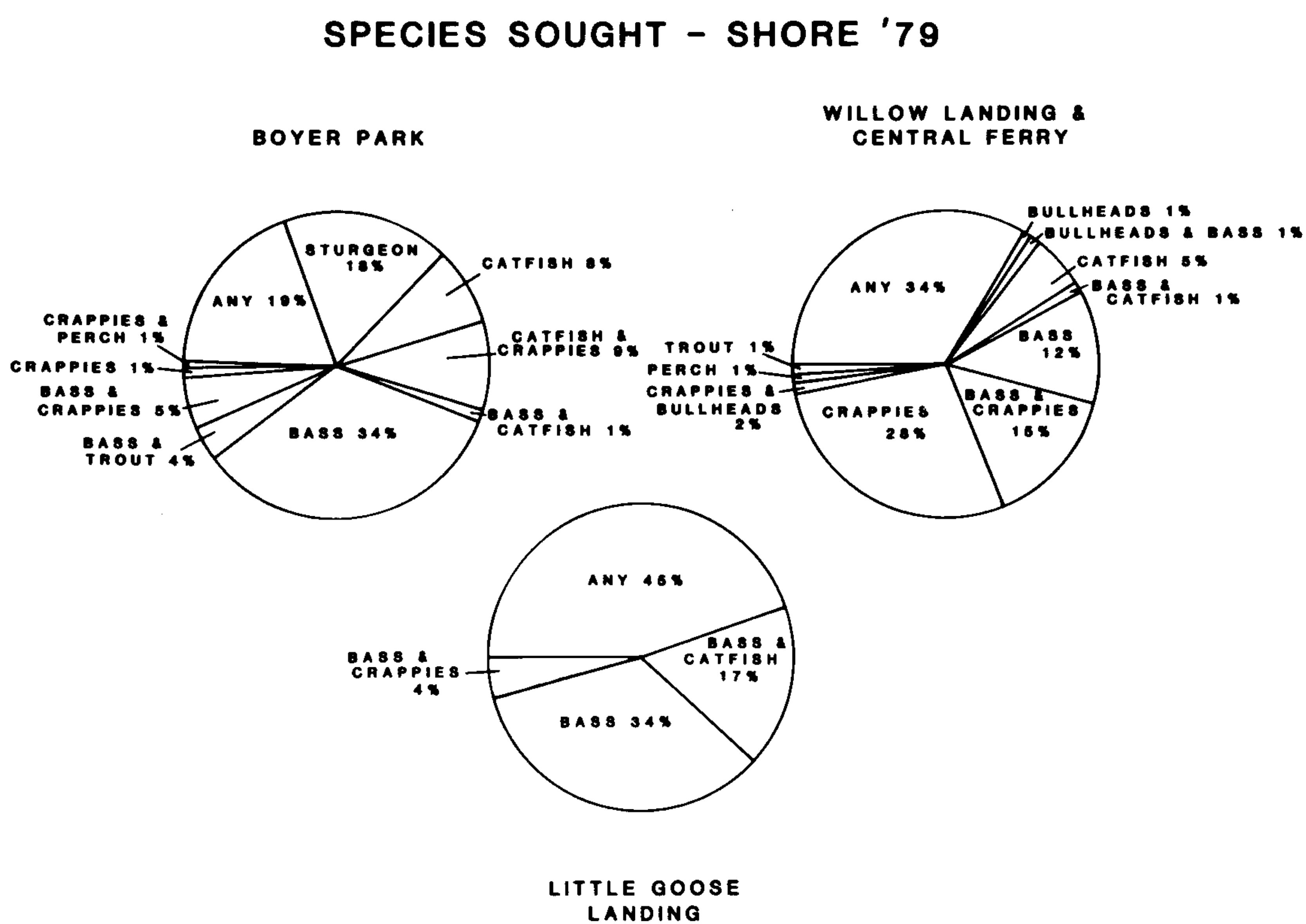

Figure 12. Species sought (percent of angler hours) by shore anglers on Little Goose Reservoir, Washington, from April - November, 1979.

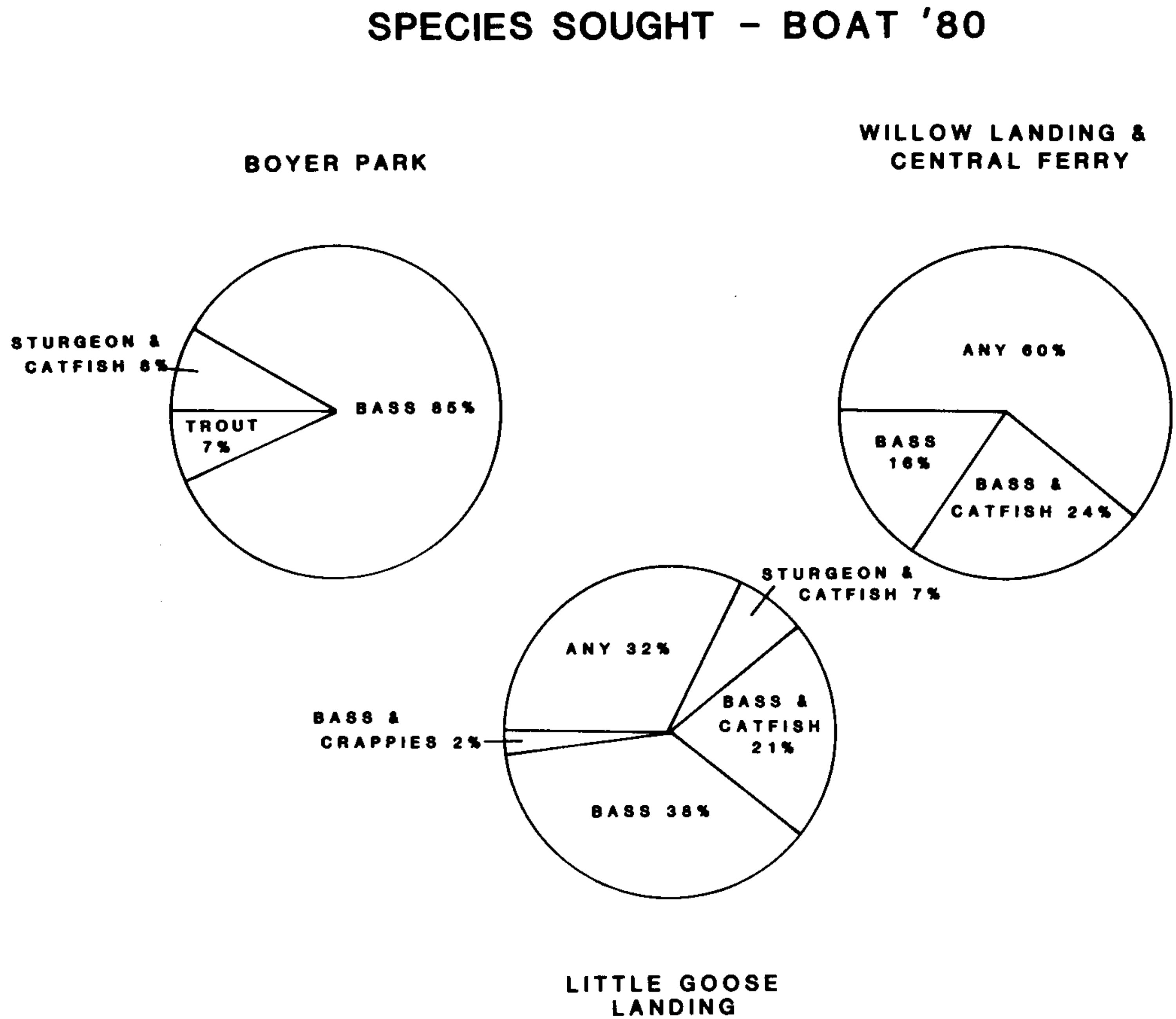

Figure 13. Species sought (percent of angler hours) by boat anglers on Little Goose Reservoir, Washington, from March - November, 1980.

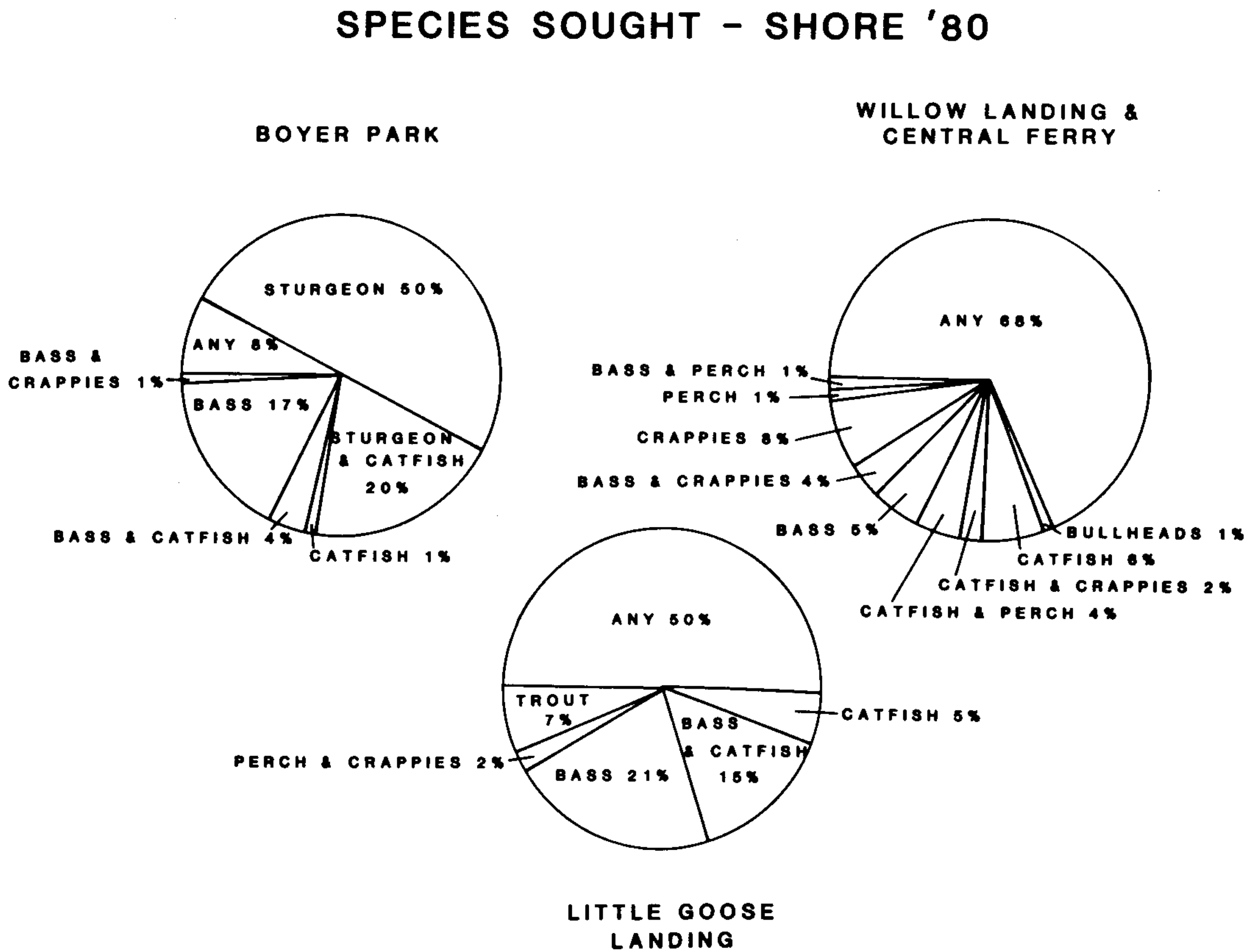

Figure 14. Species sought (percent of angler hours) by shore anglers on Little Goose Reservoir, Washington, from March - November, 1980.

Table 5. Party characteristics and angler success based on angler interviews from April through November, 1979 and March through November, 1980, on Little Goose Reservoir, Washington.

Year		Species sought[a]	No. parties interviewed	No. anglers interviewed	$\bar{X}$ time fishing (hrs)[b]	$\bar{X}$ No. anglers per party	Catch Rate (No./hour)	Harvest Rate (grams/hour)	$\bar{X}$ Weight of catch (grams)	% of parties Successful[b]
1979	Boat Anglers	Total	158	385	3.86	2.44	0.488	145.89	298.95	61.69
		bass	93	228	4.12	2.45	0.343	96.65	281.78	56.04
		crappie	31	67	3.05	2.16	0.518	106.86	206.15	41.94
		channel catfish	16	39	3.99	2.44	0.099	106.07	1074.80	40.00
	Shore Anglers	Total	222	513	2.59	2.31	0.632	129.77	205.33	50.36
		bass	85	189	2.43	2.22	0.197	48.78	247.61	33.93
		crappie	66	168	2.66	2.55	0.458	69.76	152.31	29.09
		channel catfish	19	46	3.24	2.42	0.046	43.95	955.43	36.36
1980	Boat Anglers	Total	51	139	4.89	2.73	0.553	134.96	244.05	78.72
		bass	29	79	5.01	2.72	0.454	117.68	259.21	66.67
		channel catfish	7	28	5.96	4.00	0.048	42.18	878.75	85.71
	Shore Anglers	Total	211	533	4.64	2.53	0.482	133.92	277.84	71.43
		bass	53	138	5.50	2.60	0.199	59.95	301.26	57.14
		crappie	23	42	2.50	1.83	1.120	192.13	171.54	25.00
		channel catfish	29	74	8.04	2.55	0.027	41.99	1555.19	33.33
		white sturgeon	24	59	11.25	2.46	0.010	165.01	16501.00	25.00

[a]Calculated for anglers who were fishing for a particular species or species group.

[b]Calculated from completed trips only.

parties were successful in 1980 (Table 5). Boat anglers had mean catch and harvest rates for all species of 0.49 fish/angler hour and 146 g/angler hour in 1979 (Tables 5, 6, and 7) and 0.55 fish/angler hour and 136 g/angler hour in 1980 (Tables 5, 8, and 9). Shore anglers interviewed in 1979 had mean catch and harvest rates of 0.63 fish/angler hour and 130 g/angler hour (Tables 5, 6, and 7). During 1980, shore angler catch and harvest rates were 0.48 fish/angler hour and 134 g/angler hour (Tables 5, 8, and 9).

Catch rates and harvest rates were significantly different (α=0.05) between boat and shore anglers for smallmouth bass, yellow perch (*Perca flavescens*) and bluegill (*Lepomis macrochirus*) in 1979 (Tables 6 and 7). Boat and shore anglers seeking bass, boat anglers seeking channel catfish, and shore anglers seeking crappies had significantly higher (α=0.05) catch rates and harvest rates for these species than anglers who were not seeking these species. Catch rates and harvest rates for boat anglers seeking crappies (*Pomoxis annularis* and *Pomoxis nigromaculatus*) and shore anglers seeking channel catfish, however, were not significantly different (α=0.05) than catch rates and harvest rates for anglers who were not seeking these species.

Significant differences (α=0.05) between boat and shore angler catch rates and harvest rates occurred for smallmouth bass, white sturgeon, and pumpkinseed (*Lepomis gibbosus*) in 1980 (Tables 8 and 9). Boat and shore anglers seeking bass and shore anglers seeking white sturgeon had significantly higher (α=0.05) catch and harvest rates for these species than those not seeking these species. Boat and shore anglers seeking channel catfish had significantly higher (α=0.05) catch rates for channel catfish than boat and shore anglers not seeking channel catfish, although harvest rates were not significantly different. Shore anglers seeking crappies did not manifest

Table 6. Estimates of angler catch rates from Little Goose Reservoir, Washington, 1979 (during April-November) based on party interviews (boat n = 158; shore = 222).

SPECIES	BOAT ANGLERS		SHORE ANGLERS	
	Mean Catch Rate (nos./hour)	Bound on Error of Estimation[a]	Mean Catch Rate (nos./hour)	Bound on Error of Estimation[a]
white crappie	.070	± .040	.113	± .075
black crappie	.028	± .043	.054	± .042
smallmouth bass[b]	.254	± .073	.121	± .045
channel catfish	.022	± .011	.019	± .009
yellow perch[b]	.025	± .013	.138	± .055
bullheads[c]	.066	± .040	.082	± .037
bluegill[b]	.010	± .010	.044	± .029
pumpkinseed	.004	± .003	.050	± .052
northern squawfish	.004	± .006	.006	± .006
rainbow trout	.001	± .005	.000	± .000
carp	.004	± .005	.002	± .004
All Species[d]	.488	± .109	.632	± .146

[a]Approximate 95% confidence interval (2 X standard deviation)

[b]A significant (α = .05) difference between boat and shore angler catch rates.

[c]Includes yellow and brown bullheads.

[d]May include species not listed (e.g., suckers, shiner)

Table 7. Estimates of angler harvest rates on Little Goose Reservoir, Washington, 1979 (during April-November) based on party interviews (boat n = 158; shore n = 222).

SPECIES	BOAT ANGLERS		SHORE ANGLERS	
	Mean Harvest Rate (grams/hour)	Bound on Error of Estimation[a]	Mean Harvest Rate (grams/hour)	Bound on Error of Estimation[a]
white crappie	13.56	± 7.08	18.28	± 11.56
black crappie	7.49	± 8.68	7.13	± 5.27
smallmouth bass[b]	70.74	± 20.75	26.86	± 10.59
channel catfish	24.77	± 25.33	26.76	± 13.22
yellow perch[b]	3.31	± 1.57	11.45	± 4.78
bullheads[c]	14.76	± 9.64	16.47	± 8.26
bluegill[b]	1.13	± 1.07	4.11	± 2.73
pumpkinseed	0.31	± 0.26	3.50	± 3.62
northern squawfish	1.31	± 1.79	1.24	± 1.45
rainbow trout	0.21	± 0.74	0.00	± 0.00
carp	7.13	± 8.14	11.30	± 22.04
All Species[d]	145.89	± 28.43	129.77	± 31.23

[a] Approximate 95% confidence interval (2 X standard deviation).

[b] A significant (α = .05) difference between boat and shore angler harvest rates.

[c] Includes yellow and brown bullheads.

[d] May include species not listed (e.g., suckers, shiners, etc.).

Table 8. Estimates of angler catch rates from Little Goose Reservoir, Washington, 1980 (during March-November) based on party interviews (boat n = 51; shore n = 211).

SPECIES	BOAT ANGLERS Mean Catch Rates (nos./hour)	BOAT ANGLERS Bound on Error of Estimation[a]	SHORE ANGLERS Mean Catch Rates (nos./hour)	SHORE ANGLERS Bound on Error of Estimation[b]
white crappie	.055	± .043	.082	± .106
black crappie	.006	± .007	.018	± .027
smallmouth bass[b]	.301	± .140	.081	± .026
channel catfish	.016	± .011	.009	± .006
yellow perch	.119	± .095	.198	± .060
white sturgeon[b]	.000	± .000	.002	± .001
bullheads[c]	.023	± .013	.040	± .025
bluegill	.007	± .017	.029	± .017
pumpkinseed[b]	.003	± .006	.016	± .008
northern squawfish	.004	± .005	.002	± .004
rainbow trout	.019	± .017	.003	± .005
All Species[d]	.553	± .204	.482	± .134

[a] Approximate 95% confidence interval (2 X standard deviation).

[b] Significant (α = .05) difference between boat and shore angler catch rates.

[c] Includes yellow and brown bullheads.

[d] May include species not listed (e.g., suckers, carp, etc.)

Table 9. Estimates of angler harvest rates on Little Goose Reservoir, Washington, 1980 (during March-November) based on party interviews (boat n = 51; shore n = 211).

SPECIES	BOAT ANGLERS Mean Harvest Rate (grams/hour)	BOAT ANGLERS Bound on Error of Estimation[a]	SHORE ANGLERS Mean Harvest Rate (grams/hour)	SHORE ANGLERS Bound on Error of Estimation[a]
white crappie	9.87	± 7.48	14.16	± 18.53
black crappie	0.84	± 0.87	2.95	± 4.89
smallmouth bass[b]	79.57	± 40.43	20.22	± 9.78
channel catfish	14.90	± 13.35	11.00	± 11.03
yellow perch	16.75	± 12.99	25.81	± 8.14
white sturgeon[b]	0.00	± 0.00	39.81	± 20.02
bullheads[c]	2.41	± 3.40	7.97	± 6.04
bluegill	0.92	± 2.09	3.63	± 2.07
pumpkinseed[b]	0.21	± 0.36	1.34	± 0.84
northern squawfish	1.07	± 1.97	0.47	± 1.12
rainbow trout	5.23	± 5.79	1.88	± 1.89
All Species[d]	134.96	± 51.75	133.92	± 32.73

[a]Approximate 95% confidence interval (2 X standard deviation).

[b]A significant (α = .05) difference between boat and shore angler harvest rates.

[c]Includes yellow and brown bullheads.

[d]May include species not listed (e.g., suckers, carp, etc.).

catch and harvest rates for crappies that were significantly higher (α=0.05) than those for anglers not seeking crappies.

Angler Attitudes

Attitudes of boat angling parties about the quality of the fishery on Little Goose Reservoir were not influenced (independent) by the zone where interviewed or whether or not they were successful in catching fish. Of the 158 boat angling parties interviewed in 1979, 24.7% rated the quality as excellent or good, 26.0% rated it as fair, 41.1% rated it as poor, and 8.2% had no opinion (Fig. 15). Boat angler responses were similar in 1980 when 21.6% of the 51 parties interviewed rated the fishery as excellent or good, 3.14% rated it as fair, 37.2% rated it as poor, and 9.8% had no opinion (Fig. 15).

The effects of zones and success on shore angling parties' attitudes about the quality of the fishery on Little Goose Reservoir differed between 1979 and 1980. Significant differences (x^2=20.6, p=0.0001) in attitudes of shore angling parties about the quality of the fishery on Little Goose Reservoir occurred between successful (those catching at least one fish) and unsuccessful parties in 1979. Of the 222 shore angling parties interviewed in 1979, 113 were successful and 109 were unsuccessful (Fig. 16). Ratings of fishery quality from successful parties were as follows: excellent or good, 36.3%; fair 27.4%; poor, 33.6%; and no opinion, 2.7%. Unsuccessful parties rated the quality of the fishery as: excellent or good, 24.8%; fair, 18.3%; poor, 38.5%; and no opinion, 18.4%. However, during 1980, shore anglers' attitudes about fishing quality were not significantly (x^2=3.6, p=0.31) affected by success, although significant (x^2=17.5, p=0.008) differences in responses did occur among zones (Fig. 17). The majority of shore angling parties (29.8% at the Boyer Park zone, 40.4% at the Willow

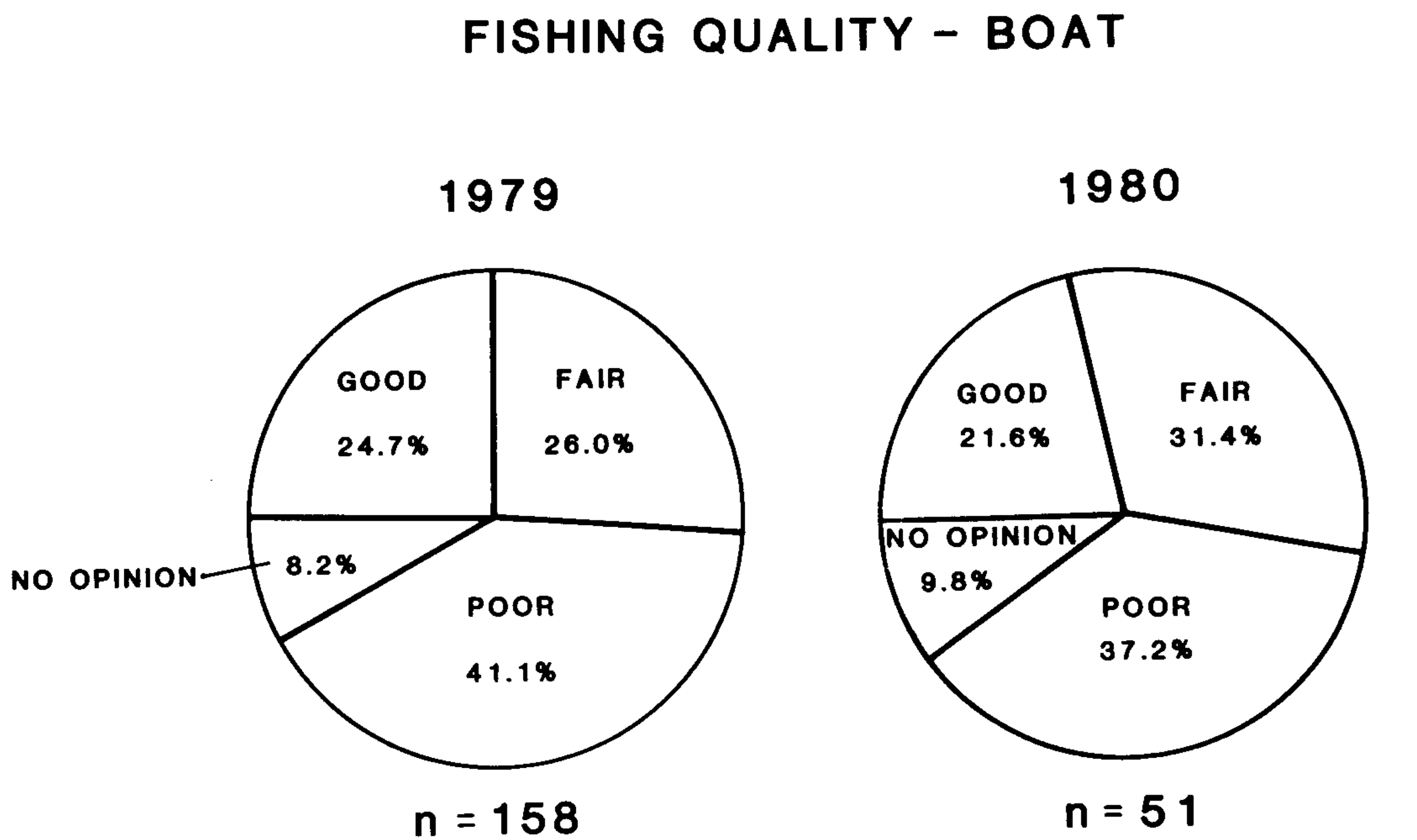

Figure 15. Quality ratings (good and excellent combined) of the fishery by boat anglers on Little Goose Reservoir, Washington.

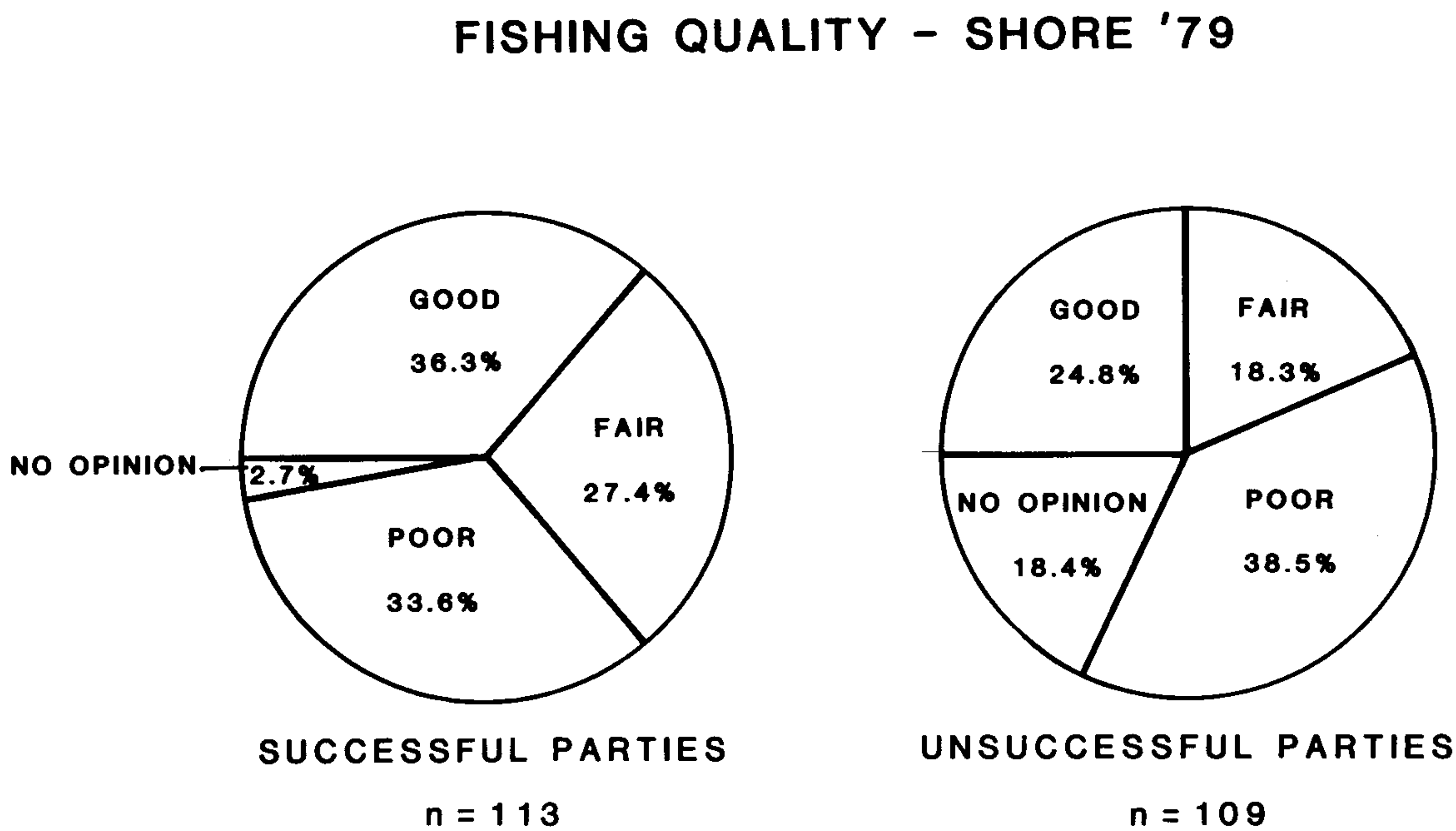

Figure 16. Quality ratings (good and excellent combined) of successful (removed at least one fish) and unsuccessful fishing parties on Little Goose Reservoir, Washington, for 1979.

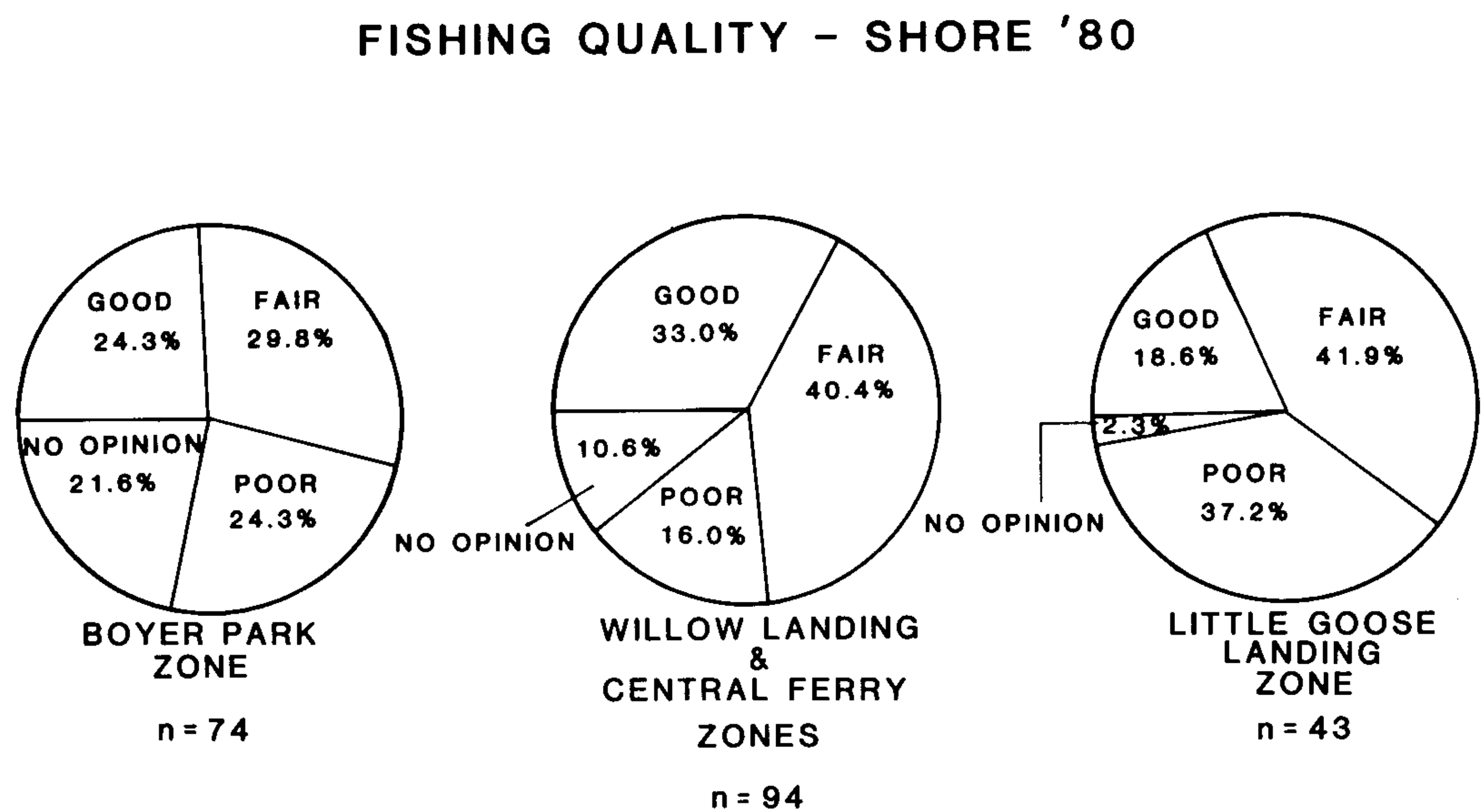

Figure 17. Responses of 211 shore angling parties, interviewed in 1980, when asked to rate the quality of the fishery on Little Goose Reservoir, Washington, as good (includes excellent ratings), fair, or poor.

Landing and Central Ferry zones, and 41.9% at the Little Goose Landing zone) rated the quality of the fishery as fair.

Angler Use

Angler attitudes about whether Little Goose Reservoir was overused, underused, or receives normal use by anglers were not significantly different among zones where interviewed and the method of fishing (boat or shore) in 1979. The majority (50.0%) of the parties interviewed in 1979 indicated that Little Goose Reservoir was underused by anglers while 23.7% said it was overused and 20.3% had no opinion (Fig. 18).

Analysis of angler attitudes about crowding in 1980, when the question was changed to ask "if they would receive the most enjoyment from their trip if there were more, fewer, or the same number of anglers using the reservoir", showed significant differences in responses among zones (x^2=11.1, p=0.085) and between boat and shore anglers (x^2=9.9, p=0.019). The majority of boat angling parties (42.8% at the Boyer Park zone, 46.6% at the Central Ferry and Willow Landing zones, and 44.8% at the Little Goose Landing zone), however, did not have an opinion about crowding affecting their enjoyment (Fig. 19). A small percentage of shore angling parties (8.1% at Boyer Park, 4.2% at Central Ferry and Willow Landing, and 4.7% at Little Goose Landing) felt they would enjoy it most if more anglers were using Little Goose Reservoir (Fig. 19). However, a large percentage of boat (41.4%) and shore (39.5%) angling parties at the Little Goose Landing zone said they would receive the most enjoyment out of their trip if there were fewer anglers using Little Goose Reservoir (Fig. 19).

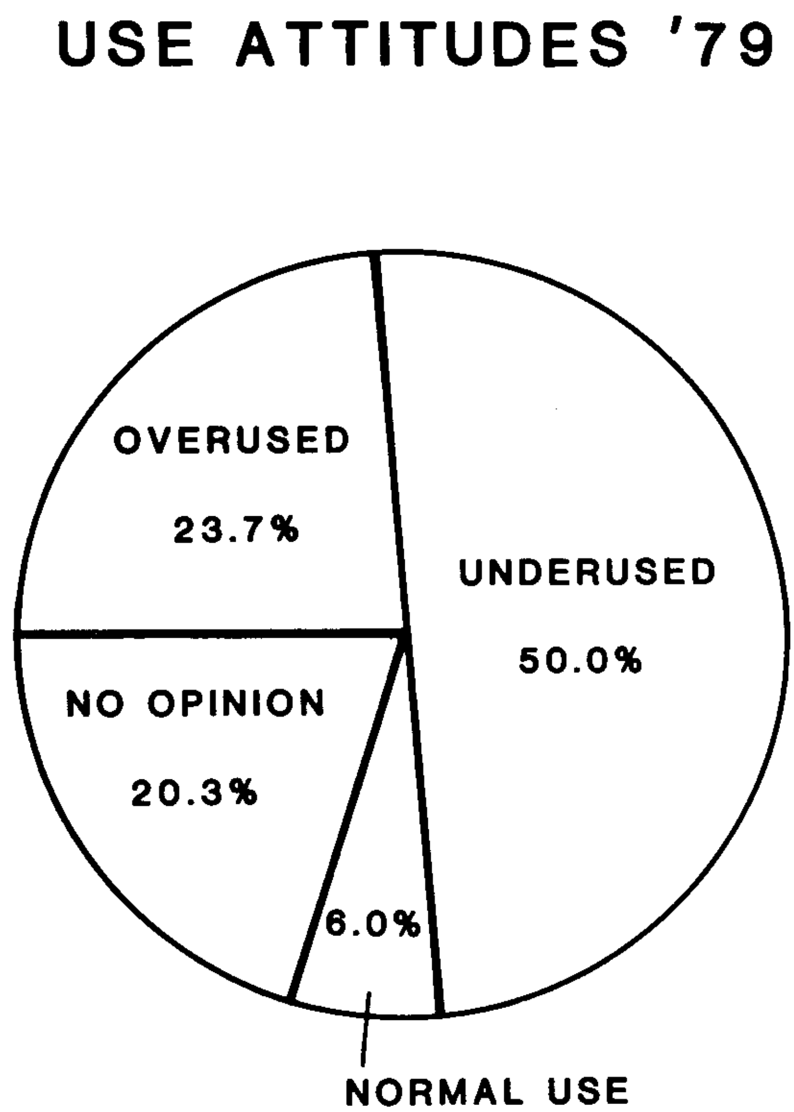

Figure 18. Responses of 380 angling parties interviewed in 1979, when asked if they felt Little Goose was overused, underused, or received normal use.

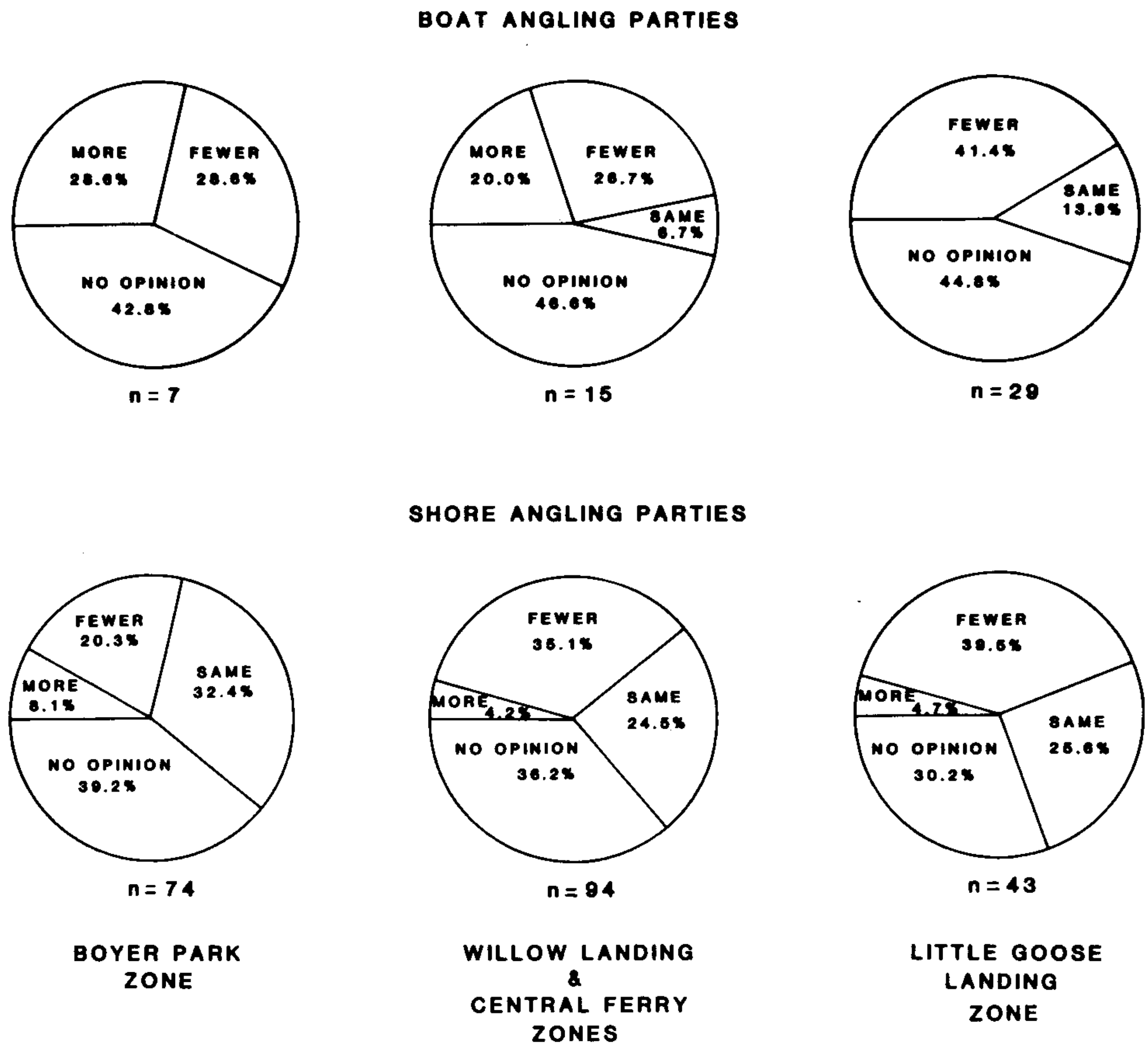

Figure 19. Responses of 262 angling parties interviewed in 1980, when asked, "if they would receive the most enjoyment from their fishing trip if there were more, fewer, or the same number of anglers using Little Goose Reservoir", Washington.

Catch, Harvest and Yield

An estimated 23,961 fish (5.91 fish/hectare), weighing 5,938.74 kg (1.46 kg/hectare), were removed from Little Goose Reservoir during April through November, 1979 (Tables 10, 11, and 12). Shore anglers accounted for 59.7% of the catch (numbers) and 51.9% of the harvest (biomass) from Little Goose Reservoir in 1979 (Tables 10 and 11). Catch and harvest by boat anglers were composed mostly of smallmouth bass (63% and 58%, respectively) in 1979 (Figs. 20 and 21). Catch by shore anglers in 1979 was composed of crappies (26%), smallmouth bass (23%), yellow perch (19%), bullheads (14%; yellow and brown), and sunfish (13%; bluegill and pumpkin-seed; Fig. 20). Crappies (18%), smallmouth bass (23%), channel catfish (20%); and bullheads (12%) accounted for most of the harvest by shore anglers in 1979 (Fig. 21).

During March through November, 1980, anglers removed an estimated 40,915 fish (10.1 fish/hectare) weighing 11,019.5 kg (2.7 kg/hectare) from Little Goose Reservoir (Tables 12, 13, and 14). Shore anglers accounted for 55.3% of the catch (numbers) and 59.2% of the harvest (biomass) in 1980 (Tables 13 and 14). As in 1979, catch and harvest by boat anglers in 1980 was composed mostly of crappies (21%), smallmouth bass (17%), and yellow perch (41%; Fig. 22). Shore angler harvest in 1980 was composed mostly of crappies (12%), smallmouth bass (15%), yellow perch (18%), and white sturgeon (32%; Fig. 23).

Exploitation Rate for White Crappie in Deadman Bay

An estimated 4,604 white crappie were removed from the Central Ferry - Port of Garfield zone in 1980. Based on data from angler interviews, 96.8%

Table 10. Estimates of total catch[a] by access zones for Little Goose Reservoir, Washington, 1979 (April-November).

	BOAT ANGLERS		SHORE ANGLERS	
ZONE	Catch	Bound on Error of Estimation	Catch	Bound on Error of Estimation
Boyer Park	617	± 509	3206	± 2347
Willow Landing and Central Ferry	4346	±1943	10410	± 3715
Little Goose Landing	4693	±2730	689	± 586
TOTAL	9656	±3390	14305	± 4434

[a]Catch = angler use X catch rate = number of fish removed from reservoir.

Table 11. Estimates of total harvest[a] by access zones for Little Goose Reservoir, Washington, 1979 (April-November).

	BOAT ANGLERS		SHORE ANGLERS	
ZONE	Harvest	Bound on Error of Estimation	Harvest	Bound on Error of Estimation
Boyer Park	175,655	± 152,904	742,711	± 505,891
Willow Landing and Central Ferry	1,325,167	± 557,216	1,987,457	± 743,825
Little Goose Landing	1,352,843	± 754,989	354,911	± 363,638
TOTALS, Little Goose Reservoir	2,853,665	± 950,724	3,085,079	± 970,275

[a]Harvest = angler use X harvest rate = grams of fish removed from reservoir

Table 12. Estimates of yield from Little Goose Reservoir, Washington, during 1979 (April - November) and 1980 (March - November).

	1979				1980			
	Yield/Hectare		Yield/Acre		Yield/Hectare		Yield/Acre	
Species	Number	Grams	Number	Pounds	Number	Grams	Number	Pounds
white crappie	0.79	136.06	0.32	0.12	1.38	240.16	0.56	0.21
black crappie	0.46	79.00	0.19	0.07	0.25	40.10	0.10	0.04
smallmouth bass	2.31	583.67	0.93	0.52	3.28	937.94	1.33	0.84
bluegill	0.25	24.50	0.10	0.02	0.38	46.42	0.15	0.04
pumpkinseed	0.26	18.51	0.11	0.02	0.23	17.98	0.09	0.02
yellow perch	0.80	71.64	0.32	0.06	3.44	449.30	1.39	0.40
channel catfish	0.20	265.91	0.08	0.24	0.23	220.00	0.09	0.20
bullheads[a]	0.71	142.38	0.29	0.13	0.62	104.28	0.25	0.09
rainbow trout	0.005	0.72	0.002	0.0006	0.20	57.49	0.08	0.05
white sturgeon	0.0	0.0	0.0	0.0	0.03	510.82	0.01	0.45
squawfish	0.06	17.57	0.02	0.02	0.05	13.35	0.02	0.01
Others	0.04	123.85	0.02	0.11	0.008	78.32	0.003	0.07
Total	5.91	1463.83	2.39	1.30	10.09	2716.16	4.08	2.42

[a] includes yellow and brown bullheads

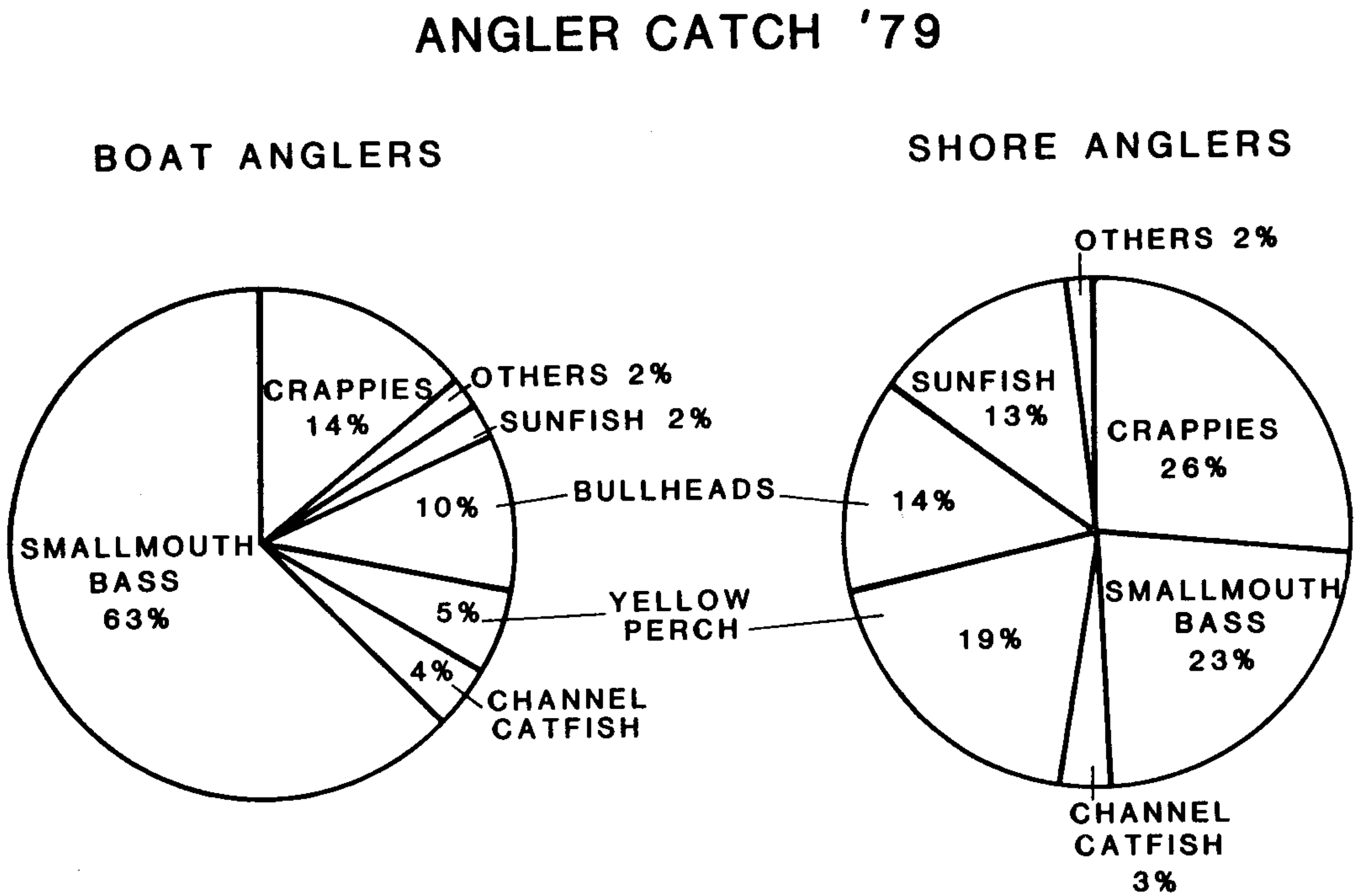

Figure 20. Composition (%) of angler catch from Little Goose Reservoir, Washington, from April - November, 1979. Crappies include white and black crappies; bullheads include yellow and brown bullheads; sunfish include bluegill and pumpkinseed; and others may include northern squawfish, rainbow trout, carp, suckers, peamouth, chiselmouth, and redside shiner.

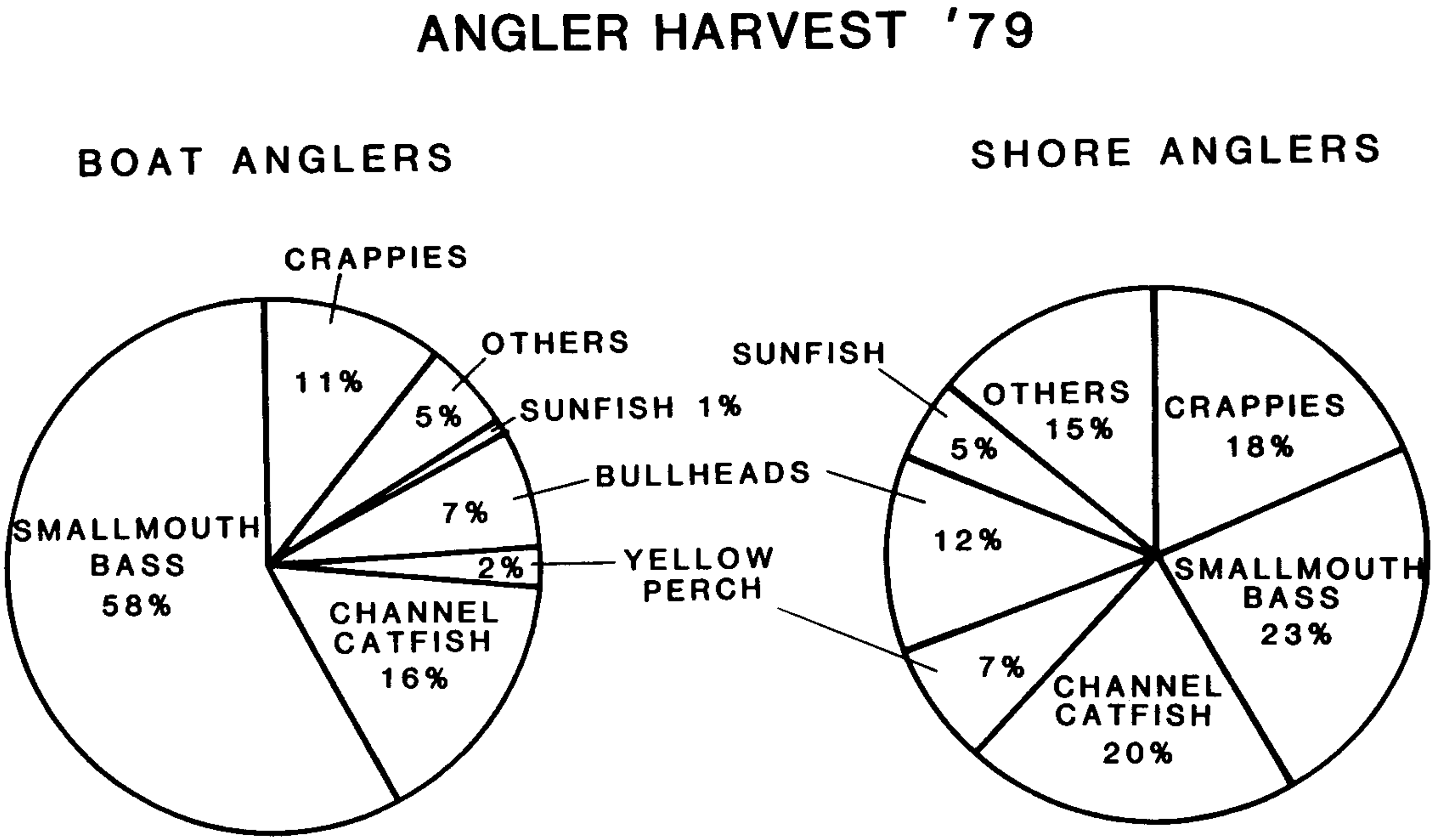

Figure 21. Composition (%) of angler harvest from Little Goose Resrvoir, Washington from April - November, 1979. Crappies include white and black crappies; bulkheads include yellow and brown bullheads; sunfish include bluegill and pumpkinseed; and, others may include northern squawfish, carp, suckers, rainbow trout, peamouth, and redside shiner.

Table 13. Estimates of total catch[a] by access zones for Little Goose Reservoir, Washington, 1980 (March-November)

ZONES	BOAT ANGLERS		SHORE ANGLERS	
	Catch	Bound on Error of Estimation	Catch	Bound on Error of Estimation
Boyer Park	5,030	± 7,180	1,837	± 982
Willow Landing and Central Ferry	4,791	± 2,800	17,834	± 6,775
Little Goose Landing	1,909	± 970	1,582	± 1,297
Other Areas[b]	6,539	± 2,857	1,393	± 862
TOTALS, Little Goose Reservoir	18,269	± 8,276	22,646	± 7,020

[a]Catch = angler use X catch rate = number of fish removed from reservoir.

[b]Areas not sampled during automobile surveys.

Table 14. Estimates of total harvest[a] by access zones for Little Goose Reservoir, Washington, 1980 (March-November).

ZONES	BOAT ANGLERS		SHORE ANGLERS	
	Harvest	Bound on Error of Estimation	Harvest	Bound on Error of Estimation
Boyer Park	1,521,316	2,033,933	2,651,585	1,089,015
Willow Landing and Central Ferry	903,819	544,967	3,158,532	1,225,900
Little Goose Landing	475,193	230,639	475,193	230,639
Other Areas[b]	1,594,987	859,210	326,963	131,462
TOTALS, Little Goose Reservoir	4,495,315	2,285,894	6,524,140	1,661,583

[a]Harvest = angler use X harvest rate = grams of fish removed from reservoir.

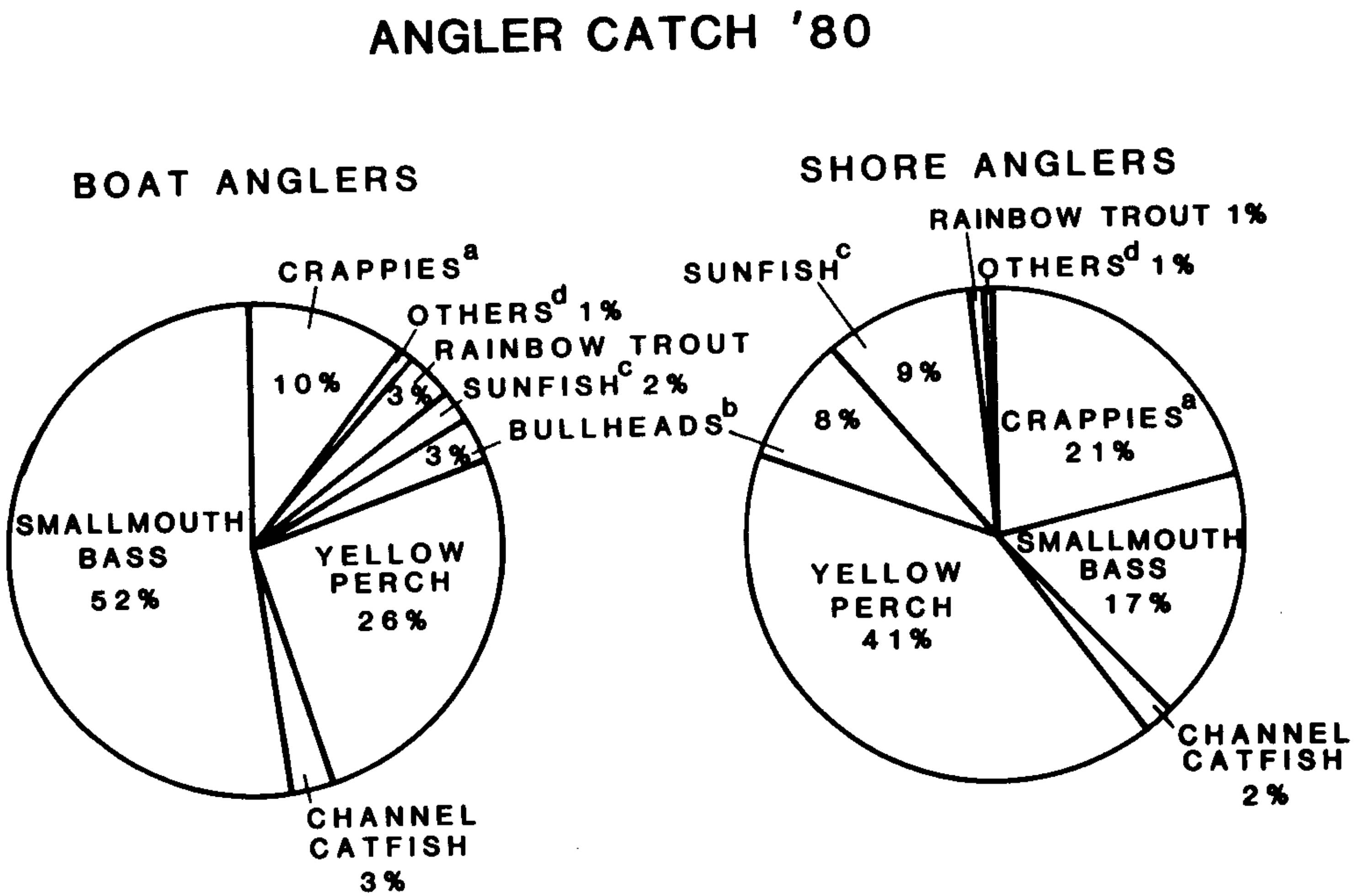

Figure 22. Composition (%) of angler catch from Little Goose Reservoir, Washington, from March - November, 1980. Crappies include white and black crappie; bullheads include yellow and brown bullheads; sunfish include bluegill and pumpkinseed; and, others may include northern squawfish, carp, suckers, peamouth, chiselmouth, redside shiner, and white sturgeon.

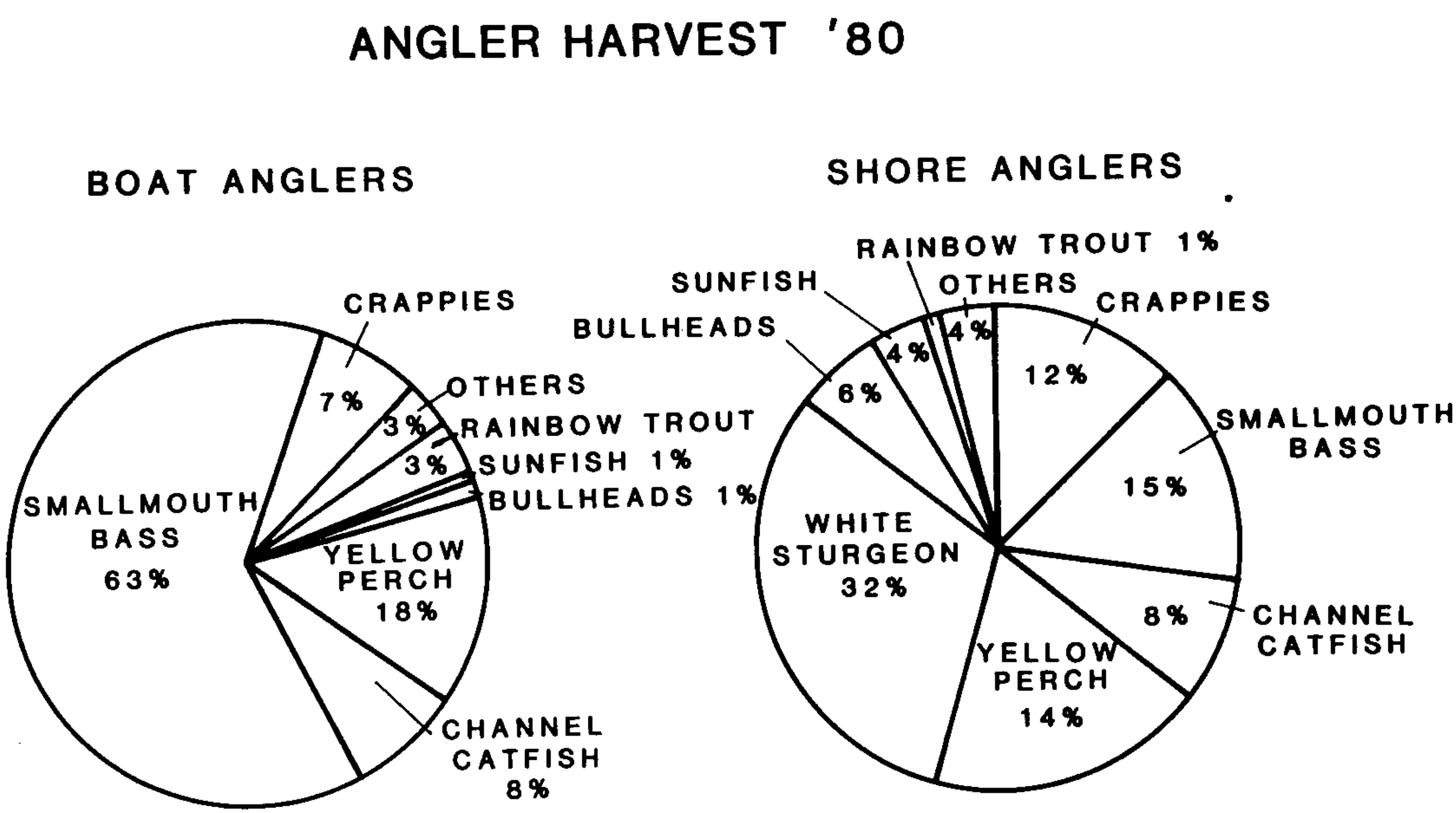

Figure 23. Composition (%) of angler harvest from Little Goose Reservoir, Washington, from March - November, 1980. Crappies include white and black crappies; bullheads include yellow and brown bullheads; sunfish include bluegill and pumpkinseed; and, others may include northern squawfish, carp, suckers, peamouth, and redside shiner.

(4,455) of these fish were longer than 200 mm and 94.5% (4,209) of the fish of this size were caught before July 1, 1980. Using the estimate of 4,209 white crappie being caught in the spring season and a population estimate of 8,423 (Subobjective 2), an exploitation rate of 50.0% occurred in the Deadman Bay area of Little Goose Reservoir in 1980.

Bass Tournaments

During our 1979 and 1980 sampling seasons, two bass tournaments were monitored on Little Goose Reservoir. On May 20, 1979, the Spokane, Washington, American Bass Federation club held a tournament on Little Goose Reservoir with their weigh-in station at Central Ferry State Park. During this tournament, 14 anglers fished a total of 168 angler hours and caught 53 bass (0.32 bass/angler hour; 52 smallmouth and 1 largemouth) weighing 31.07 kg. Forty-nine of these bass were released alive following the weigh-in. On May 3 and 4, 1980, the Washington Bass Anglers Sportsman Society State Federation held their state tournament on Little Goose Reservoir with their weigh-in station at Boyer Park. During this tournament, 83 anglers fished a total of 1,203.5 angler hours and caught 168 bass (0.14 bass/angler hour). One hundred and seventy-four smallmouth bass were tagged and released from the Boyer Park marina following the state tournament. Within five months following this tournament, 15.2% of the tagged smallmouth bass were recaptured; 88.9% of these recaptures occurred within 2 km of the tournament release site.

DISCUSSION

Aerial Surveys

Angler and boat uses were similar among the four lower Snake reservoirs during 1979 and 1980 with the exceptions of lower angler use on Lower Monumental Reservoir and higher summer pleasure boat use on Ice Harbor Reservoir (Tables 2-4). Significantly lower angler use at Lower Monumental and higher pleasure boat use at Ice Harbor compared to other lower Snake Reservoirs is probably related to accessibility and distance from eastern Washington population centers. Lower Monumental is the smallest of the four reservoirs and is the farthest removed from eastern Washington population centers. Also, no major highways in the area lead directly to Lower Monumental Reservoir. Our data from Little Goose Reservoir would suggest that most anglers travel to the nearest access area to use that reservoir and travel less than 100 km (Figs. 7-10). For example, on Little Goose Reservoir, anglers using the Boyer Park zone (Fig. 2) were mostly from the Moscow - Pullman area, whereas anglers using the Little Goose Landing zone were mostly from Walla Walla. Population centers closest to Lower Monumental Reservoir are the Tri-Cities (Pasco, Kennewick, and Richland) and Walla Walla. Our data from Little Goose Reservoir would suggest that the majority of users of Ice Harbor Reservoir are probably from the Tri-Cities area. Users from Walla Walla may prefer Little Goose Reservoir because traveling from Walla Walla to Little Goose Reservoir does not require long trips on secondary roads as is required to reach most access areas (with the exception of Lyons Ferry) on Lower Monumental. Travel distances from Walla Walla to Little Goose Reservoir and Lower Monumental Reservoir are similar. The high pleasure boat use on Ice Harbor Reservoir, relative to the other three reservoirs, also is probably the result of proximity to the Tri-Cities area.

Angler Survey Methods for Little Goose Reservoir

Angler surveys on Little Goose Reservoir, during the 1979 and 1980 sampling seasons, permitted evaluation of stratified cluster and stratified random sampling techniques to quantify angler use and catch. Extensive travel time required to cover all of Little Goose Reservoir precluded sampling the entire reservoir; therefore, we divided the reservoir into four zones. In 1979, with no previous information on the distribution of angler use throughout the reservoir, monthly allocation of samples among the four zones was based on the distribution of use observed in the previous month's aerial surveys. Our allocations of sampling effort in 1979 were similar to Malvestuto et al. (1978). They allocated monthly samples among six sections of West Point Reservoir, Georgia, based on probabilities proportional to use that was expected to occur in each section. Their probabilities also were determined from aerial surveys.

From the data collected on Little Goose Reservoir in 1979, we calculated sample sizes (allocated among zones based on variability within that zone in 1979), travel costs (automobile), and man-hours of effort required for cluster sampling and stratified random sampling in 1980. Stratified random sampling required higher travel costs than cluster sampling; however, stratified random sampling was chosen for 1980 surveys because it required less total man hours of effort to conduct the surveys. The stratified random sampling design used in 1980 provided a good estimate of use at areas that could not be sampled by automobile. These areas were sampled using periodic air and boat surveys. In 1979, using stratified cluster sampling, clerks were required to note boats leaving the zone during morning surveys and interview those that entered the zone in the evenings and adjust their counts to account for use in areas that could not be seen. Although stratified random sampling provided a good estimate of use, one weakness was the difficulty in obtaining angler interviews. Using cluster sampling in 1979 (when a clerk would spend an entire half day at one zone), 77% of the 380 parties interviewed were completed trips, whereas in 1980, using stratified random sampling (where clerks would move through a zone and interview as many parties as they could), 29% of the 262 parties interviewed were completed trips. Also, interviews of boat angling parties were more difficult to obtain using stratified random sampling; e.g. 158 boat angling parties were interviewed during 1979 using cluster sampling, whereas 51 boat angling parties were interviewed using stratified random sampling in 1980 (Table 5).

We believe that stratified cluster sampling and stratified random sampling designs provided good estimates of angler use and catch on Little Goose Reservoir. A number of trade-offs must be considered when selecting one of these designs for angler surveys on large reservoirs. For example, cluster sampling requires less travel expense and is more effective in obtaining angler interviews, whereas stratified random sampling requires less manpower and is more effective in enumerating use at areas that are not accessible by automobile.

Estimates of Use on Little Goose Reservoir

The estimated 79,605 angler hours of use for Little Goose Reservoir in 1980 was 74% greater than the 45,752 angler hours estimated for 1979 (Figs. 3 and 4; Appendix II). Increased use occurred in spite of the eruption of Mt. St. Helens, which curtailed fishing for approximately one week in late May, 1980, a period of peak angler use in 1979 (Appendix I). We believe that although different methods were used to quantify use between 1979 and 1980, the differences are real and reflect actual increased use. One possibility for the increased angler use in 1980 is that weather conditions may have been more favorable to anglers. Climatological data from the National Oceanic and Atmospheric Administration station at Pomeroy, Washington, (Anonymous 1979, 1980) indicate that average temperatures for April, 1980 were 3.0 C (5.3 F) warmer than in April, 1979 (Fig. 24), while average temperatures for June through September were 1.0 to 3.3 C (1.7 to 6.0 F) cooler in 1980 than in 1979. Also, average temperatures for the month of November were 2.6 C (4.6 F) warmer in 1980 than in 1979. Based on these differences in air temperatures and the observations of survey clerks, we believe the early spring and cooler summer of 1980 probably accounted for a significant increase in angler use from 1979 to 1980. Other possible explanations for differences in use estimates between 1979 and 1980 are: the 1980 sampling season included March which was not included in 1979; the sampling design in 1980 probably provided a better estimate of use in areas inaccessible to automobiles (14,708 angler hours were estimated from air and boat surveys of these areas in 1980); and, increased use may indicate increasing popularity of Little Goose Reservoir to anglers.

The Boyer Park - Illia Landing zone contributed to some of the difference in angler use estimates between 1979 and 1980. A total of 13,907 angler hours were estimated for the Boyer Park zone in 1979, whereas 23,896 angler hours were estimated for 1980 (Figs. 3 and 4; Appendix II). However, this large an increase in angler use (72%) was not observed at other zones and may have been a result of differences in the types of angler

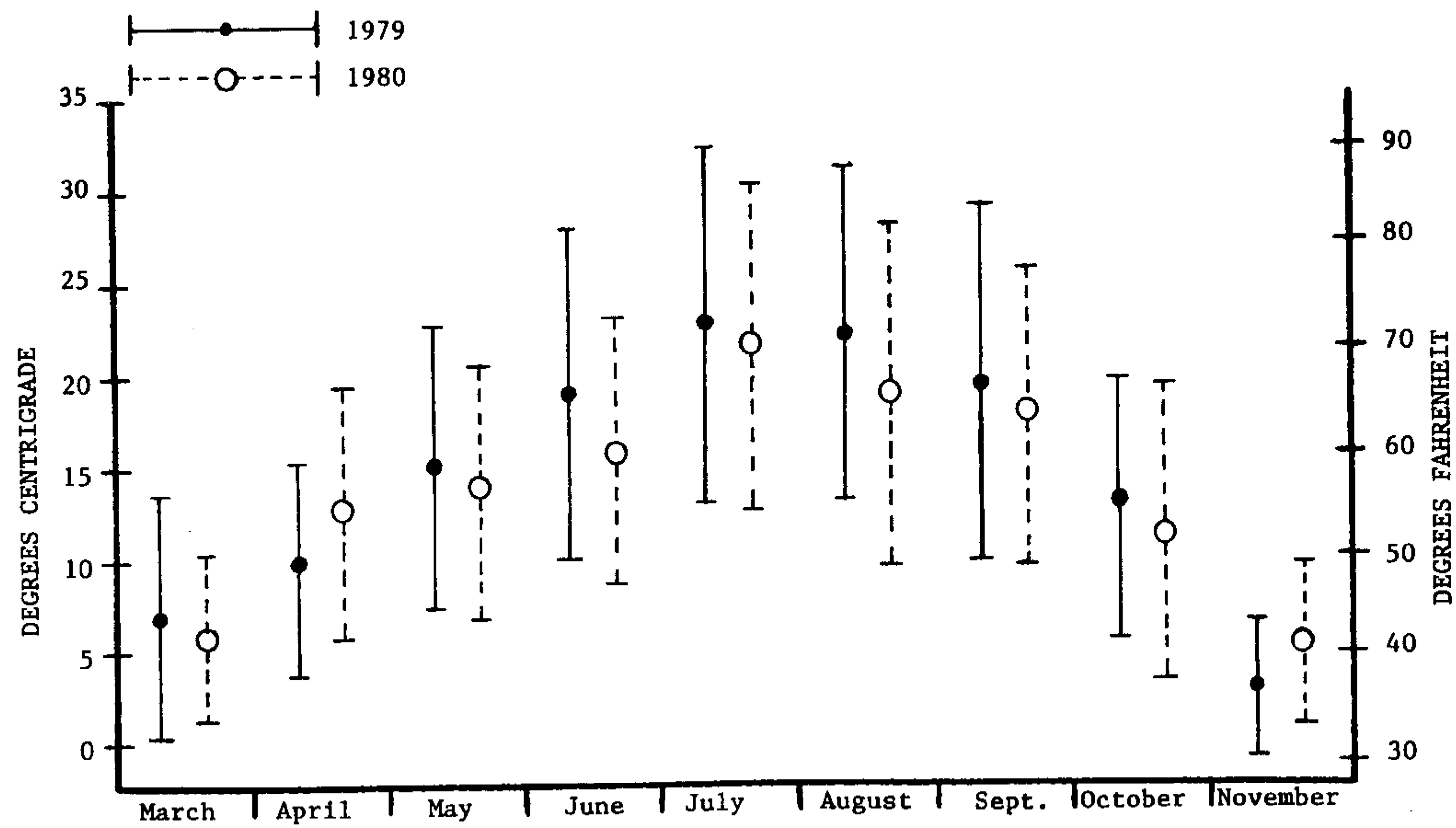

Figure 24. Average temperatures, average daily maximum temperatures and average daily minimum temperatures at Pomeroy, Washington, March-November, 1979 and 1980 (Anonymous 1979, 1980).

activities occurring at the Boyer Park zone between 1979 and 1980. One such difference was the increased popularity of white sturgeon fishing below Lower Granite Dam in 1980. Anglers seeking sturgeon expended many hours of effort (average length of trip was 11.25 hours in 1980; Table 5) and sturgeon fishermen comprised 8% of the boat angler hours and 70% of the shore angler hours from interviews at the Boyer Park zone in 1980. In comparison, 19% of the boat angler hours and 18% of the shore angler hours in 1979 were sturgeon fishermen (Figs. 11-14).

Another factor affecting use at the Boyer Park zone was the opening of the steelhead trout fishery in fall, 1980. Steelhead fishing was most common in the tailwater area below Lower Granite Dam and probably accounted for increased angler use in the Boyer Park zone during the fall of 1980 (Appendix I). In addition, the Washington State Bass Anglers Sportsman Society tournament, held May 3 and 4, 1980, may have attracted anglers to the Boyer Park zone who were not familiar with this area prior to the bass tournament.

Estimates of use at the Willow Landing - Penawawa zone in 1979 and 1980 were low compared to the other zones (Figs. 3-6; Appendix II). Access to this zone requires traveling on gravel roads and access to the water is seriously affected by water level fluctuations in the reservoir. At low water level, the embayment at Penewawa is almost completely de-watered, while the boat ramp at Willow Landing does not have sufficiently deep water to launch boats from trailers.

Angler Attitudes About Use

Analysis of angler attitudes regarding use indicates most anglers feel Little Goose Reservoir is "underused" and their enjoyment is not affected by other anglers. In 1979, 50.0% of the 380 parties interviewed felt Little Goose Reservoir was underused by anglers (Fig. 18). In 1980, when asked if they would enjoy their trip most if more, fewer, or the same number of anglers were using the reservoir, the majority of boat anglers did not have an opinion (Fig. 19). A large percentage of shore anglers either did not have an opinion or responded that they would enjoy their trip most if the same number of anglers were using the reservoir. One exception to this occurred at the Little Goose Landing zone where 41.4% of the boat angling parties and 39.5% of the shore angling parties indicated they would enjoy their trip most if fewer anglers were using the reservoir (Fig. 19). This response is especially interesting because shore angling use at Little Goose Landing is less than at the Boyer Park or Central Ferry zones (Figs. 3-6; Appendix II), and shoreline access extends from Little Goose Dam upstream to the end of the Little Goose airstrip. Thus, this area should provide sufficient dispersal opportunities for shore anglers.

Fishery Quality

Our estimates of angler success rates indicate that Little Goose Reservoir supports a good fishery for several warmwater species. Mean catch rates were similar for boat and shore anglers in 1979 and 1980 ranging from 0.48 fish/angler hour to 0.63 fish/angler hour (Tables 6 and 8). Harvest rates also were similar in 1979 and 1980, ranging from 130 grams/angler hour to 146 grams/angler hour (Tables 7 and 9). Another factor that reflects the quality of the fishery is that greater than 50% of the completed trip interviews in 1979 and 1980 were successful parties (Table 5). In 1980, greater than 70% of the interviews were successful parties; however, the number of completed trip interviews included in this analysis was small (48 boat angling parties and 27 shore angling parties).

Resident species such as crappies (white and black crappies), smallmouth bass, yellow perch, channel catfish, bullheads (yellow and brown bullheads), bluegill, and pumpkinseed accounted for 98% and 97% of the yield in numbers from Little Goose Reservoir in 1979 and 1980, respectively. Another important species in the fishery was white sturgeon. Although catch rates for sturgeon were low (anglers seeking sturgeon caught 0.01 sturgeon/angler hour in 1980; Table 5), sturgeon accounted for 19% of the yield in biomass from Little Goose Reservoir in 1980 because of their large size (Table 12). Rainbow trout were occasionally caught by anglers on Little Goose Reservoir; however, rainbow trout accounted for less than 1% of the yield in 1979 and 2% of the yield in 1980 (Table 12).

The sport fishery in Little Goose Reservoir compares favorably with the results from other surveys on reservoirs supporting warmwater fisheries. Horton (1981) reported catch rates of 0.92 fish/angler hour for boat anglers using Dworshak Reservoir, Idaho in 1979. Catch rates of 0.72 fish/angler hour and 0.57 fish/angler hour were reported for boat and shore anglers using Dworshak Reservoir in 1980. Estimated catch rates on Anderson Ranch Reservoir, Idaho, were 0.73 to 1.33 fish/angler hour from 1968 to 1971 (Pollard 1972). Irizarry (1970) reported catch rates of 0.73 to 1.37 fish/angler hour on Cascade Reservoir, Idaho, in 1968 and 1969. Although most of these estimates are higher than those for Little Goose Reservoir, it should be noted that the warmwater fisheries in these Idaho reservoirs are combined with high yield fisheries for salmonids such as kokanee (Oncorhynchus nerka) and catchable rainbow trout. Goodnight (1972) reported catch rates of 1.42 fish/angler hour on C. J. Strike Reservoir, on the upper Snake River in Idaho, in 1971. An attempt was made to supplement the warmwater fishery (mainly yellow perch, black crappie, and black bullhead) in C. J. Strike with catchable rainbow trout; however, fewer than 5% of the 7,120 catchable trout planted in 1971 were returned to the creels of anglers. On Folsom Lake, California, catch rates reported for 1962 and 1965-1969 ranged from 0.10 to 0.34 fish/angler hour and yield in 1962 was 5.4 Kg/hectare (Von Geldern 1972). Harvest rates for Merle Collins Reservoir, California, were between 52 and 92 grams/angler hour from 1965-1976, resulting in yields of 2.9 to 18.9 kg/hectare (Pelzman 1979). Catch rate estimates for Boyd Reservoir, Colorado, averaged 0.16 fish/angler hour from 1969-1977, and yields were 3.0 to 7.3 Kg/hectare (Puttman 1978). Catch and harvest rates on these California and Colorado reservoirs were less than our estimates for Little Goose Reservoir; however, these are high use fisheries and yields are as much as seven times greater than those for Little Goose.

Hanson and Dillard (1978) reported catch rates of 0.40 to 0.68 fish/angler hour and yields of 20 to 82 fish/hectare for Thomas Hill Reservoir, Missouri, from July 1972 - June, 1974. Catch rates and yields for Stockton Reservoir, Missouri, were 0.41 to 1.51 fish/angler hour and 31 to 235 fish/hectare from 1971-1980 (Lawrence C. Belusz, Missouri Department of Conservation, personal communication). Davis and Hughes (1964) reported catch rates of 0.89 to 2.29 fish/angler hour and yields of 16 to 241 Kg/hectare on Bayor DeSiard, Black Bayou, Bussey and LaFourche Lakes, Louisiana, from

1962-1964. Catch rates on Little Goose Reservoir are similar to the lower ends of the ranges of catch rates for these southern reservoirs, although yields from these southern reservoirs are up to 10 times higher than those estimated for Little Goose Reservoir.

These data from other reservoirs in the northwest and throughout the United States indicate that catch rates on Little Goose Reservoir are good (high when compared to other northwest reservoirs), although yields are low. The estimated yield of 1.5 to 2.7 Kg/hectare for Little Goose Reservoir is considerably lower than the national average for reservoirs of 25.4 Kg/hectare (Jenkins 1968).

Although comparative data indicates a good quality fishery on Little Goose Reservoir, a majority of anglers interviewed rated the quality of the fishery as fair or poor. More than half of the parties interviewed rated the quality of the fishery as fair or poor, whereas less than one-third of the parties rated it as excellent or good (Figs. 15-17). This result indicates that anglers using Little Goose Reservoir are not satisfied with the present quality of the fishery, even though catch rates are moderately high when compared to other reservoir fisheries.

We found that smallmouth bass made the largest single contribution to the sport fishery on Little Goose Reservoir. In 1979, smallmouth bass accounted for 39% of the yield in numbers and 40% of the yield in biomass from Little Goose Reservoir (Table 12). In comparison, smallmouth bass accounted for 33% of the yield in numbers and 35% of the yield in biomass from Little Goose Reservoir in 1980. Smallmouth bass were particularly important to boat anglers using Little Goose Reservoir. A majority of boat anglers were seeking bass (more than 80% of the angler hours from interviews at the Boyer Park zone and more than 60% of the angler hours from interviews at the Little Goose Landing zone; Figs. 11-14). Boat angler success rates (catch rates and harvest rates) for smallmouth bass were significantly higher ($\alpha = 0.05$) than success rates for shore anglers in 1979 and 1980 (Tables 6-9) and boat and shore anglers seeking bass had significantly higher ($\alpha = 0.05$) catch and harvest rates for bass than anglers who were not seeking bass. Boat anglers seeking bass on Little Goose Reservoir had mean catch and harvest rates of 0.34 bass/angler hour and 96.7 g/angler hour in 1979 and 0.45 bass/angler hour and 117.7 g/angler hour in 1980 (Table 5). Lambou (1966) stated that catch rates while fishing for a given species or species group should be used as an index of the quality of the fishery for that species. The catch and harvest rates for anglers seeking bass on Little Goose Reservoir compare favorably with other reservoirs in the United States that support bass fisheries. For example, Horton (1981) estimated that anglers seeking bass in Dworshak Reservoir, Idaho, caught 0.51 bass/angler hour. Catch rates for anglers seeking bass on Merle Collins Reservoir, California, were 0.01 to 0.08 smallmouth bass/angler hour and 0.10 to 0.36 largemouth bass (*Micropterus salmoides*)/angler hour from 1965 to 1976 (Pelzman 1979). On Stockton Reservoir, Missouri, anglers seeking bass caught 0.04 to 0.21 bass/angler hour from 1971 to 1980 (Lawrence C. Belusz, Missouri Department of Conservation, personal communication). Alexander and Holbrook (1978) reported catch and harvest rates of 0.27 bass/angler hour and 170 g/angler hour; 0.16 bass/angler hour and 135 g/angler hour; and, 0.23 bass/angler hour and 155 g/angler hour for anglers seeking bass on Douglas, Cherokee, and Norris Reservoirs, Tennessee, respectively. These comparative data indicate that catch rates and harvest rates for anglers seeking bass on Little Goose Reservoir are similar to those at other reservoirs with bass fisheries throughout the United States.

Comparison of catch rates for bass tournaments on Little Goose Reservoir with those from other reservoirs also attests to the quality of the bass fishery on Little Goose Reservoir. During the tournament held May 20, 1979, by the Spokane, Washington American Bass Federation, bass club anglers caught 0.32 bass/angler hour. On May 3 and 4, 1980, anglers participating in the Washington Bass Anglers Sportsman Society State tournament caught 0.14 bass/angler hour. Zook (1978) reported tournament catch rates ranging from 0.06 to 0.51 bass/angler hour for Potholes Reservoir, Washington, 0.06 to 0.16 bass/angler hour for Banks Lake, Washington, and 0.08 to 0.10 bass/angler hour for Long Lake, Washington during 1978. Alexander and Holbrook (1978) reported bass tournament catch rates of 0.23, 0.14, and 0.14 bass/angler hour for Douglas, Cherokee, and Norris Reservoirs, Tennessee, respectively. The tournament catch rates that we recorded for Little Goose Reservoir are similar to those reported for these other Washington and Tennessee reservoirs.

Annual exploitation rates of 15-42% have been reported for smallmouth bass in lakes throughout the U.S. (Yeager and Van Den Avyle 1978). By comparison, the 15.2% exploitation on smallmouth bass released following the Washington B.A.S.S. tournament in May, 1980 is within the lower portion of this range. However, this 15.2% included only reported catches of tagged bass occurring within five months following the tournament. Folmar et al. (1980) found that 66% of catches of tagged bass in West Point Reservoir, Alabama-Georgia, were not reported. Similar results were reported by Matlock (1981) for a salt water sport fishery in Texas where 77% of catches of tagged fish were not reported. If non-reporting of tagged fish on Little Goose Reservoir was similar to these studies, then the rate of exploitation is probably much higher than 15.2%. Based on these facts and the low use-low yield nature of the fishery on Little Goose Reservoir, we believe that this rate of exploitation on tournament caught bass is high.

Other warmwater species making significant contributions to the sport fishery in Little Goose Reservoir include crappies (white and black crappies), sunfish (bluegill and pumpkinseed), yellow perch, channel catfish, and bullheads (yellow and brown bullheads). In 1979, yield in numbers was made up of 21% crappies, 9% sunfish, 5% yellow perch, 3% channel catfish, and 12% bullheads. Yield in biomass, in 1979, was made up of 15% crappies, 3% sunfish, 5% yellow perch, 18% channel catfish, and 10% bullheads (Table 11). In 1980, yield was generally similar to 1979 except for a greater contribution by yellow perch (Table 12). Yield in numbers was made up of 16% crappies, 6% sunfish, 34% yellow perch, 2% channel catfish, and 6% bullheads, while yield in biomass was made up of 10% crappies, 2% sunfish, 17% yellow perch, 8% channel catfish, and 4% bullheads in 1980 (Table 12).

The highest catch rates that we recorded in Little Goose Reservoir were for anglers seeking crappies. Boat anglers seeking crappies in 1979 caught 0.52 crappie/angler hour while shore anglers seeking crappies caught 0.46 crappie/angler hour in 1979 and 1.12 crappie/angler hour in 1980 (Table 5). These catch rates are similar to those reported for Stockton Reservoir, Missouri, where anglers seeking crappies caught 0.17 to 1.54 crappie/angler hour from 1971 to 1980 (Lawrence C. Belusz, Missouri Department of Conservation, personal communication).

Most of the crappie fishing on Little Goose Reservoir occurs within the Deadman Bay area (Central Ferry-Port of Garfield zone) during the months of April - June. During 1979, 90% of the crappie catches we recorded and 91% of the parties seeking crappies were from interviews at the Central

Ferry zone. Sixty-nine percent of the crappie catches, recorded from interviews in 1979, were during the months of April - June. Results were similar in 1980 when 91% of the recorded crappie catches and 71% of the parties seeking crappies were from interviews at the Central Ferry zone. During 1980, 84% of the crappie catches were recorded during April - June. The seasonal nature of this fishery and its concentration within the Central Ferry zone probably contributed to the high use occurring at the Central Ferry zone from late April through June (Appendix I).

Estimates of white crappie population size (Palmer 1982) and angler catch of white crappie in the Central Ferry zone allowed estimation of exploitation rate for white crappie in Deadman Bay. The 50% exploitation rate estimated for white crappie in Deadman Bay is based on the following assumptions: 1) that the seasonal distribution of crappie catches recorded from angler interviews is representative of catches of all anglers using the Central Ferry zone; 2) that lengths of white crappie recorded from interviews accurately represents lengths of crappie caught by all anglers using the Central Ferry zone; and, 3) that there is no recruitment into the longer than 200 mm size class of white crappie during the months of March through June. We believe that our information from angler interviews accurately represents the seasonal distribution and length frequency of white crappie catches in the Central Ferry zone. Also, we believe that our assumption of no recruitment to the >200 mm size class (i.e., no growth of individual white crappie) during March through June is reasonable based on available data (Hal C. Hansel, University of Idaho, personal communication). Our estimate of 50% exploitation may be inflated, however, because our catch estimate used in the calculation included white crappie catch for the entire Central Ferry zone while the population estimate was only for Deadman Bay. Observations by project personnel indicated that the majority of white crappie catches occurred within the Deadman Bay area although some white crappie were caught in other areas of the Central Ferry zone.

Comparisons of Use Estimates With Other Reservoirs

The 11.3 and 19.6 angler hours/hectare estimated for Little Goose Reservoir are similar to use estimates from other reservoirs on the Snake River and its tributaries. Estimated use on Dworshak Reservoir, Idaho, varied from 3.7 to 27.1 angler hours/hectare from 1972-1980 (Horton 1981). Angler use on Anderson Ranch Reservoir, Idaho, was 14.1 to 21.5 angler hours/hectare from 1968-1971 (Pollard 1972). Pallisades Reservoir, Idaho, received 45.4 angler hours of use/hectare in 1980 (Moore 1981). Angler use on Cascade Reservoir, Idaho, was 4.9 and 5.5 angler hours/hectare in 1968 and 1969, respectively (Irizarry 1970). C. J. Strike Reservoir, Idaho, received an estimated 7.2 angler hours of use/hectare in 1971 (Goodnight 1972). These estimates indicate that use on Little Goose Reservoir is similar to that on Dworshak and Anderson Ranch reservoirs but higher than use on Cascade and C. J. Strike reservoirs. We should note, however, that the angler surveys on Cascade and C. J. Strike were conducted 10 years prior to our surveys on Little Goose Reservoir, and their popularity may have increased by 1979.

Reservoirs in more populated areas of the U.S. receive much higher fishing pressure than Little Goose Reservoir. For example, Folsom Lake, California, received 70.7 angler hours/hectare in 1962 (Von Geldern 1972). Angler use on Merle Collins Reservoir, California, varied from 53.8 to 296.1 angler hours/hectare from 1965-1976 (Pelzman 1979). Angler use on

Boyd Reservoir, Colorado, was 35.5 to 114.9 angler hours/hectare from 1969-1977 (Puttman 1978). Estimates of angler use on Thomas Hill Reservoir, Missouri, were 50.2 to 120.3 angler hours/hectare from 1972-1974 (Hanson and Dillard 1978). Estimates ranging from 42.3 to 165.9 angler hours/hectare were reported for Stockton Reservoir, Missouri, from 1971-1980 (Lawrence C. Belusz, Missouri Department of Conservation, personal communication). Davis and Hughes (1964) reported estimates of angler use ranging from 58.0 to 458.5 angler hours/hectare on Bayou De Siard, Black Bayou, Bussey and La Fourche Lakes, Louisiana, from 1962-1964. Estimates of angler use for these Louisiana, Missouri, Colorado, and California reservoirs were based on surveys of the entire calendar year, whereas our estimates for Little Goose Reservoir and most of the reports for Idaho reservoirs, did not include the winter months (December-February). Although we did not survey from December-February, a few spot checks indicated that little angler use occurred on Little Goose Reservoir during the winter months.

SUMMARY

1) Aerial and ground surveys and angler interviews were conducted on Little Goose Reservoir, Washington, from April-November 1979, and March, 1980 to assess angler use, catch, and harvest. Aerial surveys of each of the remaining three lower Snake River reservoirs (Lower Granite, Lower Monumental, and Ice Harbor) also were conducted from March-November, 1979 and 1980, to assess relative angler and boat use among the four reservoirs.

2) Little Goose, Lower Granite, and Ice Harbor reservoirs received similar angler use. Lower Monumental received the least angler use, while Ice Harbor Reservoir received the most pleasure boat use in 1979 and 1980.

3) In 1979, using cluster sampling techniques, angler use on Little Goose Reservoir was estimated to be 45,752 hours (11.3 angler hours/hectare). In 1980, using stratified random sampling, the estimated angler use was 79,605 hours (19.6 angler hours/hectare). Higher use estimates in 1980 than 1979 were attributed mostly to improved weather conditions for fishing. Estimates of fishing pressure on Little Goose Reservoir were similar to those for other reservoirs in the Snake River system but low compared to reservoirs in more populated areas of the United States.

4) Average angler catch rates for all species ranged from 0.49 to 0.63 fish/angler hour and harvest rates ranged from 130 to 146 grams/angler hour on Little Goose Reservoir in 1979 and 1980. Anglers seeking

crappies manifested the highest catch rates (0.46 to 1.12 crappie/angler hour), whereas anglers seeking white sturgeon had the lowest catch rates (0.01 sturgeon/angler hour). These success rates compare favorably with other warmwater fisheries throughout the United States and are high when compared to other reservoirs in the northwest.

5) Although angler success rates were relatively high and more than 50% of the parties were successful, most anglers rated the quality of the fishery on Little Goose Reservoir as fair or poor.

6) Yield from Little Goose Reservoir was estimated to be 1.5 kg/hectare in 1979 and 2.7 kg/hectare in 1980. These estimates of yield are low when compared to reservoirs throughout the United States.

7) Smallmouth bass was the most commonly sought and harvested species in Little Goose Reservoir accounting for more than 1/3 of the yield in 1979 and 1980. Other important species included black and white crappies, yellow perch, channel catfish, and brown and yellow bullheads.

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Subobjective 2

To assess species composition, relative abundance, fish species associations, habitat preference, and movement of fishes in lower Snake River reservoirs.

Limited sampling for fishes has been conducted in the lower Snake River reservoirs since impoundment. These collections had specific objectives and generally were associated with collection of downstream migrating smolts and their potential predators. For example, the U.S. National Marine Fisheries Service has conducted purse seining and Merwin lake trapping efforts in some of these reservoirs (Ebel 1977). Data from these collections provided some indication of species composition and relative abundance, but because of the specific nature and location of sampling, had limited application. No known information exists, however, on differences in abundance of resident fishes among habitats and their movement patterns.

METHODS

Fish Collections

Fish collections on lower Snake reservoirs were initiated in April, 1979 and continued through November, 1980. Seasonal sampling was conducted to assess changes in each of the reservoirs. Seasons were designated as follows:

Spring	March-May
Summer	June-August
Fall	September-November

Stations sampled seasonally on other lower Snake reservoirs (Fig. 1) were as follows:

LOWER GRANITE	LOWER MONUMENTAL	ICE HARBOR
Gulch	Embayment	Embayment
Deepwater	Lower Shoal	Lower Shoal
Lower Shoal	Upper Shoal	Tailwater

Intensive sampling for adult and subadult fish was conducted monthly at six stations (lower embayment, lower gulch, deepwater, lower shoal, upper shoal, and tailwater) representing major habitat types on Little Goose Reservoir (Fig. 2).

The status of the fish stocks was assessed by making fish collections at the designated stations in each of the reservoirs (Fig. 1). Information on species composition, relative abundance, distribution, and habitat preferences was obtained in each of the lower Snake reservoirs. In Little

Goose Reservoir, additional information on fish movement, annual survival, and fish species associations was collected. Daily movement patterns and population estimates were obtained for selected species at the lower embayment station (Deadman Bay).

Electrofishing, horizontal and vertical experimental gill nets, hoop trap nets, and beach seine were employed to sample the fish populations. Because of morphometric differences between stations, not all gear types could be fished in each area. Littoral habitat (embayment, gulch, shoal, and tailwater stations) was sampled with all gear types except vertical gill nets. Limnetic habitat (deepwater stations) was sampled only with vertical gill nets. Each sampling method employed equal units of effort to facilitate direct comparison of fish abundance among stations. The specifics of the collecting gear used are:

Electrofishing:

Nighttime electrofishing was conducted using a 4.9 m aluminum boat driven parallel to the shoreline. The electrofishing gear consisted of a Smith-Root type VI variable voltage pulsator (VVP), which in conjunction with a 230 volt generator, was capable of producing varying out-put voltages and currents. Four positive and two negative electrodes, each 2.1 m in length, were mounted approximately 3 m in front and on each side of the boat, respectively. The VVP unit was equipped with a timer which enabled measurement of "current on" effort.

Preliminary electrofishing trials suggested an output range of 280-400 volts DC was most effective. This voltage adequately stunned the fish but caused little mortality. Fish stunned by the electrofishing gear were netted and placed in a live well for later identification and enumeration. Effective depth of shocking was estimated to be approximately 2 m.

Gill nets:

Four different types of gill nets were employed to sample stations on lower Snake reservoirs:

1. Horizontal monofilament - 38 m long x 1.8 m deep, 5 panels each 7.6 m long, at 1.27 cm, 2.54 cm, 3.81 cm, 5.08 cm, 6.35 cm bar measurement (only used in 1979).
2. Horizontal monofilament - 61 m long x 1.8 m deep, 8 panels each 7.6 m long, at 1.27 cm, 2.54 cm, 3.81 cm, 5.08 cm, 6.35 cm, 7.62 cm, 8.89 cm, 10.16 cm bar measurement.
3. Horizontal multifilament - same as horizontal monofilament (61x1.8 m).
4. Vertical monofilament - 5.5 m wide with three 1.8 m panels at 2.54 cm, 5.08 cm and 7.62 bar measurement. Net depth was 30 m.

Horizontal gill nets were set perpendicular to shore with the smallest mesh toward shore for approximately 24 hour periods. Contour bottom and floating sets were employed. Contour bottom sets were fished during all seasons. Floating sets were fished only during the summer season when fewer migrating salmonids were in the reservoirs.

Limnetic areas were sampled with vertical gill nets. These nets fished the surface to the reservoir bottom for 24-hour periods and were set approximately 100 m from the shoreline perpendicular to shore in 23-25 m of water. Aluminum poles were placed in the net at 5-7 m intervals to keep the net spread.

Hoop trap nets:

Trap nets were employed to sample areas with shallow water (< 3 m). Two different sizes of trap nets were used:

1. Large trap - 1.2 m diameter mouth with 3.81 cm square mesh, one 15 m lead 1.2 m deep, two 9 m wings 1.2 m deep.
2. Small trap - 0.9 m diameter mouth with 2.54 cm square mesh, one 23 m lead 0.9 m deep, two 9 m wings 0.9 m deep (only used in embayment stations).

Trap nets were fished perpendicular to shore with the lead adjacent to the shoreline. The lead, wings, and cod end were anchored with cement blocks. Trap nets were checked at least once during a 24-hour period.

Beach seine:

Beach seining was conducted using a 30.5 x 2.4 m seine constructed of 6.35 mm knotless nylon mesh, with a 2.4 x 2.4 x 2.4 m bag. A standard haul was made by setting the seine parallel to the shoreline at a distance of 15 m using extension ropes. The seine was then drawn directly into shore. Three seine hauls were completed at each sampling station per sampling period.

Fish collected with all gear types were identified by species, weighed (nearest gram), and measured to total length (mm). To determine movement patterns in Little Goose Reservoir and estimate fish populations at the lower embayment station (Deadman Bay), some fish greater than 200 mm were marked with individually numbered Floy anchor tags at the posterior base of the dorsal fin and released. Smaller fish, between 100 and 200 mm, captured at the lower embayment station were marked by clipping a pelvic fin.

Relative Abundance Estimates

The methodology employed to estimate the numerical relative abundance of age I and older resident fishes in lower Snake reservoirs reduced the effect of gear selectivity on abundance estimates by incorporating effective gear types and a ranking procedure into each estimate. Only gear types that effectively sampled various size groups within a given species were used to estimate relative abundance. Since our method was dependent upon the effectiveness of various gear types and a full compliment of fishing gear was not available until August, 1979, only samples collected during 1980 were used to estimate relative abundance.

A sample consisted of the number of fish collected with each gear type at a station during a particular time period. Time periods for samples collected at stations on Little Goose Reservoir were as follows:

Spring	Sample 1 -	March 1 - April 15
	Sample 2 -	April 16 - May 31
Summer	Sample 3 -	June 1 - June 30
	Sample 4 -	July 1 - July 31
	Sample 5 -	August 1 - August 31
Fall	Sample 6 -	September 1 - October 15
	Sample 7 -	October 16 - November 30

Time periods for samples collected at stations on Lower Granite, Lower Monumental, and Ice Harbor reservoirs were spring, summer, and fall.

Annual and seasonal relative abundance estimates were calculated. Annual estimates, utilizing samples collected during all time periods, were calculated for stations sampled in each of the lower Snake reservoirs.

Seasonal estimates, utilizing samples collected during the appropriate season, were calculated for stations sampled on Little Goose Reservoir.

To obtain an estimate of abundance, the number of fish in a sample collected with each effective gear type was adjusted for equal effort among stations, then weighted by the following formula to obtain a sample frequency:

$$\text{Sample Frequency} = \sum_{i=1}^{k} \left(\frac{f_i^2}{n} \right)$$

where: f_i = frequency of fish captures associated with i^{th} effective gear type

n = sum of effective gear frequencies

k = number of effective gear types

After sample frequencies were calculated for each species in a sample, each species present received a rank (for example, if 14 species were present in the sample, rank 14 would be assigned to the most frequent species, rank 13 to the second most frequent species, and so forth, to rank 1 for the least frequent species present in the sample).

Percent frequency and rank were then calculated for each species in a sample by the following formulas:

$$\text{Percent frequency} = \frac{f_i}{\sum_{i=1}^{n} f_i}$$

$$\text{Percent Rank} = \frac{r_i}{\sum_{i=1}^{n} r_i}$$

where: f_i = sample frequency

r_i = sample rank

n = number of species

After percentages were calculated for frequency and rank, means of the percentages were calculated for each species according to the number of samples present in the estimate. Annual and seasonal abundance estimates for each species were then calculated from the formula:

$$\text{Percent Relative Abundance} = \frac{(PR)\ (PF)}{\sum_{i=1}^{n} \left((PR)\ (PF)\right)}$$

where: PR = mean percent rank

PF = mean percent frequency

n = number of species

Overall Fish Abundance in Little Goose Reservoir:

Overall reservoir fish abundance was estimated in Little Goose Reservoir utilizing annual abundance estimates at each station and shoreline distance of major habitat types. Major habitat types were defined by physical limnological characteristics of sampling stations. Shoreline distance of major habitat types was calculated from a NOAA navigational chart using a digital planimeter. Percent relative abundance for each species was calculated from the formula:

$$\text{Percent Relative Abundance} = \frac{\sum_{i=1}^{n} (h_i \times a_i)}{\sum_{i=1}^{m} \left(\sum_{i=1}^{n} (h_i \times a_i)\right)}$$

where h_i = percent of shoreline classified as a particular habitat

a_i = percent annual abundance for a species in a particular habitat

n = number of habitats (stations)

m = number of species

We assumed that stations sampled were representative of major habitat types.

Comparison of Reservoir Fish Abundance

Mean sample frequencies were plotted against mean catch per unit of effort (CPE) to compare species abundance among lower Snake reservoirs. Sample frequencies were obtained from abundance estimates and CPE was calculated for the gear type that was most effective in collecting a particular species. Fish abundance was compared at three different habitat types. Embayment and tailwater stations sampled on Ice Harbor, Lower Monumental, and Little Goose reservoirs were compared. All main river channel stations sampled on each of the reservoirs were pooled together for comparison. The tailwater station on Lower Monumental Reservoir was sampled only with electrofishing gear, therefore, this station was comparable with tailwater stations on Little Goose and Ice Harbor reservoirs only when electrofishing gear was the most effective gear type for a species.

Population Estimates in Deadman Bay

Schnabel (1938) and Schumacher-Eschmeyer (1943) multiple census techniques were employed to estimate populations of selected species at the lower embayment station (Deadman Bay) on Little Goose Reservoir (Fig. 2). These techniques allowed for multiple marking and recapture over a short time period. Calculations were confined to restricted segments of each population collected with a particular gear type. The validity of each estimate rests on the following assumptions by Ricker (1975):

1. "The marked fish suffer the same natural mortality as the unmarked." The known mortality of tagged and fin-clipped fish during the study was minimal. Ricker (1949) concluded that trapping, handling, removing fins, and tagging resulted in little or no mortality for sunfishes. Therefore, we assumed that the mortality rate of marked and unmarked fish was similar.

2. "The marked fish are as vulnerable to the fishing being carried on as are the unmarked ones."

Angler and net recaptures suggested that tagged and fin-clipped fish were equally vulnerable to fishing. We assumed that unmarked fish were as vulnerable as marked fish.

3. "The marked fish do not lose their mark."

Based on the appearance of tags in recaptured fish, tag retention was deemed good, therefore, no adjustment was needed for lost tags.

4. "The marked fish become randomly mixed with the unmarked; or the distribution of fishing effort is proportional to the number of fish present in different parts of the body of water."

Tag returns from nets indicated freedom of movement throughout the lower embayment. Angling and netting effort was assumed proportional to the numbers of fish present.

5. "All marks are recognized and reported on recovery."

Floy anchor tags and fin-clips were easily recognized during our field sampling.

6. "There is only negligible amount of recruitment to the catchable population during the time recoveries are being made."

It was not necessary to adjust for recruitment due to growth because of the short time period over which estimates were made.

The formula used for each Schnabel estimate was a modified version (Chapman 1952, 1954):

$$\frac{\sum_{t=1}^{n} (C_t M_t)}{\sum_{t=1}^{n} r_t + 1}$$

where: C_t = total sample taken on day t

M_t = total marked fish at large at the start of the t^{th} day

Σr_t = total recaptures during the experiment

n = number of catches examined

Approximate limits of confidence were obtained by considering r (number of recaptures) as a Poisson variable (Ricker 1975).

Schumacher-Eschmeyer estimates were calculated by the following formula:

$$1/N = \frac{\sum_{t=1}^{n} (M_t \; r_t)}{\sum_{t=1}^{n} (C_t \; M_t^2)}$$

The reciprocal of the above formula is an estimate of N with variance as:

$$S^2 = \frac{\sum_{t=1}^{n} (r_t^2/C_t) - \left(\sum_{t=1}^{n} r_t \; M_t\right)^2 \Big/ \sum_{t=1}^{n} (C_t M_t)^2}{n-1}$$

where: C_t = total sample taken on day t

M_t = total marked fish at large at the start of the t^{th} day

r_t = number of recaptures in sample C

n = the number of catches examined

Instead of computing confidence limits for N, they were computed using the more symmetrically distributed 1/N (DeLury 1958) which has a variance:

$$S_1^2 = \frac{S^2}{\sum_{t=1}^{n} C_t \; M_t^2}$$

For computing confidence limits for 1/N from the above variance, tabular t-values were used corresponding to n-1 degrees of freedom:

$$N_L = 1/N - S_1^2 \; (t \; (n-1 \; df)$$

$$N_u = 1/N - S_1^2 \; (t \; (n-1 \; df)$$

Annual Survival Estimates

Utilizing age information obtained from scales and spines, catch curves were constructed to estimate annual survival for selected game species in Little Goose Reservoir. For a given species, only catches for a particular gear type in a single season were used. To estimate annual survival, we assumed constant year class strength and survival (Robson and Chapman 1961).

To calculate annual survival rate for a particular species, an age-frequency table was constructed with the youngest age group fully vulnerable to the sampling gear coded as age 0:

Age	Coded Age	Number of Catch
IV+	0	N_0
V+	1	N_1
VI+	2	N_2
VII+	3	N_3
VIII+	4	N_4

Robson and Chapman's (1961) estimate of annual survival was based upon the total or mean coded age in the sample and was calculated by the following formula:

$$S = \frac{T}{n + T - 1}$$

where: S = Annual Survival Estimate

$$T = N_1 + 2N_2 + 3N_3 + 4N_4$$

$$n = N_0 + N_1 + N_2 + N_3 + N_4$$

As a check for sampling bias, we calculated annual survival by Heincke's (1913) method:

$$S = \frac{n - No}{n}$$

Vertical Distribution

Depth distribution of fishes was determined by setting vertical gill nets in limnetic areas of lower Snake reservoirs. The main channel near Central Ferry and deepwater station were sampled seasonally on Little Goose Reservoir (Fig. 2). Also, one deepwater area was sampled on each of the other lower Snake reservoirs during summer and fall (Fig. 1). Depth of fish captured in the nets at each area was recorded to the nearest meter. Water temperature (C) profiles also were collected at the time of sampling.

Fish Movement

Movement of resident fishes was assessed in Little Goose Reservoir by recording specific locations where each fish was tagged and recaptured. The reservoir was arbitrarily divided into three zones to facilitate analysis: the lower zone extended from Little Goose Dam to Willow Landing; the upper zone from Willow Landing to Lower Granite Dam; and, the third zone was at the lower embayment station (Deadman Bay). Fish movement was analyzed within and between each zone. Straight line distance traveled by individual fish was calculated from a NOAA navigational chart. Angler tag returns were included in analysis when adequate recapture information was available.

Daily Movement Patterns

Diel movement of various fish species was determined at the lower embayment station (Deadman Bay) on Little Goose Reservoir using gill nets and trap nets. Six 24-hour periods were sampled during the 1980 summer season. Nets were checked at approximately 6 hour intervals during each sampling period. Time intervals were defined as follows:

Night	2400 - 0600
Morning	0600 - 1200
Afternoon	1200 - 1800
Evening	1800 - 2400

Diel activity patterns for each species were assessed by comparing the catch per unit of effort for each time interval. We assumed that the more active a fish becomes, the greater the chance that it will be captured with passive gear (Lawler 1969).

Species Habitat Preferences

Habitat preferences of resident fishes in lower Snake reservoirs were assessed by calculating percent of each species collected at each station. Seasonal habitat preferences were examined on Little Goose Reservoir, whereas general habitat preferences were examined at stations sampled on Ice Harbor, Lower Monumental, and Lower Granite reservoirs.

Fish Species Associations

Fish species associations were assessed in Little Goose Reservoir by calculating Pearson product-moment correlations between sample frequencies for each species. Sample frequencies for each sampling station were obtained from relative abundance calculations.

RESULTS

Species Composition

Thirty-one species representing 9 families and consisting of over 52,000 age I and older fish were collected in the lower Snake reservoirs from April, 1979 through November, 1980 (Table 15). Thirty species representing 78% of the fish were collected in Little Goose Reservoir. Individuals representing 19, 23, and 24 species were collected in Lower Granite, Lower Monumental, and Ice Harbor reservoirs, respectively. Species collected only in Little Goose Reservoir included sockeye salmon, brown trout, speckled dace, and warmouth. Flathead catfish were collected only in Ice Harbor Reservoir. All other species were collected in two or more reservoirs. A comprehensive listing of fishes collected, including scientific and common names, appears in Table 15.

Relative Abundance Estimates

Annual Fish Abundance

Annual relative abundance estimates calculated for stations sampled on each lower Snake reservoir indicate wide variations in species numerical abundance between habitat types (Fig. 25-28). Game species, including white crappie, black crappie, yellow perch, smallmouth bass, largemouth bass, pumpkinseed, bluegill, channel catfish, brown bullhead, and yellow bullhead comprised a larger proportion of our catch at embayment stations than non-game species. Relative abundance of game species in embayments sampled on Little Goose, Lower Monumental, and Ice Harbor reservoirs was 77, 65, and 67% respectively. No embayment habitat was sampled on Lower Granite Reservoir.

Table 15. List of fishes (age I and older) collected with gill nets, trap nets, beach seine, and electrofishing gear in lower Snake reservoirs from April, 1979 through November, 1980.

Family	Scientific Name	Common Name	Reservoirs: Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Acipenseridae	*Acipenser transmontanus*	white sturgeon	0	235	3	2	240
Clupeidae	*Alosa sapidissima*	American shad	0	5	3	0	8
Salmonidae	*Oncorhynchus nerka*	sockeye salmon	0	1	0	0	1
	Oncorhynchus tshawytscha	chinook salmon	4	75	3	2	84
	Prosopium williamsoni	mountain whitefish	2	39	2	10	53
	Salmo gairdneri	rainbow trout	4	172	22	6	204
	Salmo trutta	brown trout	0	1	0	0	1
Cyprinidae	*Acrocheilus alutaceus*	chiselmouth	310	1456	408	99	2273
	Cyprinus carpio	carp	120	1057	187	256	1620
	Mylocheilus caurinus	peamouth	2	76	25	23	126
	Ptychocheilus oregonensis	northern squawfish	354	2510	823	347	4034
	Rhinichthys osculus	speckled dace	0	4	0	0	4
	Richardsonius balteatus	redside shiner	246	3847	219	553	4865
Catostomidae	*Catostomus columbianus*	bridgelip sucker	274	3803	490	402	4969
	Catostomus macrocheilus	largescale sucker	1255	7972	849	1257	11333
Ictaluridae	*Ictalurus natalis*	yellow bullhead	15	240	22	1	278
	Ictalurus nebulosus	brown bullhead	36	629	31	20	716
	Ictalurus punctatus	channel catfish	7	1152	118	218	1495
	Noturus gyrinus	tadpole madtom	0	72	1	1	74
	Pylodictis olivaris	flathead catfish	0	0	0	2	2
Centrarchidae	*Lepomis gibbosus*	pumpkinseed	16	1926	145	70	2157
	Lepomis gulosus	warmouth	0	13	0	0	13
	Lepomis macrochirus	bluegill	12	1218	5	21	1256
	Micropterus dolomieui	smallmouth bass	218	2104	301	106	2729
	Micropterus salmoides	largemouth bass	0	61	0	31	92
	Pomoxis annularis	white crappie	68	7011	440	118	7637
	Pomoxis nigromaculatus	black crappie	79	1672	129	141	2021
Percidae	*Perca flavescens*	yellow perch	68	3046	396	145	3655
Cottidae	*Cottus sp.*[a]	sculpin	0	201	80	38	319
			3090	40598	4702	3869	52259

[a] Includes prickly sculpin (*Cottus asper*), Piute sculpin (*Cottus beldingi*), and mottled sculpin (*Cottus bairdi*).

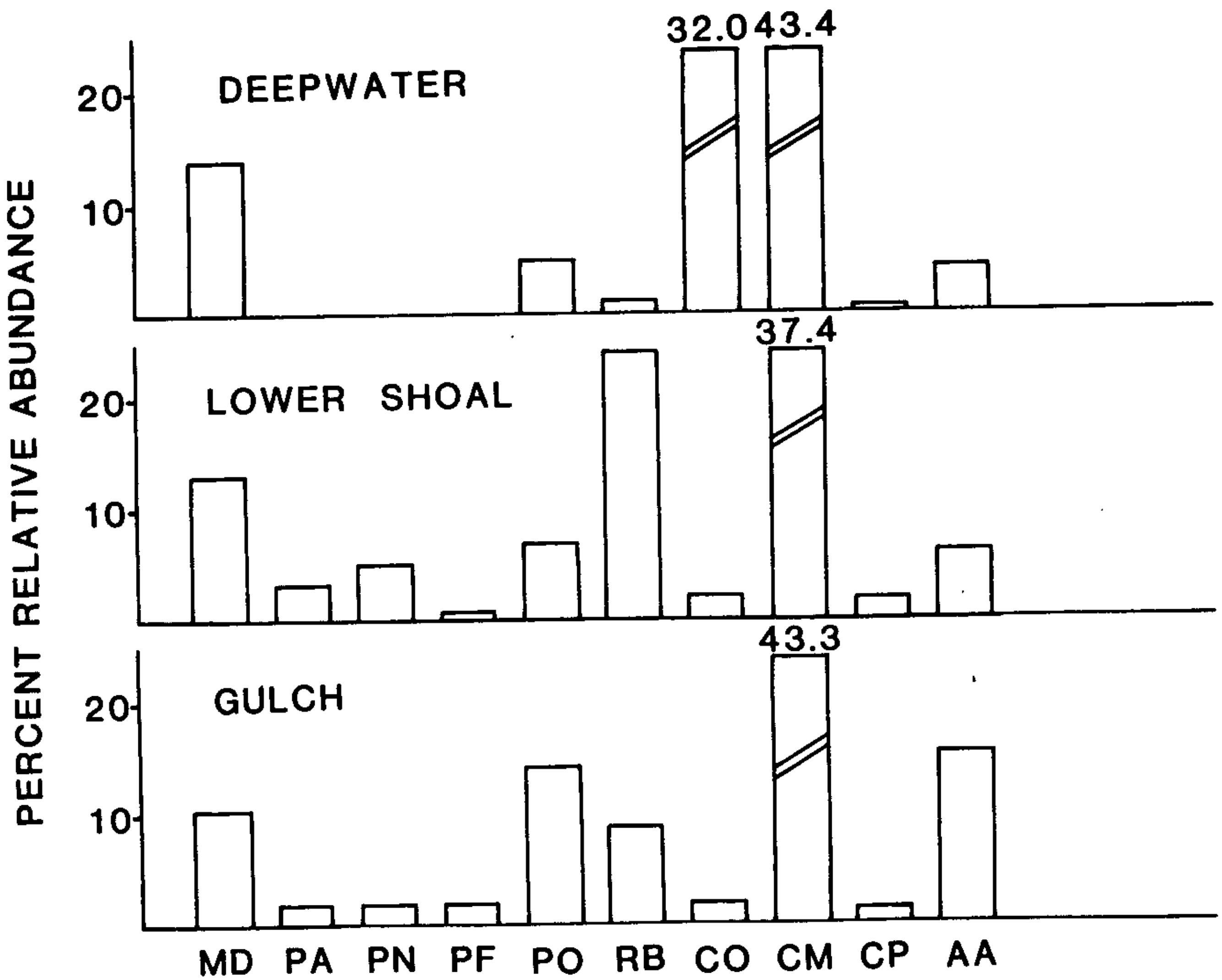

Figure 25. Relative abundance (%) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at stations sampled on Lower Granite Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth.

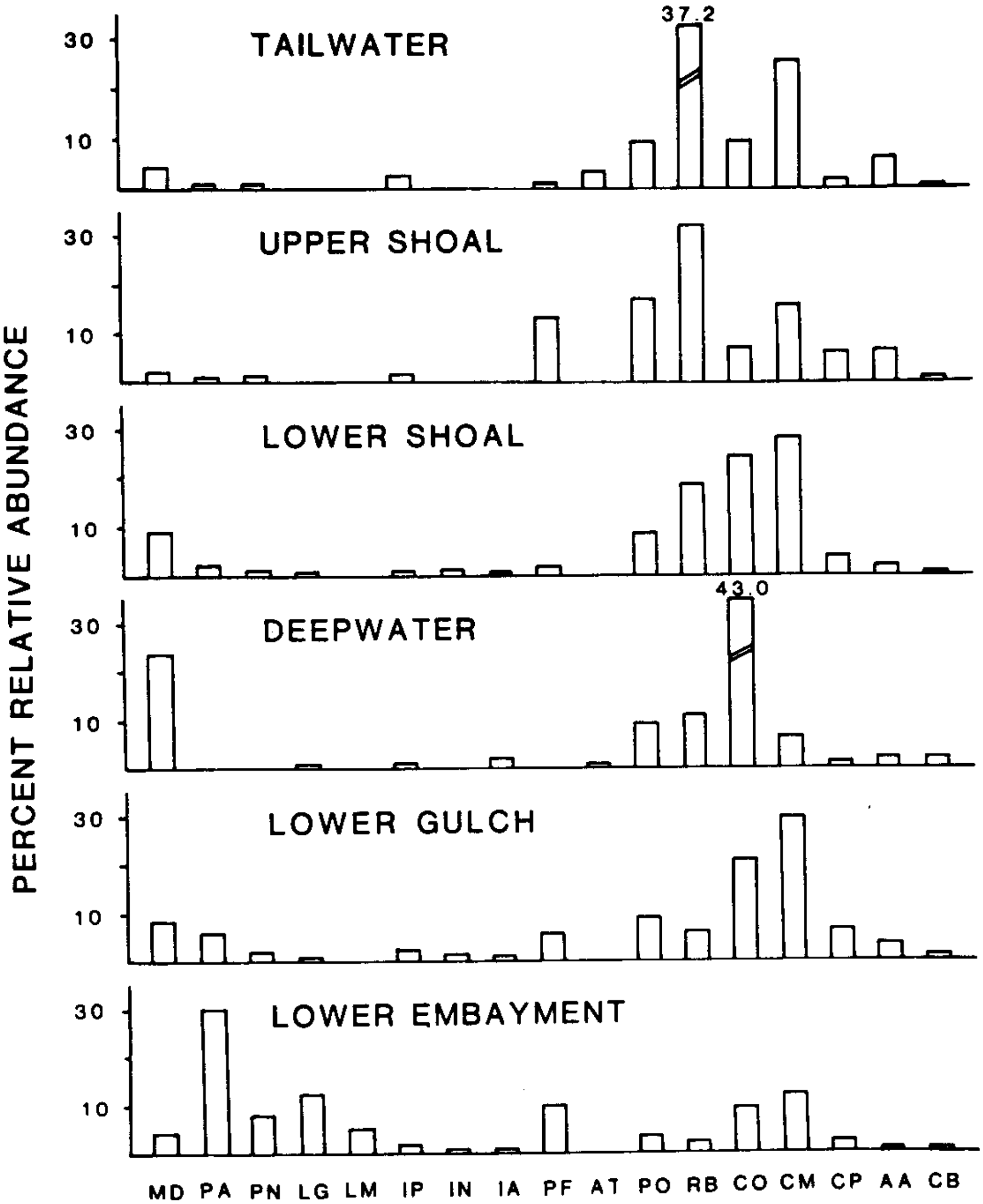

Figure 26. Relative abundance (%) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at stations sampled on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; LG - pumpkinseed; LM - bluegill; IP - channel catfish; IN - brown bullhead; IA - yellow bullhead; PF - yellow perch; AT - white sturgeon; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth; CB - sculpin.

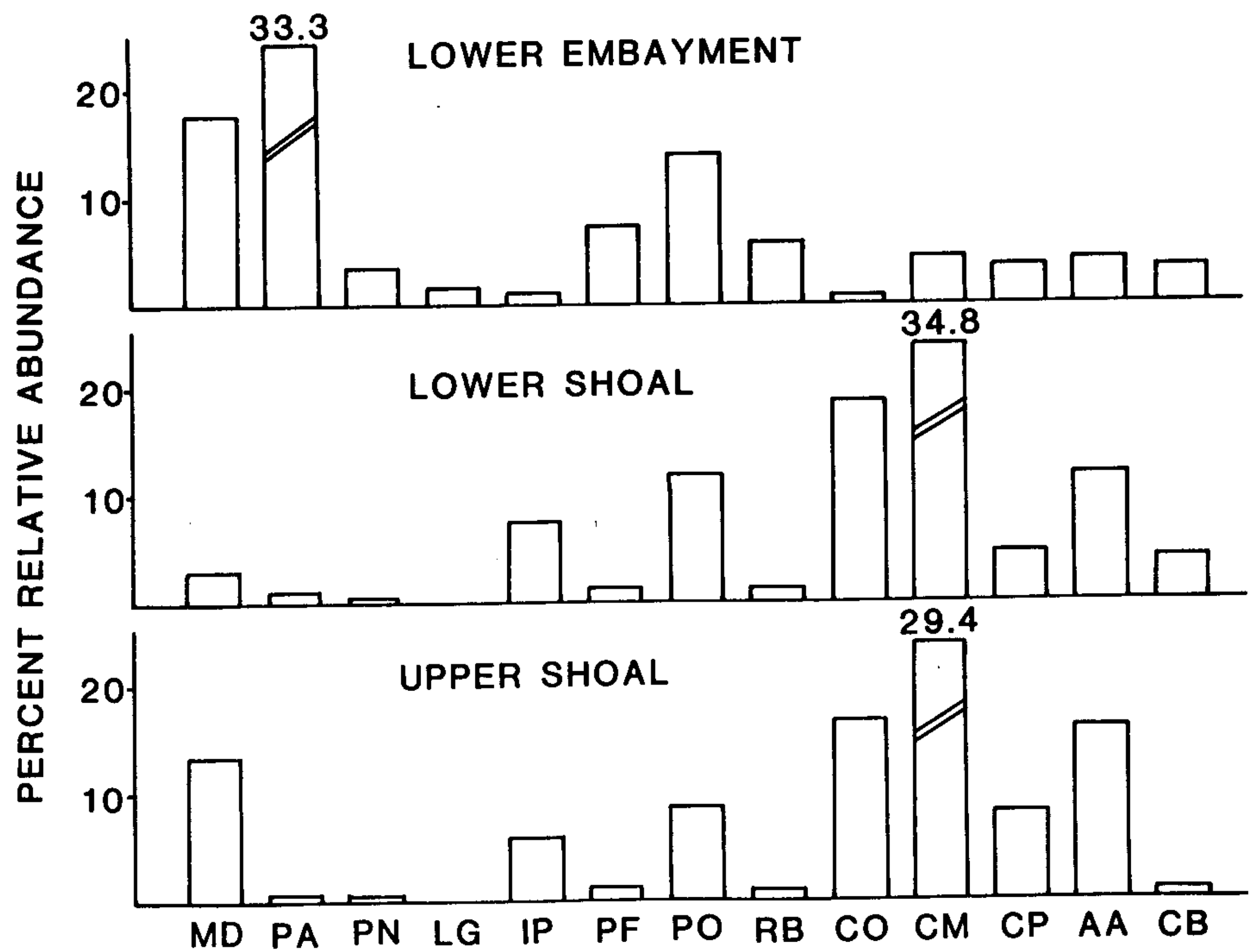

Figure 27. Relative abundance (%) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at stations sampled on Lower Monumental Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; LG - pumpkinseed; IP - channel catfish; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth; CB - sculpin.

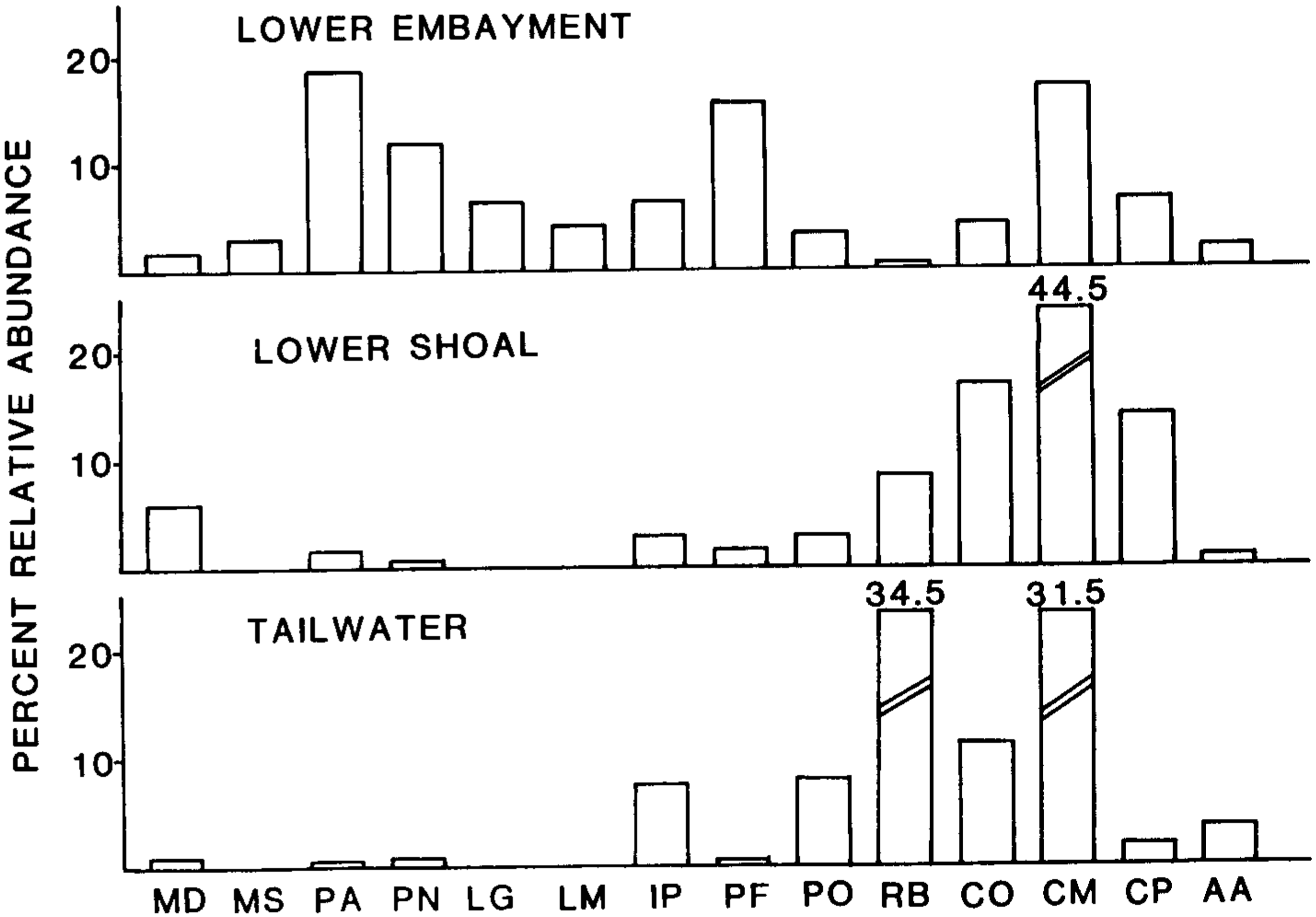

Figure 28. Relative abundance (%) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at stations sampled on Ice Harbor Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; LG - pumpkinseed; LM - bluegill; IP - channel catfish; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth.

Relative abundance of game species at embayment stations varied among reservoirs. Game species, which individually comprised greater than 10% of the fish present at embayment stations, included white crappie and pumpkinseed in Little Goose Reservoir, white crappie and smallmouth bass in Lower Monumental Reservoir, and white crappie, black crappie, and yellow perch in Ice Harbor Reservoir. White crappie was consistently the most abundant game species comprising 30, 13, and 18% of the fish at embayments in Little Goose, Lower Monumental and Ice Harbor reservoirs, respectively.

Non-game species were more abundant at stations sampled along the main river channel (shoal, gulch, deepwater, and tailwater). Northern squawfish, redside shiner, bridgelip sucker, largescale sucker, carp, and chiselmouth comprised 81, 80, 81, and 85% of the fish captured at main river channel stations on Lower Granite, Little Goose, Lower Monumental, and Ice Harbor reservoirs, respectively (Figs. 25-28). Largescale sucker was the most abundant non-game species collected at the majority of main river channel stations with the only exceptions being redside shiner and bridgelip sucker. For example, redside shiner was the most abundant species at all tailwater stations and at the upper shoal station on Little Goose Reservoir. Bridgelip sucker was the most abundant species at the deepwater station on Little Goose Reservoir.

Seasonal Fish Abundance

Relative abundance estimates calculated seasonally for each of the six stations sampled on Little Goose Reservoir indicated seasonal fluctuations in numerical fish abundance (Figs. 29-34). For some species, seasonal abundance trends were similar among sampling stations. Abundance of white crappie and yellow perch was highest in spring at all stations. Abundance of redside shiner was highest in spring at all main channel stations except

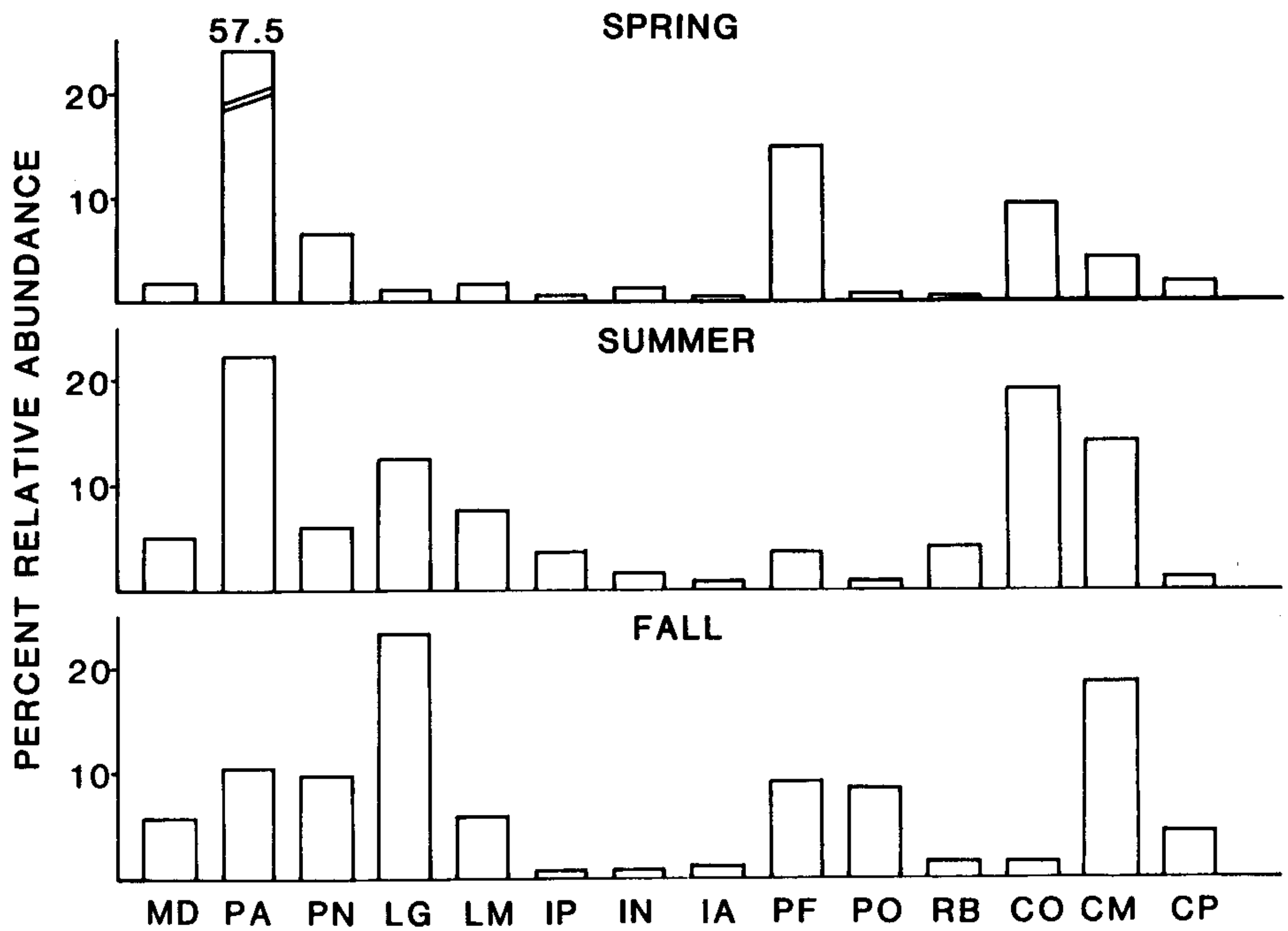

Figure 29. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at the lower embayment station (Deadman Bay) on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; LG - pumpkinseed; LM - bluegill; IP - channel catfish; IN - brown bullhead; IA - yellow bullhead; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp.

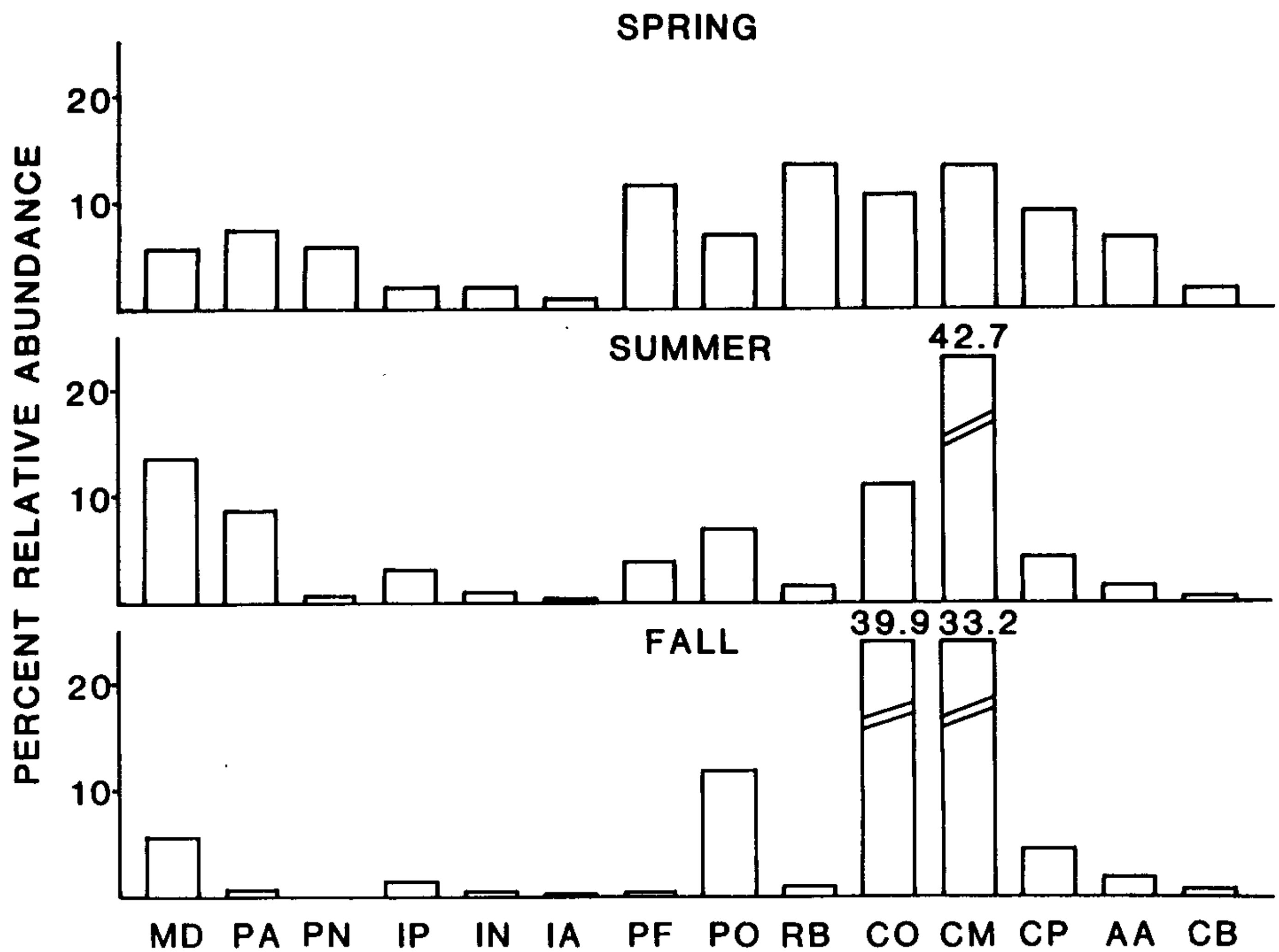

Figure 30. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at the lower gulch station on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; IP - channel catfish; IN - brown bullhead; IA - yellow bullhead; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth; CB - sculpin.

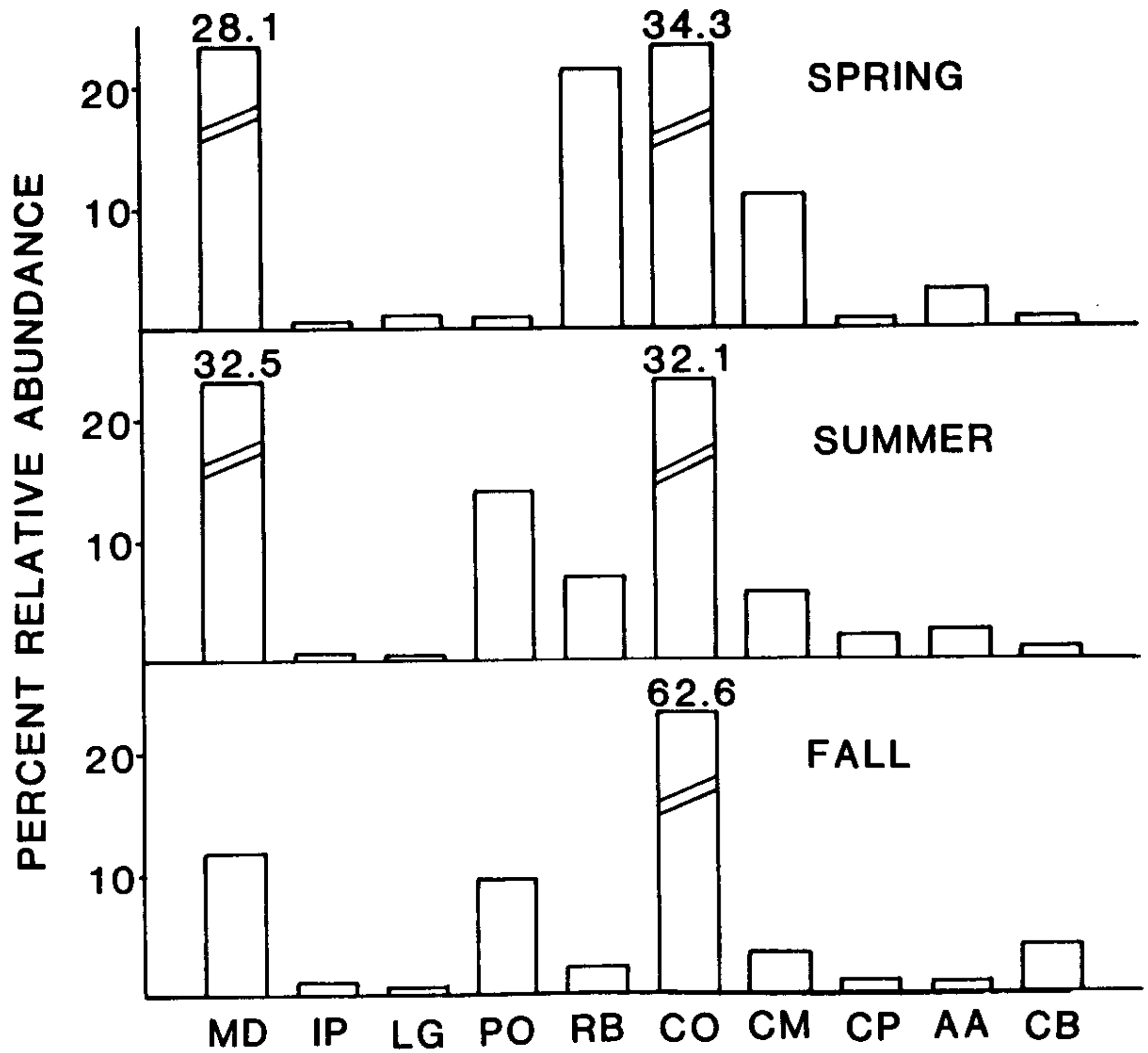

Figure 31. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with vertical gill nets and electrofishing gear at the deepwater station on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD-smallmouth bass; IP-channel catfish; LG-pumpkinseed; PO-northern squawfish; RB-redside shiner; CO-bridgelip sucker; CM-largescale sucker; CP-carp; AA-chiselmouth; CB-sculpin.

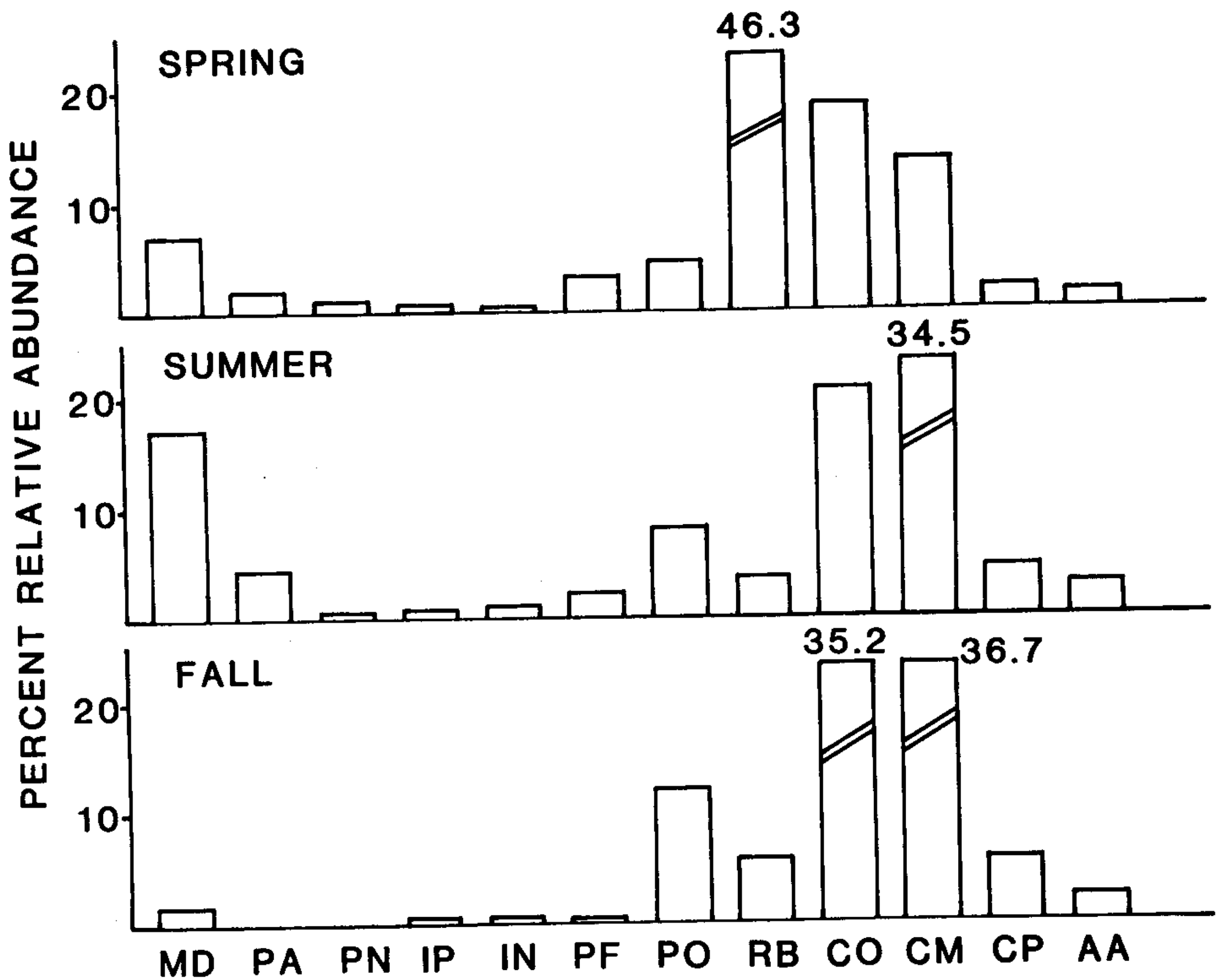

Figure 32. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at the lower shoal station sampled on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; IP - channel catfish; IN - brown bullhead; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth.

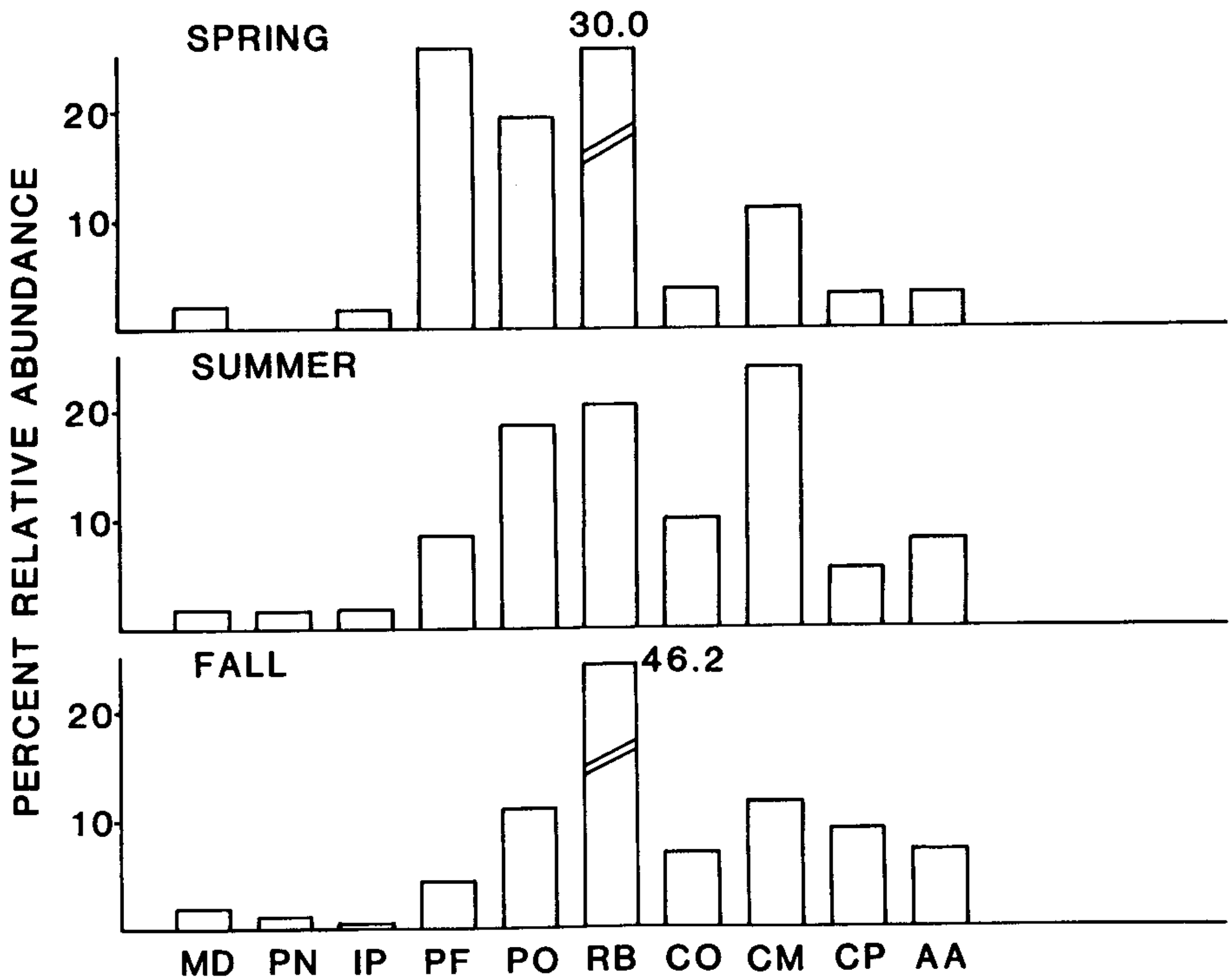

Figure 33. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at the upper shoal station on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; PN - black crappie; IP - channel catfish; PF - yellow perch; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth.

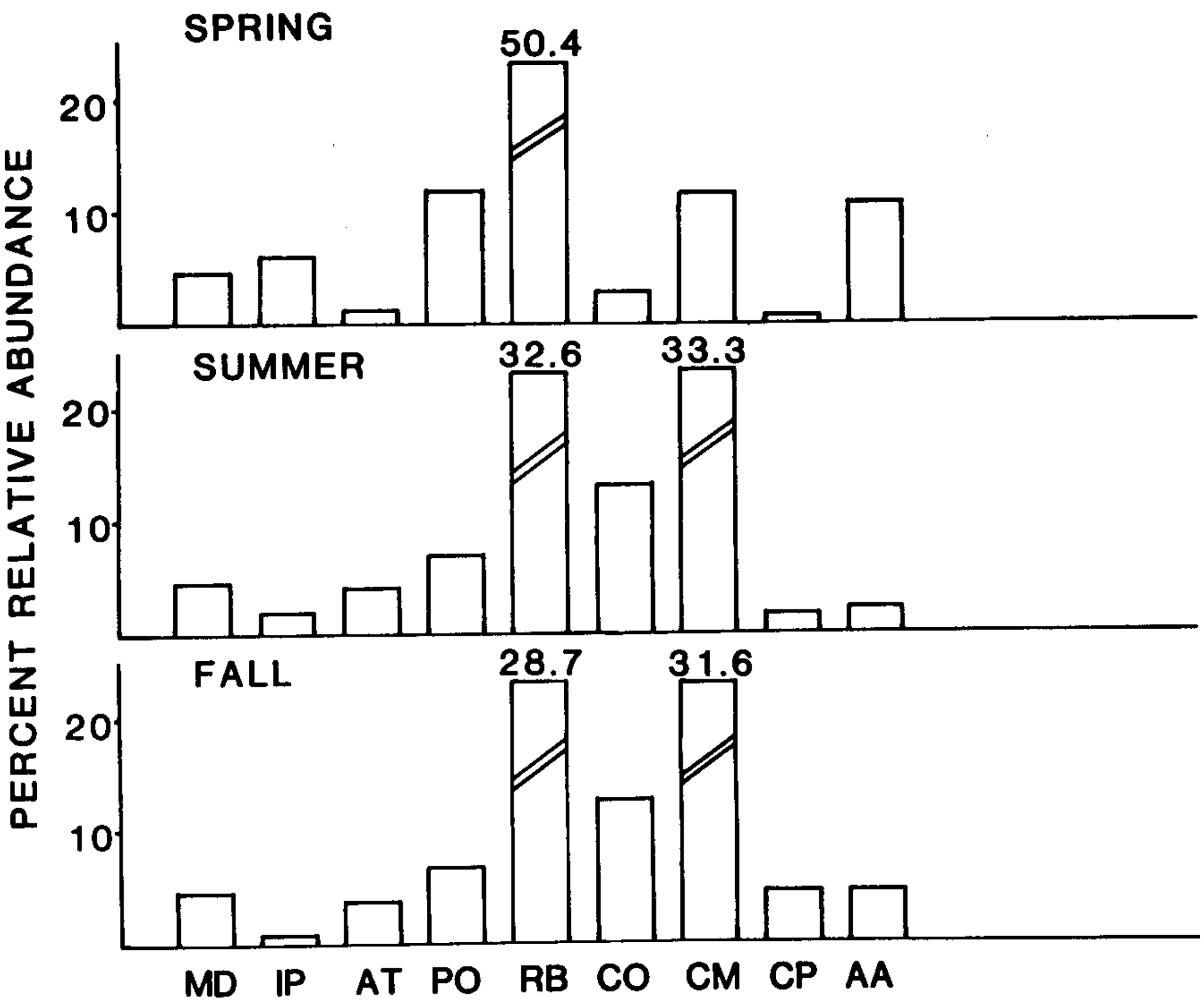

Figure 34. Seasonal relative abundance (%) (spring-summer-fall) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine at the tailwater station on Little Goose Reservoir, Washington, during 1980. Species abbreviations are: MD - smallmouth bass; IP - channel catfish; AT - white sturgeon; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth.

for the upper shoal where abundance was highest in fall. Species exhibiting higher abundance at all stations during summer and fall included largescale sucker, bridgelip sucker, pumpkinseed, and bluegill.

Seasonal abundance of other species differed among sampling stations. Abundance of smallmouth bass was highest during summer at the lower gulch, lower shoal, and deepwater stations with little seasonal change (spring-fall) occurring at other stations. Abundance of channel catfish and northern squawfish was highest at the tailwater station during spring and at the upper shoal station during spring and summer. At other stations, however, abundance of northern squawfish was highest in summer and fall. Abundance of channel catfish changed little at other stations except at the lower embayment where highest abundance occurred during summer. Little change in seasonal abundance was observed in other species.

Overall Fish Abundance in Little Goose Reservoir

When annual relative abundance estimates for stations sampled on Little Goose Reservoir were weighted according to shoreline distance of major habitat types, fish species inhabiting deepwater habitat appeared more abundant than species occurring in other habitat types. Deepwater habitat comprised 47.8% of total shoreline distance on Little Goose Reservoir compared to upper shoal, lower shoal, embayment, tailwater, and gulch habitat types which comprised 14.8, 11.9, 9.4, 8.6, and 7.4% of total shoreline distance, respectively. Therefore, fish species more abundant in the annual estimate of abundance at the deepwater station (Fig. 26) also were more abundant in the total reservoir estimate (Fig. 35). Bridgelip sucker was the most abundant species followed by redside shiner, largescale sucker, smallmouth bass, and northern squawfish. These species represented 80% of all fish captured in Little Goose Reservoir.

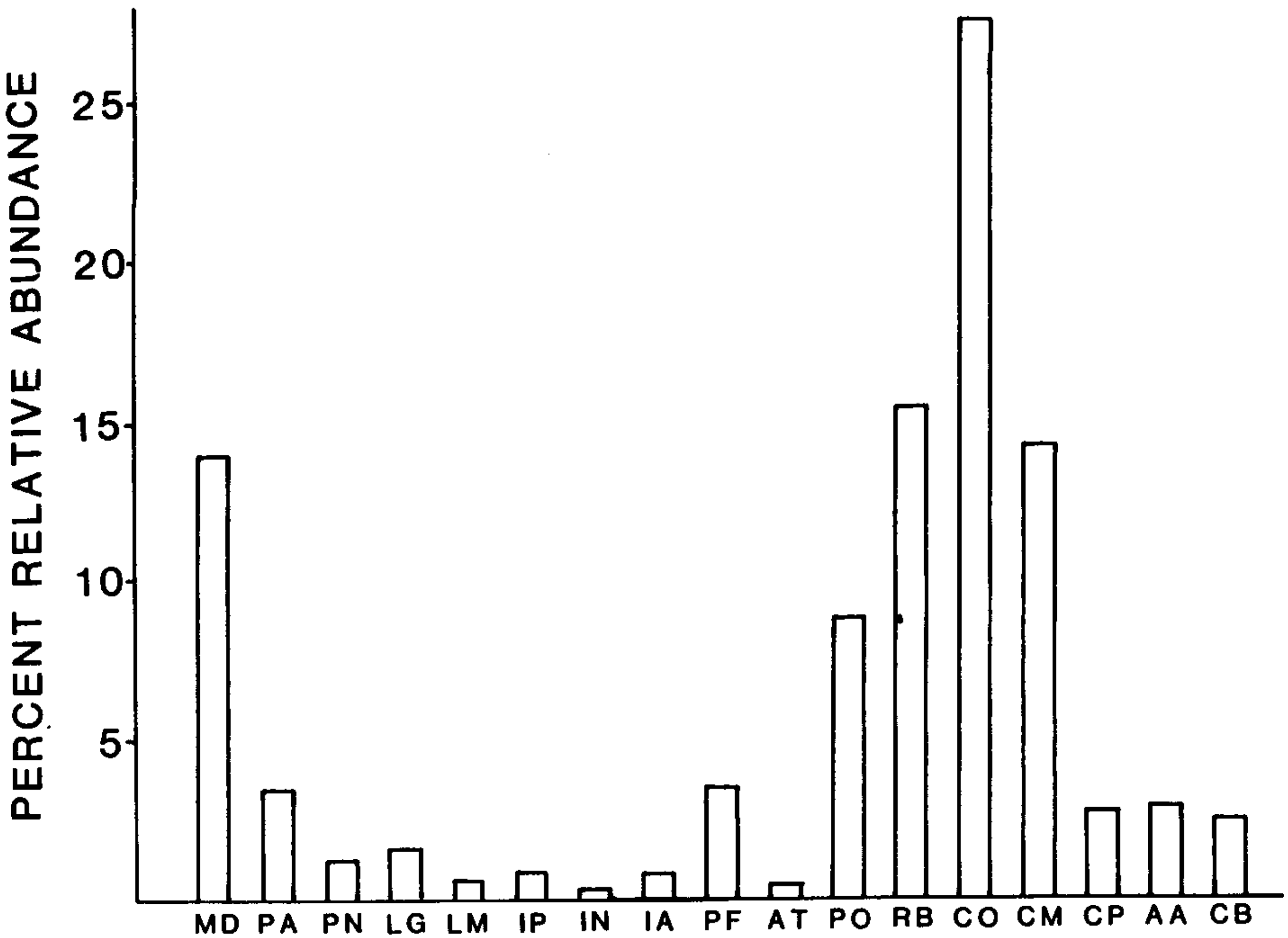

Figure 35. Relative abundance (%) of age I and older fishes collected with gill nets, trap nets, electrofishing gear, and beach seine in Little Goose Reservoir, Washington, during 1980. Relative abundance of each species was calculated by weighting annual abundance estimates at each station with shoreline distances of major habitat types. Species abbreviations are: MD - smallmouth bass; PA - white crappie; PN - black crappie; LG - pumpkinseed; LM - bluegill; IA - yellow bullhead; PF - yellow perch; AT - white sturgeon; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; CP - carp; AA - chiselmouth; CB - sculpin.

Non-game species were more abundant than game species in Little Goose Reservoir. Non-game species, found primarily in main channel habitats, comprised 73% of the fish. Game species, with the exception of smallmouth bass, were most abundant in embayment habitat and comprised 13% of the fish. Smallmouth bass, found in all habitats, comprised 14% of the fish in Little Goose Reservoir and was the most abundant game species.

Comparison of Reservoir Fish Abundance

Some fish species exhibited definite trends in abundance when similar habitat types in upriver and downriver reservoirs were compared (Figs. 36-39). Species more abundant in upriver reservoirs included smallmouth bass, pumpkinseed, and white crappie, whereas channel catfish and carp were more abundant in downriver reservoirs.

Distinct trends in abundance were not apparent with other species as some appeared more abundant in certain habitats of particular reservoirs. For example, abundance of chiselmouth and northern squawfish was substantially higher at the embayment station on Lower Monumental Reservoir than in embayments sampled on Little Goose and Ice Harbor reservoirs. Abundance of chiselmouth also was higher at the main channel stations on Lower Monumental and Lower Granite reservoirs. Abundance of yellow perch at main channel stations on Little Goose Reservoir was higher than at main channel stations on Ice Harbor, Lower Monumental, and Lower Granite reservoirs (Appendix Tables III).

Population Estimates in Deadman Bay

Schnabel and Schumacher-Eschmeyer population estimates were calculated for white crappie, black crappie, pumpkinseed, bluegill, brown bullhead, and largescale sucker at the lower embayment station (Deadman Bay) on Little Goose Reservoir (Table 16). Highest population estimates were obtained for

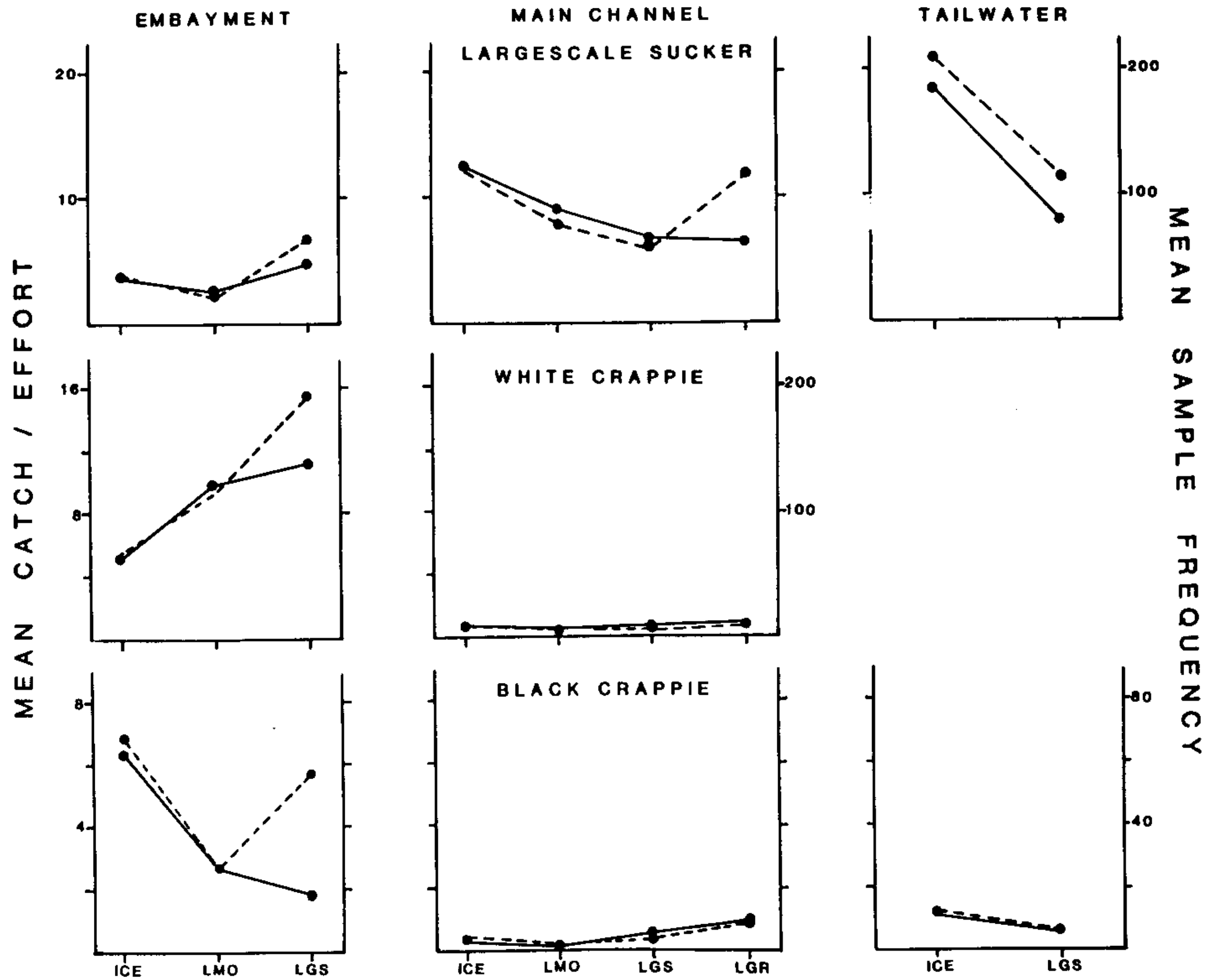

Figure 36. Abundance of largescale sucker, white crappie, and black crappie at embayment, main channel, and tailwater areas of Lower Snake reservoirs during 1980 based on mean catch per effort (CPE) (solid line) and mean sample frequency (broken line). CPE was calculated from trap nets, the gear most effective in collecting these species. Sample frequencies were obtained from annual abundance estimates. Reservoir abbreviations are: ICE - Ice Harbor; LMO - Lower Monumental; LGS - Little Goose; LGR - Lower Granite.

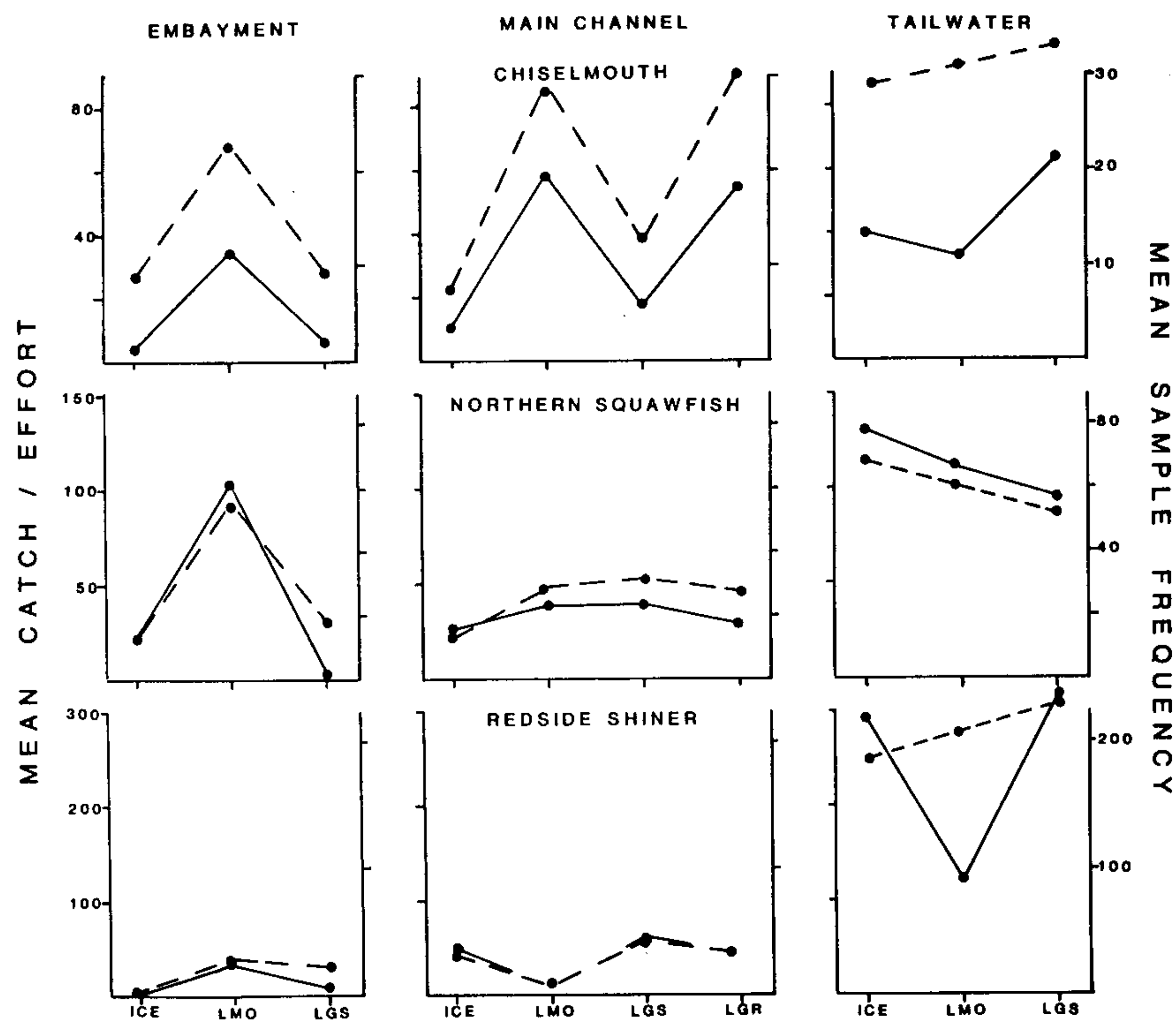

Figure 37. Abundance of chiselmouth, northern squawfish, and redside shiner at embayment, main channel, and tailwater areas of Lower Snake reservoirs during 1980 based on mean catch per effort (CPE) (solid line) and mean sample frequency (broken line). CPE was calculated from electrofishing gear, the gear most effective in collecting these species. Sample frequencies were obtained from annual abundance estimates. Reservoir abbreviations are: ICE-Ice Harbor; LMO-Lower Monumental; LGS-Little Goose; LGR-Lower Granite.

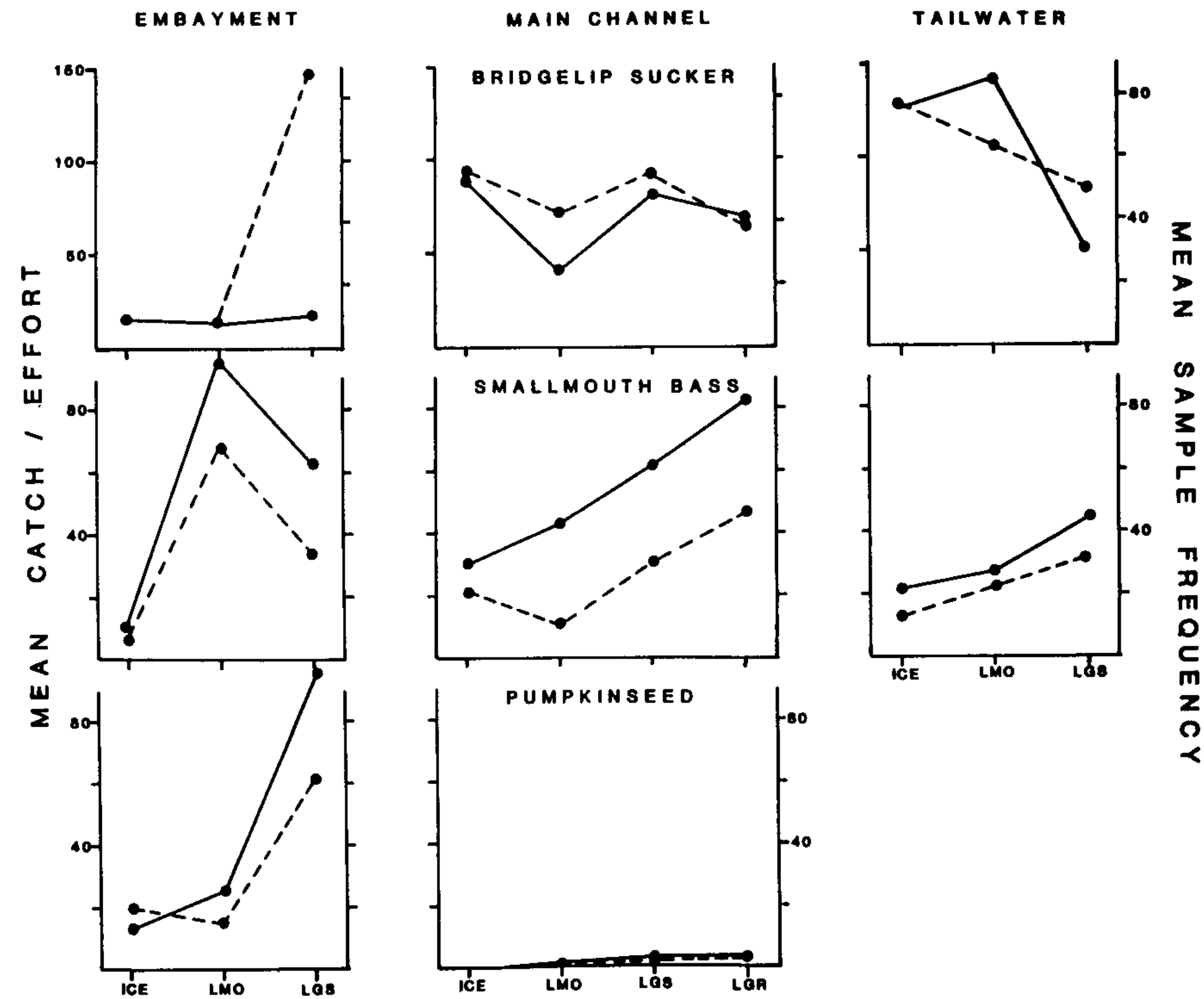

Figure 38. Abundance of bridgelip sucker, smallmouth bass, and pumpkinseed at embayment, main channel, and tailwater areas of Lower Snake reservoirs during 1980 based on mean catch per effort (CPE) (solid line) and mean sample frequency (broken line). CPE was calculated from electrofishing gear, the gear most effective in collecting these species. Sample frequencies were obtained from annual abundance estimates. Reservoir abbreviations are: ICE - Ice Harbor; LMO - Lower Monumental; LGS - Little Goose; LGR - Lower Granite.

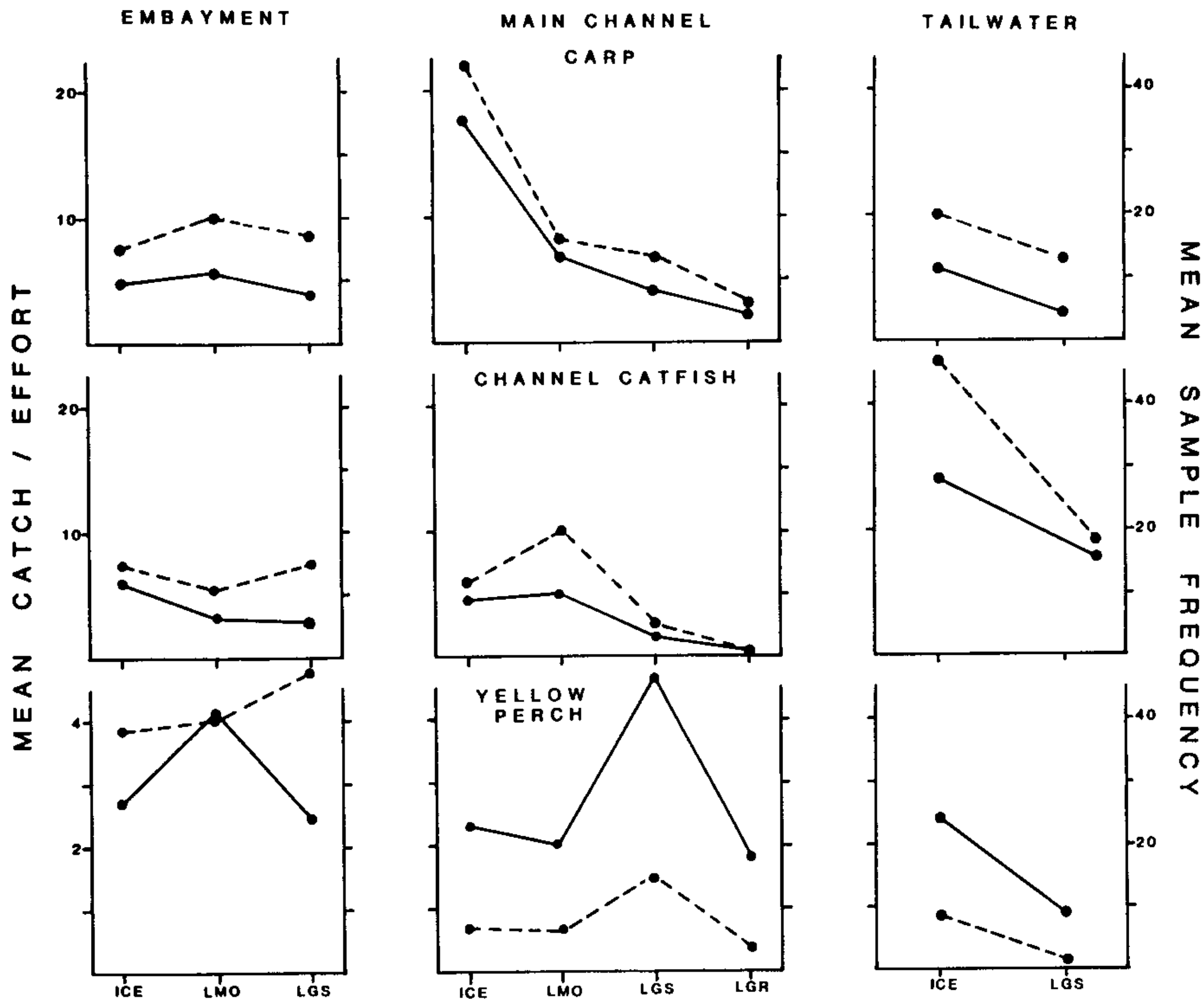

Figure 39. Abundance of carp, channel catfish, and yellow perch at embayment, main channel, and tailwater areas of Lower Snake reservoirs during 1980 based on mean catch per effort (CPE) (solid line) and mean sample frequency (broken line). CPE was calculated from gill nets, the gear most effective in collecting these species. Sample frequencies were obtained from annual abundance estimates. Reservoir abbreviations are: ICE - Ice Harbor; LMO - Lower Monumental; LGS - Little Goose; LGR - Lower Granite.

Table 16. Population estimates of fishes in the lower embayment (Deadman Bay) of Little Goose Reservoir, Washington.

Species	Minimum Size (mm)	Sampling Method	Season/ Year	Schnabel Estimate	Confidence Limits[a]	Schumacher-Eschmeyer Estimate	Confidence Limits[a]
white crappie	200	trap net	Spring 80	8483	7164-10212	8423	7241-10071
black crappie	200	trap net	Spring 80	1154	641-3297	1342	783-4684
pumpkinseed	100	electro-fishing	Summer 80	708	508-1059	765	626-985
bluegill	100	electro-fishing	Summer 80	570	292-2139	544	310-2227
brown bullhead	200	trap net	Summer 79	506	308-1125	656	379-2428
largescale sucker	250	trap net	Summer 79	9241	5898-18002	9608	8203-11587

[a] 95% confidence intervals

white crappie and largescale sucker. From our estimates, black crappie was the third most numerous species. Population estimates for pumpkinseed, bluegill, and brown bullhead were very similar. For all species, Schnabel and Schumacher-Eschmeyer population estimators were in close agreement which attests to the validity of these estimates.

Annual Survival Estimates

Annual survival estimates for smallmouth bass, white crappie, black crappie, bluegill, pumpkinseed, and yellow perch in Little Goose Reservoir were generally less than 50% (Table 17). Lowest annual survival rates were calculated for smallmouth bass, black crappie, and white crappie. Pumpkinseed, bluegill, and yellow perch had annual survival rates greater than 40%. Estimates of annual survival calculated by Heincke's (1913) method ranged from 3 to 13% higher than estimates calculated by the Robson and Chapman (1961) method.

Population Density and Standing Crop

Estimates of population density and standing crop for white crappie, black crappie, pumpkinseed, and bluegill in Deadman Bay were highly variable (Table 18). Density and standing crop of white crappie were highest at low pool and were estimated at 200 fish/ha and 33.8 kg/ha, respectively. Lowest densities and standing crops were estimated for pumpkinseed and bluegill. The variation of surface area in Deadman Bay between high (53.8 ha) and low (42.5 ha) pool levels resulted in population density and standing crop differences to 21%.

Table 17. Annual survival estimates for selected game species in Little Goose Reservoir, Washington.

SPECIES	Ages	Robson & Chapman's[1] Estimate	Heincke's[2] Estimate
smallmouth bass	IV-VIII	0.28	0.31
white crappie	IV-VII	0.36	0.40
black crappie	III-VII	0.33	0.38
bluegill	II-VII	0.53	0.62
pumpkinseed	II-V	0.47	0.60
yellow perch	IV-VI	0.40	0.48

[1]Robson and Chapman 1961

[2]Heincke 1913

Table 18. Estimates of population density (number/area) and standing crop (biomass/area) for selected centrarchid fishes at the lower embayment station (Deadman Bay), Little Goose Reservoir, Washington. Estimates are given for Deadman Bay at high (53.8 ha) and low (42.5 ha) pool levels.

Species	Minimum Size (mm)	High Pool Level Population Density (fish/ha)	High Pool Level Standing Crop (kg/ha)	Low Pool Level Population Density (fish/ha)	Low Pool Level Standing Crop (kg/ha)
white crappie	200	158	26.7	200	33.8
black crappie	200	21	4.2	27	5.3
pumpkinseed	100	13	0.51	17	0.64
bluegill	100	11	0.72	13	0.92

Vertical Distribution

Eight of sixteen fish species were captured in sufficient numbers with vertical gill nets to evaluate their vertical distribution in lower Snake reservoirs. Seasonal vertical distribution of northern squawfish, redside shiner, carp, chiselmouth, largescale sucker, channel catfish, white sturgeon, and residing chinook salmon was evaluated in Little Goose Reservoir (Figs. 40 and 41). Catches of northern squawfish, carp, largescale sucker, chiselmouth, and channel catfish were pooled to evaluate their summer and fall vertical distribution in Lower Granite, Lower Monumental, and Ice Harbor reservoirs (Fig. 42). Vertical distributions of fish were similar among reservoirs at all deepwater stations. Fish species that were most abundant in the upper 10 m of the water column included northern squawfish, redside shiner, and chiselmouth. Channel catfish and white sturgeon occurred primarily in the lower 10 m of the water column. Widely distributed species were carp, largescale sucker, and residing chinook salmon. Seasonal differences in vertical distribution were not apparent, however, catch per unit of effort for all species in the vertical gill nets during spring was low compared with summer and fall (Appendix Tables III).

Fish Movement

In Little Goose Reservoir, 12 species consisting of 7057 fish were tagged from June, 1979 through November, 1980. During this period, 9.5% of the tagged fish (670) were recaptured. Of the fish recaptured, 57% (382) were captured by various types of sampling gear and 43% (288) were caught by anglers. Seventy-five percent of the angling returns were tags from white crappie caught at the lower embayment station (Deadman Bay).

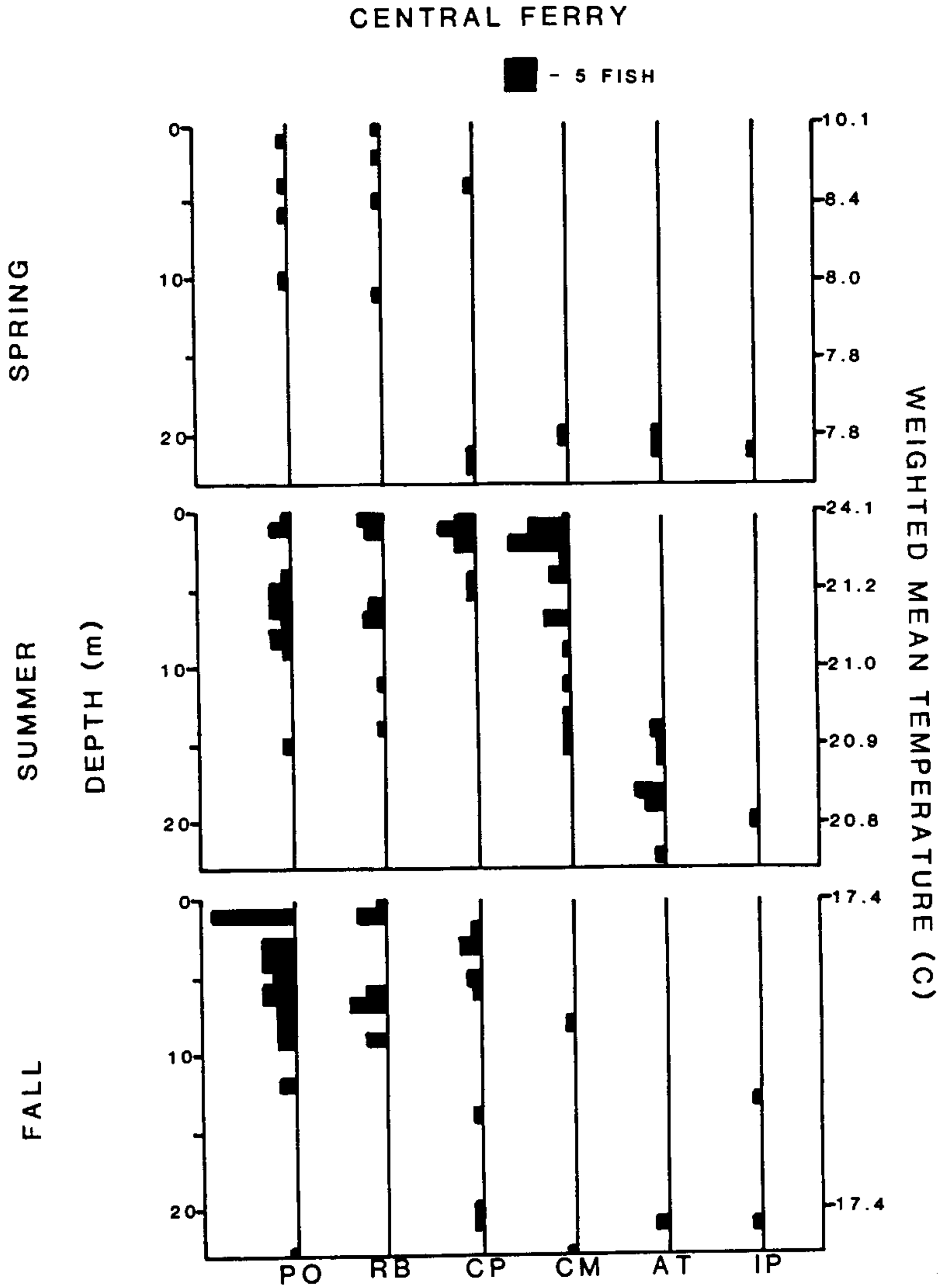

Figure 40. Seasonal vertical distribution (spring-summer-fall) of fishes collected with vertical gill nets in the main river channel near Central Ferry on Little Goose Reservoir, Washington, during 1979 and 1980. Depth (m) of fish capture (left) vs. weighted mean temperature (C) at various depths (right). Species abbreviations are: PO-northern squawfish; RB-redside shiner; CP-carp; CM-largescale sucker; AT-white sturgeon; IP-channel catfish.

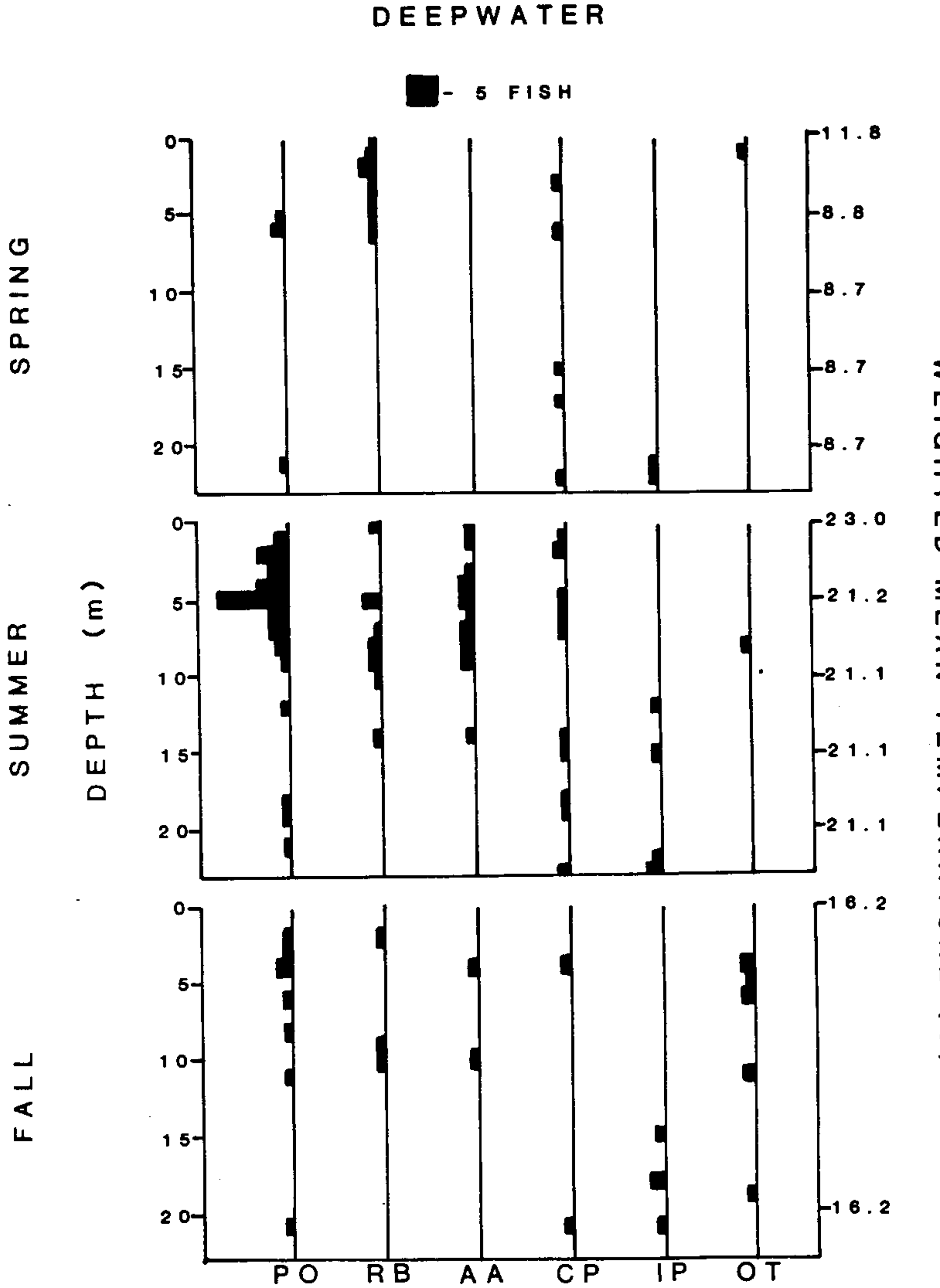

Figure 41. Seasonal vertical distribution (spring-summer-fall) of fishes collected with vertical gill nets at the deepwater station on Little Goose Reservoir, Washington, during 1979 and 1980. Depth (m) of fish capture (left) vs. weighted mean water temperature (C) at various depths (right). Species abbreviations are: PO-northern squawfish; RB-redside shiner; AA-chiselmouth; CP-carp; IP-channel catfish; OT-chinook salmon.

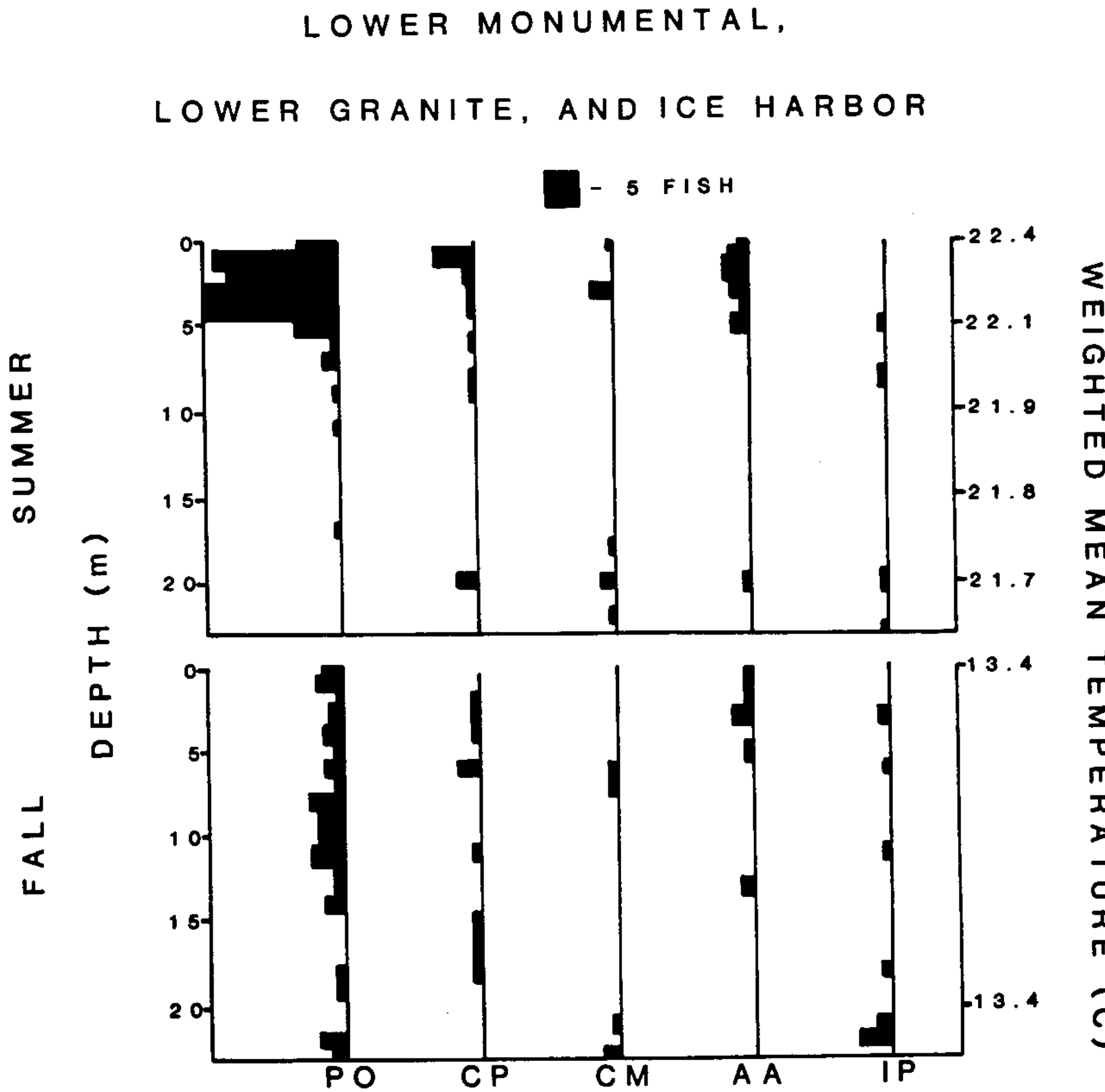

Figure 42. Seasonal vertical distribution (summer-fall) of fishes collected with vertical gill nets at deepwater areas sampled in Lower Granite, Lower Monumental, and Ice Harbor reservoirs, Washington, during 1979 and 1980. Depth (m) of fish capture (left) vs. weighted mean water temperature (C) at various depths (right). Species abbreviations are: PO-northern squawfish; CP-carp; CM-largescale sucker; AA-chiselmouth; IP-channel catfish.

Intra-zone Movement

Individuals of several fish species moved extensively within reservoir zones. Largescale sucker and white crappie exhibited the widest range of movement in the lower zone, whereas largescale sucker, channel catfish, and smallmouth bass exhibited the widest range of movement in the upper zone (Tables 19 and 20). These species traveled mean distances greater than 1 km, and distances ranged from 8.2 to 12.8 km. Fish exhibiting some movement but traveling mean distances less than 1 km included brown bullhead and black crappie in the lower zone and bridgelip sucker in the upper zone. Tagged fish recaptured at the same location and exhibiting no movement included white sturgeon, channel catfish, and smallmouth bass in the lower zone and white sturgeon and white crappie in the upper zone.

The majority of fish tagged and recaptured in Little Goose Reservoir were in the lower embayment zone (Table 21). Fish movement was limited in this zone; however, white crappie, black crappie, channel catfish, brown bullhead, largescale sucker, and carp traveled extensively within the zone. Individuals of fish species which exhibited no movement in the lower embayment zone included white sturgeon, yellow bullhead, smallmouth bass, and largemouth bass.

Inter-zone Movement

Several fish exhibited movement among reservoir zones (Table 22). Fish exhibiting the highest amount of movement, traveling mean distances longer than 27 km, included bridgelip sucker, largescale sucker, and channel catfish. The least amount of movement was observed in smallmouth bass and brown bullhead. These fish traveled mean distances less than 6 km.

Table 19. Movement of fish in the lower zone of Little Goose Reservoir, Washington, based on the recovery of tagged individuals.

SPECIES	Number Tagged	Recaptures	% Recaptured	Mean Distance (km)	Range (km)
white sturgeon	13	1	7.7	0	-
carp	64	0	0	-	-
northern squawfish	5	0	0	-	-
bridgelip sucker	31	0	0	-	-
largescale sucker	745	16	2.1	1.1	0-8.2
yellow bullhead	14	0	0	-	-
brown bullhead	61	5	8.2	0.3	0-0.9
channel catfish	57	1	1.8	0	-
smallmouth bass	115	7	6.1	0	-
white crappie	82	5	6.1	2.3	0-10.5
black crappie	17	2	11.8	0.4	0-0.8
TOTALS	1204	37	3.1	0.6	0-10.5

Table 20. Movement of fish in the upper zone of Little Goose Reservoir, Washington, based on recovery of tagged individuals.

SPECIES	Number Tagged	Recaptures	% Recaptured	Mean Distance (km)	Range (km)
white sturgeon	170	7	4.1	0	-
carp	169	0	0	-	-
northern squawfish	20	0	0	-	-
bridgelip sucker	97	2	2.1	0.7	0-1.3
largescale sucker	758	12	1.6	4.4	0-12.8
yellow bullhead	13	0	0	-	-
brown bullhead	44	1	2.3	1.2	-
channel catfish	88	2	2.3	4.8	0-9.7
smallmouth bass	221	29	13.1	1.2	0-9.7
white crappie	4	1	25.0	0	-
black crappie	38	0	0	-	-
TOTALS	1622	54	3.3	1.8	0-12.8

Table 21. Movement of fish in the lower embayment zone (Deadman Bay), Little Goose Reservoir, Washington, based on recovery of tagged individuals.

SPECIES	Number Tagged	Recaptures	% Recaptured	Mean Distance (km)	Range (km)
white sturgeon	5	1	20.0	0	-
carp	99	2	2.0	0.5	0.2-0.8
northern squawfish	24	0	0	-	-
bridgelip sucker	79	0	0	-	-
largescale sucker	1240	29	2.3	0.3	0-1.2
yellow bullhead	27	1	3.7	0	-
brown bullhead	187	21	11.2	0.5	0-1.2
channel catfish	117	1	0.9	0.5	-
smallmouth bass	66	4	6.1	0	-
largemouth bass	11	5	45.5	0	-
white crappie	2139	448	20.9	0.4	0-1.2
black crappie	237	38	16.0	0.6	0-1.2
TOTALS	4231	550	13.0	0.3	0-1.2

Table 22. Movement of fish between reservoir zones in Little Goose Reservoir, Washington, based on the recovery of tagged individuals.

SPECIES	Number of Fish						Mean Distance (km)	Range (km)
	To Lower Zone		To Lower Embayment		To Upper Zone			
	from lower embay-ment	from upper zone	from lower zone	from upper zone	from lower zone	from lower embay-ment		
bridgelip sucker	-	1	-	-	-	1	36.9	31.0-42.9
largescale sucker	2	1	3	2	1	1	27.4	8.8-54.7
brown bullhead	1	1	-	-	-	-	5.8	1.60-10.1
channel catfish	-	-	-	1	-	1	34.3	28.4-40.2
smallmouth bass	3	-	-	-	-	-	1.4	0.8-2.1
white crappie	5	-	-	-	-	2	19.6	1.3-38.0
black crappie	-	1	-	-	-	-	18.6	11.3-25.8

Three fish recaptures moved between reservoirs. A black crappie tagged in the lower reservoir zone of Little Goose Reservoir was recaptured by an angler near Lyons Ferry, Lower Monumental Reservoir. The straight line distance moved in four months was approximately 25 km. The other two fish were largescale suckers. One largescale sucker tagged at Ayer boat basin, Lower Monumental Reservoir, in August, 1979 was recaptured at the lower embayment station in Little Goose Reservoir in June, 1980. Linear distance traveled from Ayer boat basin to the lower embayment was approximately 55 km. The second largescale sucker was tagged in June, 1980 at the lower embayment station and recovered two months later at the Lower Granite fish ladder by National Marine Fisheries Service personnel. Straight line distance traveled was approximately 40 km.

Daily Movement Patterns

Fluctuations in catch per effort (CPE) for gill nets and/or trap nets at various time intervals indicated daily movement patterns of species at the lower embayment station in Little Goose Reservoir (Figs. 43 and 44). The catch of most species, including carp, pumpkinseed, largescale sucker, and yellow perch was higher during daylight hours than the hours of darkness.

Diel activity patterns for white crappie and black crappie were identical. The catch gradually increased throughout the morning, peaked in the afternoon, then decreased in the evening.

Ictalurid species were most active during night and morning hours (Figs. 43 and 44). Catch per effort of brown bullhead was highest during the hours of darkness. The catch of channel catfish peaked during morning hours and remained fairly constant throughout other time periods.

Species Habitat Preferences

Habitat preferences of most fish species in Little Goose Reservoir were similar among seasons sampled with the majority of introduced species occurring in embayment habitat and native species occurring in habitats along the main river channel (Figs. 45-49). Some species occurred primarily at one station, whereas others occurred at two or more stations. Introduced species which occurred primarily at the lower embayment station included pumpkinseed, warmouth, bluegill, largemouth bass, white crappie, black crappie, brown bullhead, and tadpole madtom. White sturgeon were found primarily at the tailwater station and probably preferred lotic conditions.

Species occurring frequently at two stations included yellow perch, yellow bullhead, chiselmouth, and redside shiner. Yellow perch occurred primarily at the lower embayment and upper shoal stations. Yellow bullhead

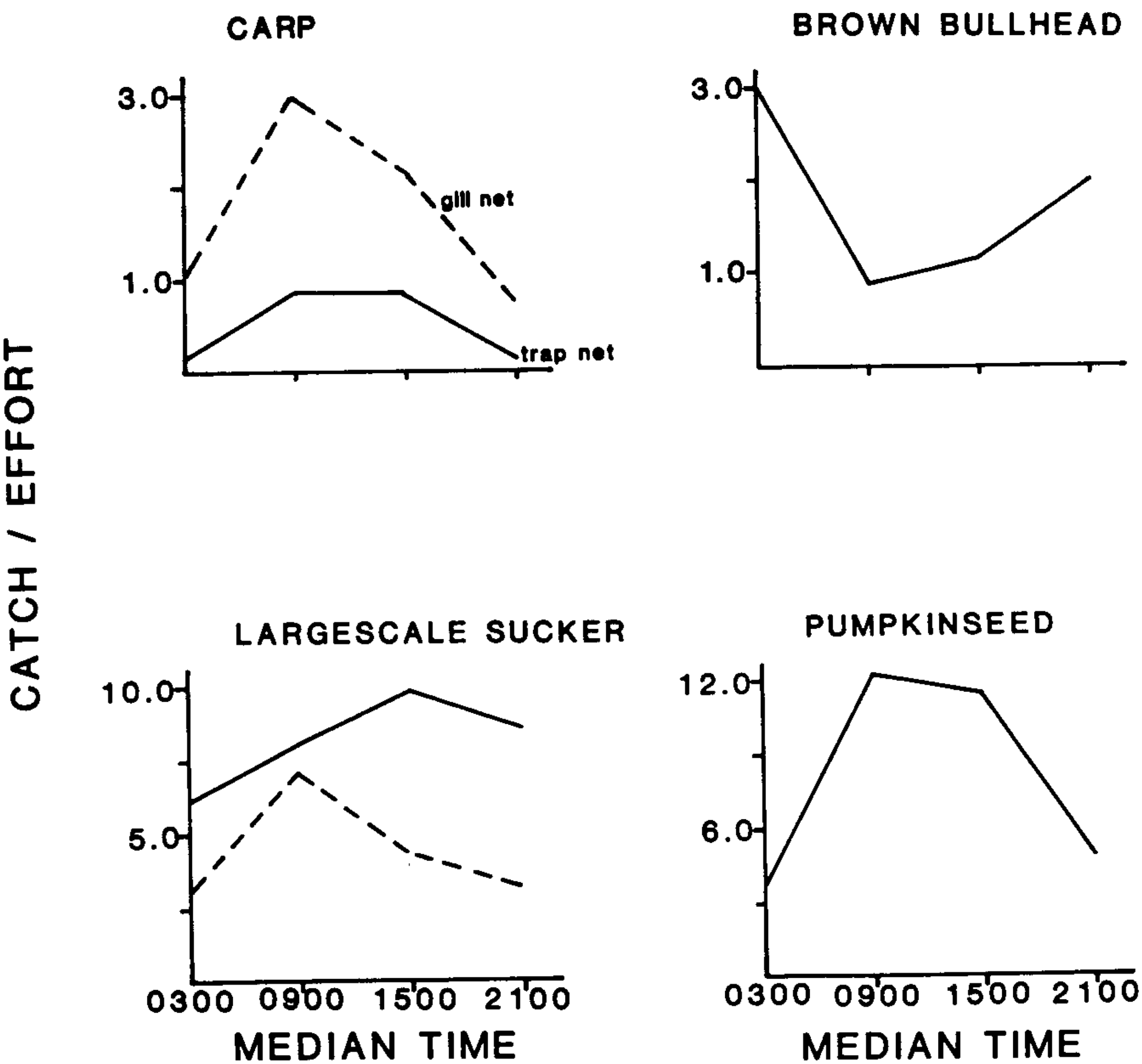

Figure 43. Catch per effort (CPE) for carp, brown bullhead, largescale sucker, and pumpkinseed in gill and/or trap nets during various hours of the day at the lower embayment station (Deadman Bay) on Little Goose Reservoir, Washington, during the summer in 1980.

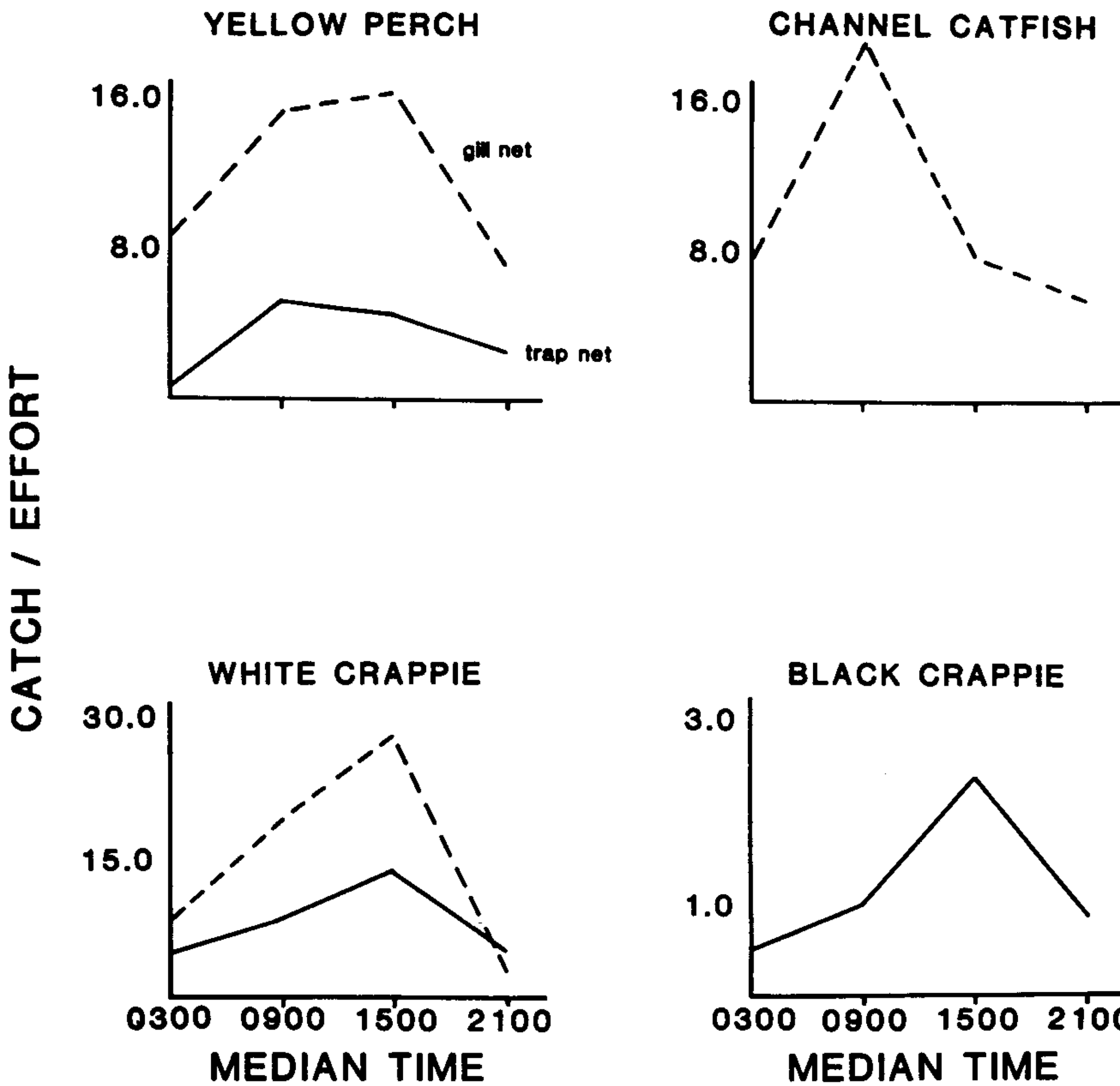

Figure 44. Catch per effort (CPE) for yellow perch, channel catfish, white crappie, and black crappie in gill and/or trap nets during various hours of the day at the lower embayment station (Deadman Bay) on Little Goose Reservoir, Washington, during the summer in 1980.

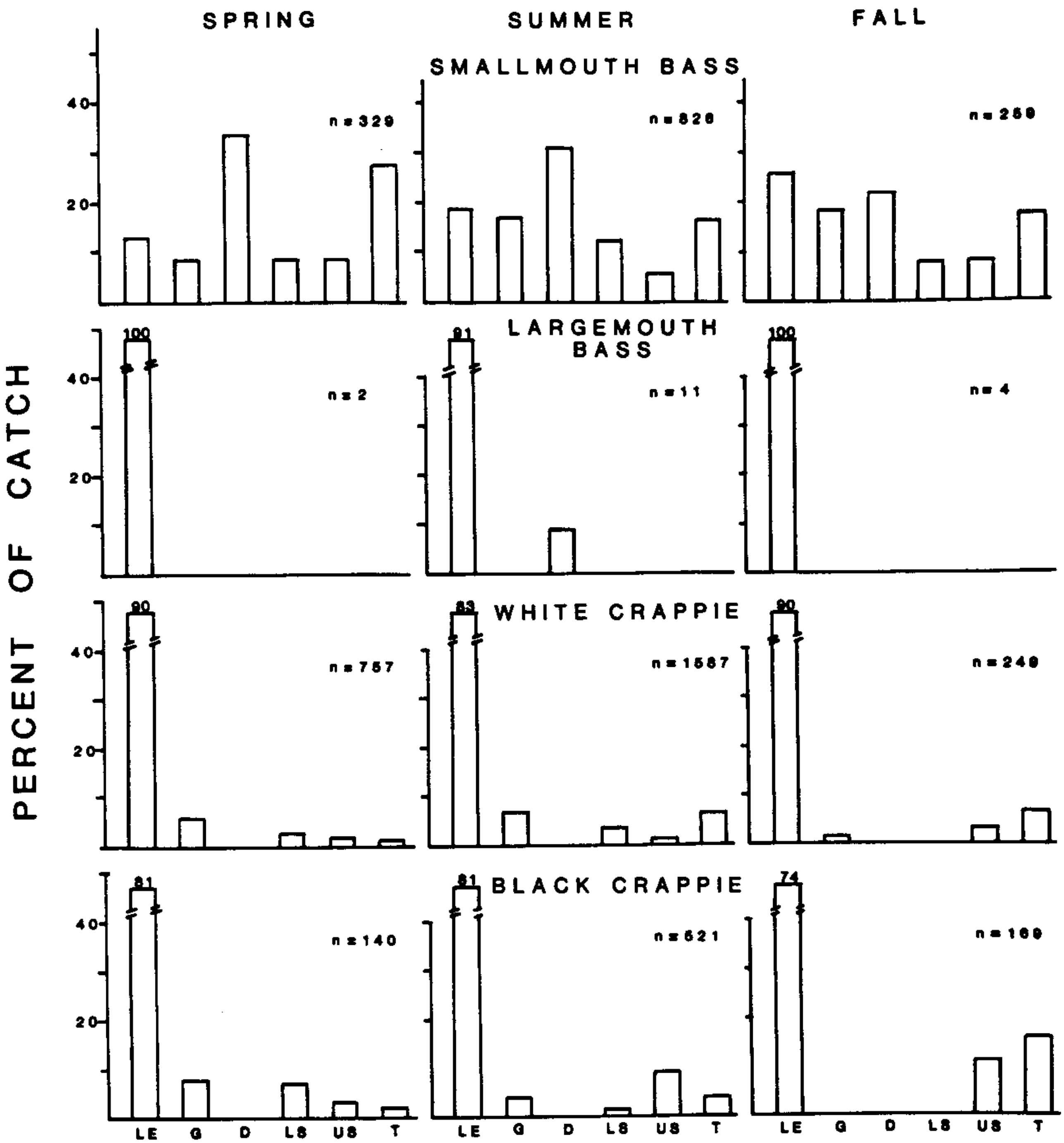

Figure 45. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at major sampling stations for smallmouth bass, largemouth bass, white crappie, and black crappie from Little Goose Reservoir, Washington, during 1979 and 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: LE-lower embayment; G-lower gulch; D-deepwater; LS-lower shoal; US-upper shoal; T-tailwater.

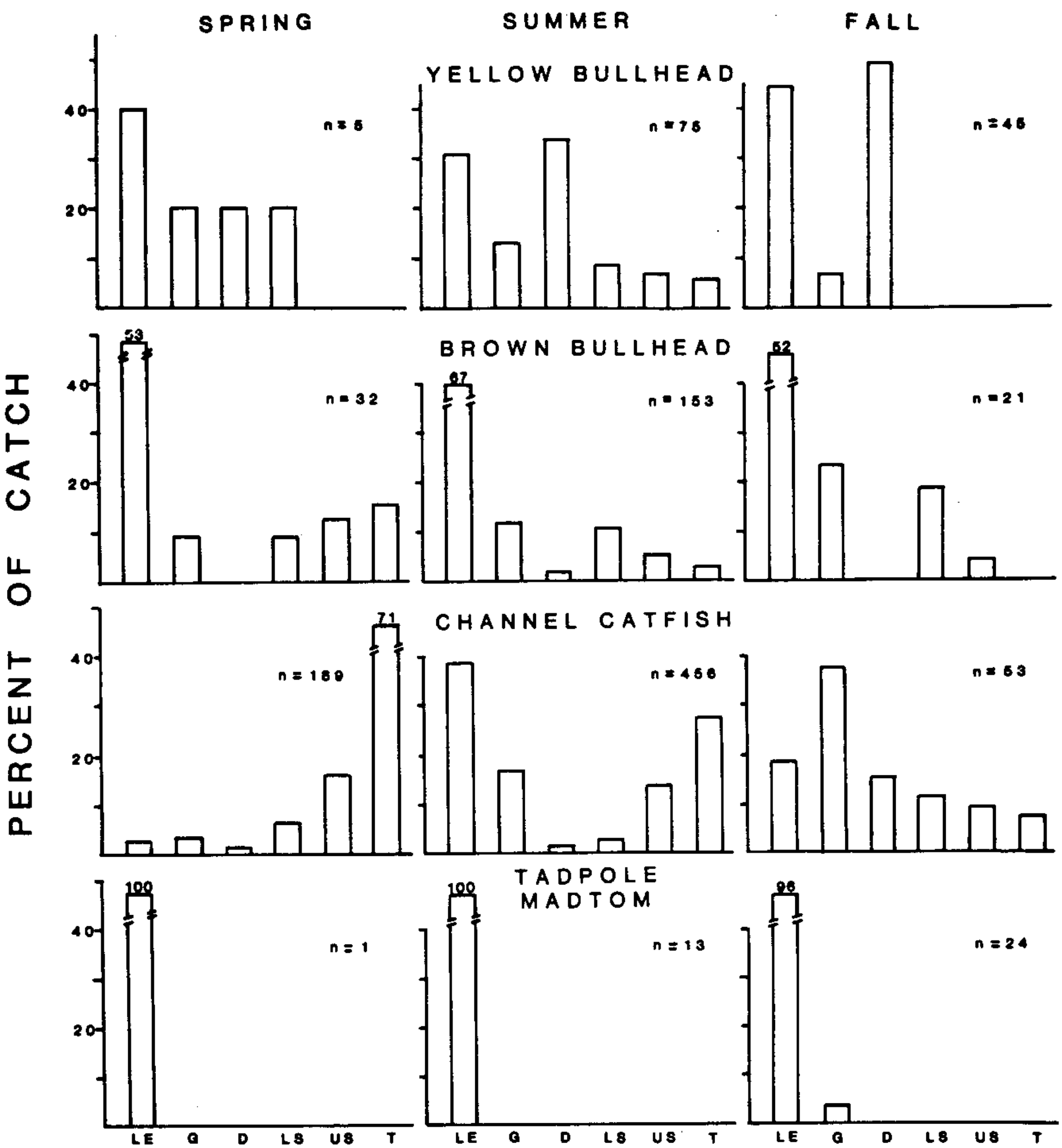

Figure 46. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at major sampling stations for yellow bullhead, brown bullhead, channel catfish, and tadpole madtom from Little Goose Reservoir, Washington, during 1979 and 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: LE-lower embayment; G-lower gulch; D-deepwater; LS-lower shoal; US-upper shoal; T-tailwater.

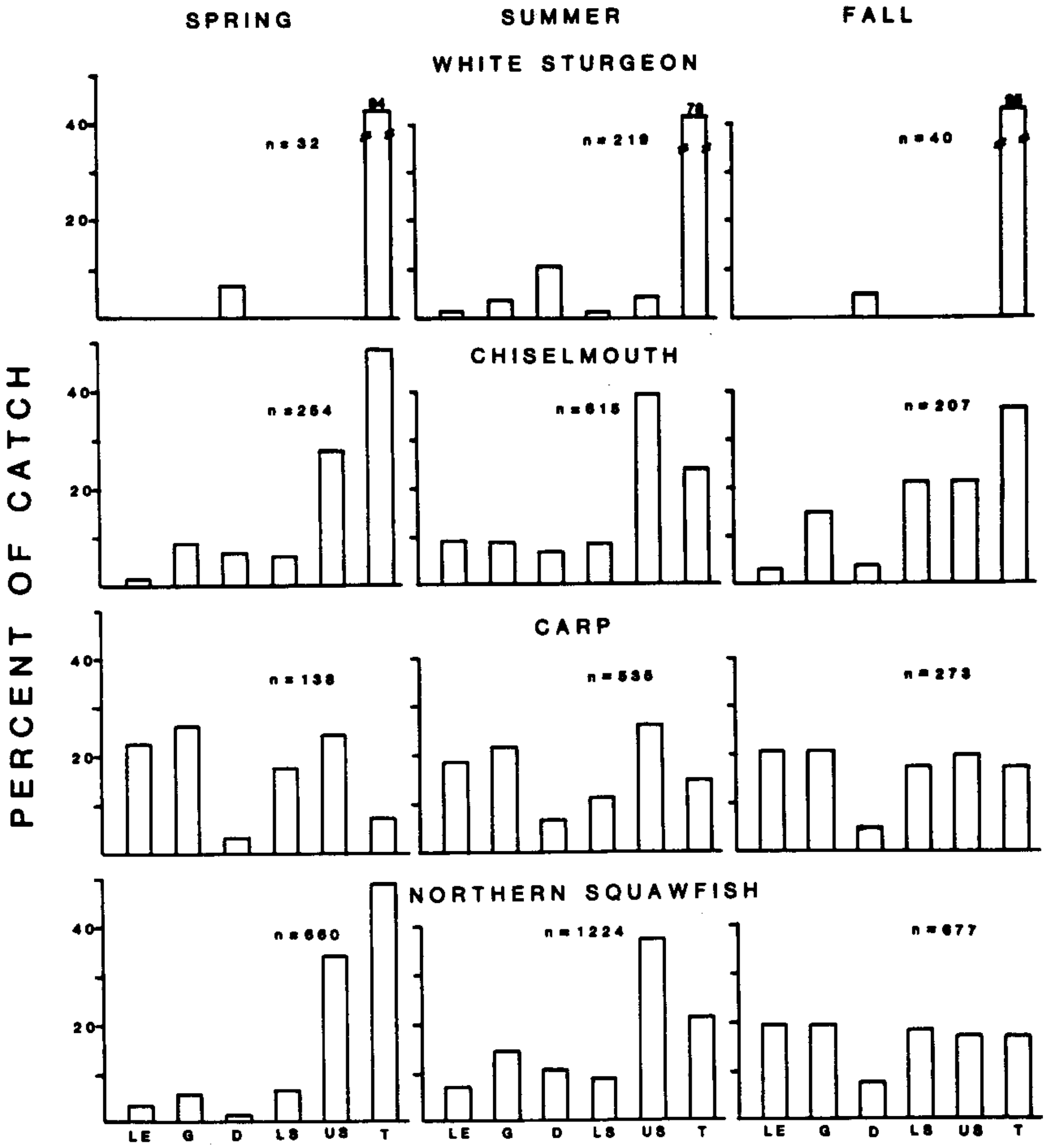

Figure 47. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at major sampling stations for white sturgeon, chiselmouth, carp, and northern squawfish from Little Goose Reservoir, Washington, during 1979 and 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: LE-lower embayment; G-lower gulch; D-deepwater; LS-lower shoal; US-upper shoal; T-tailwater.

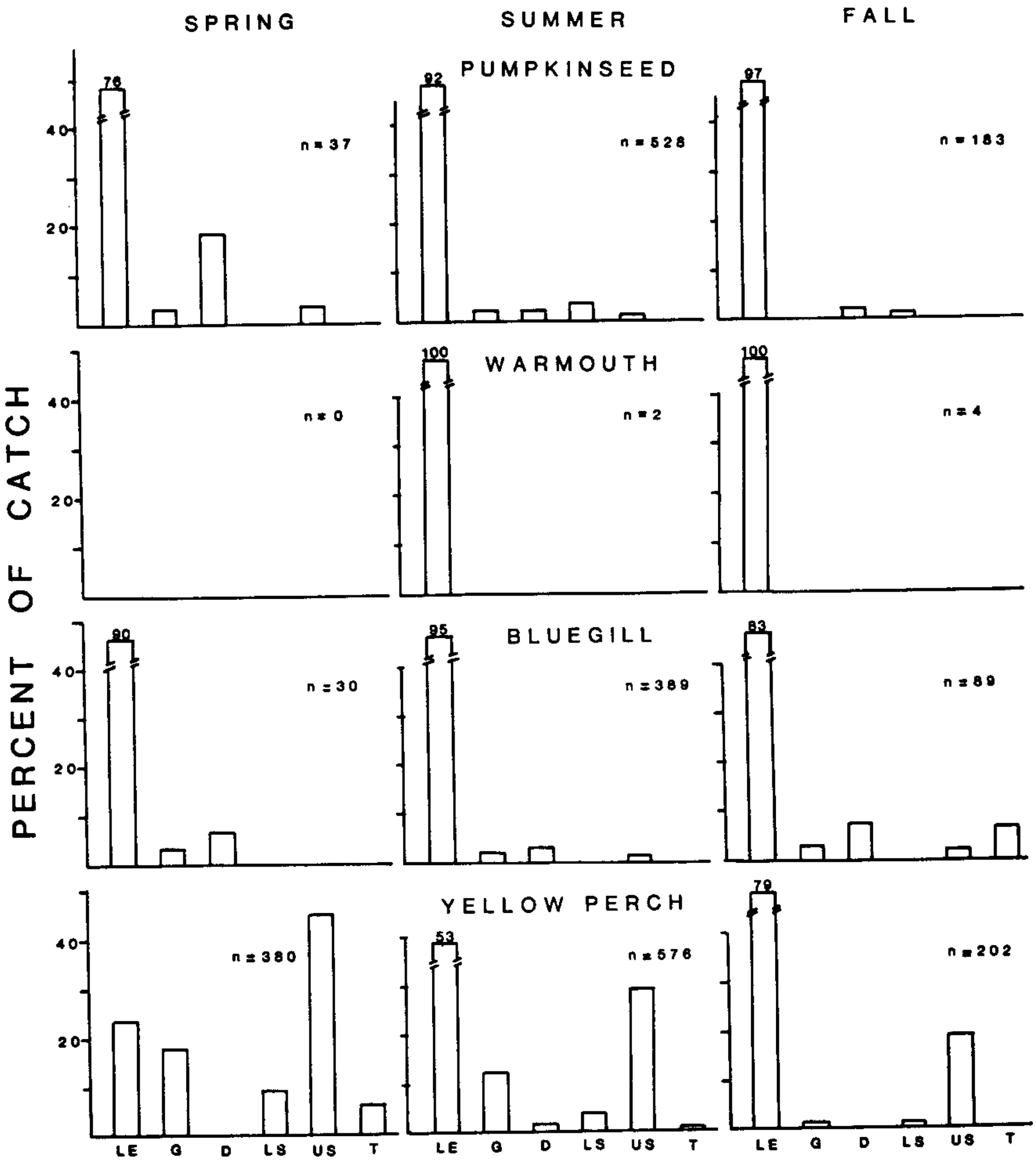

Figure 48. Seasonal habitat preferences (spring-summer-fall) based on percent catch at major sampling stations for pumpkinseed, warmouth, bluegill, and yellow perch from Little Goose Reservoir, Washington, during 1979 and 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: LE-lower embayment; G-lower gulch; D-deepwater; LS-lower shoal; US-upper shoal; T-tailwater.

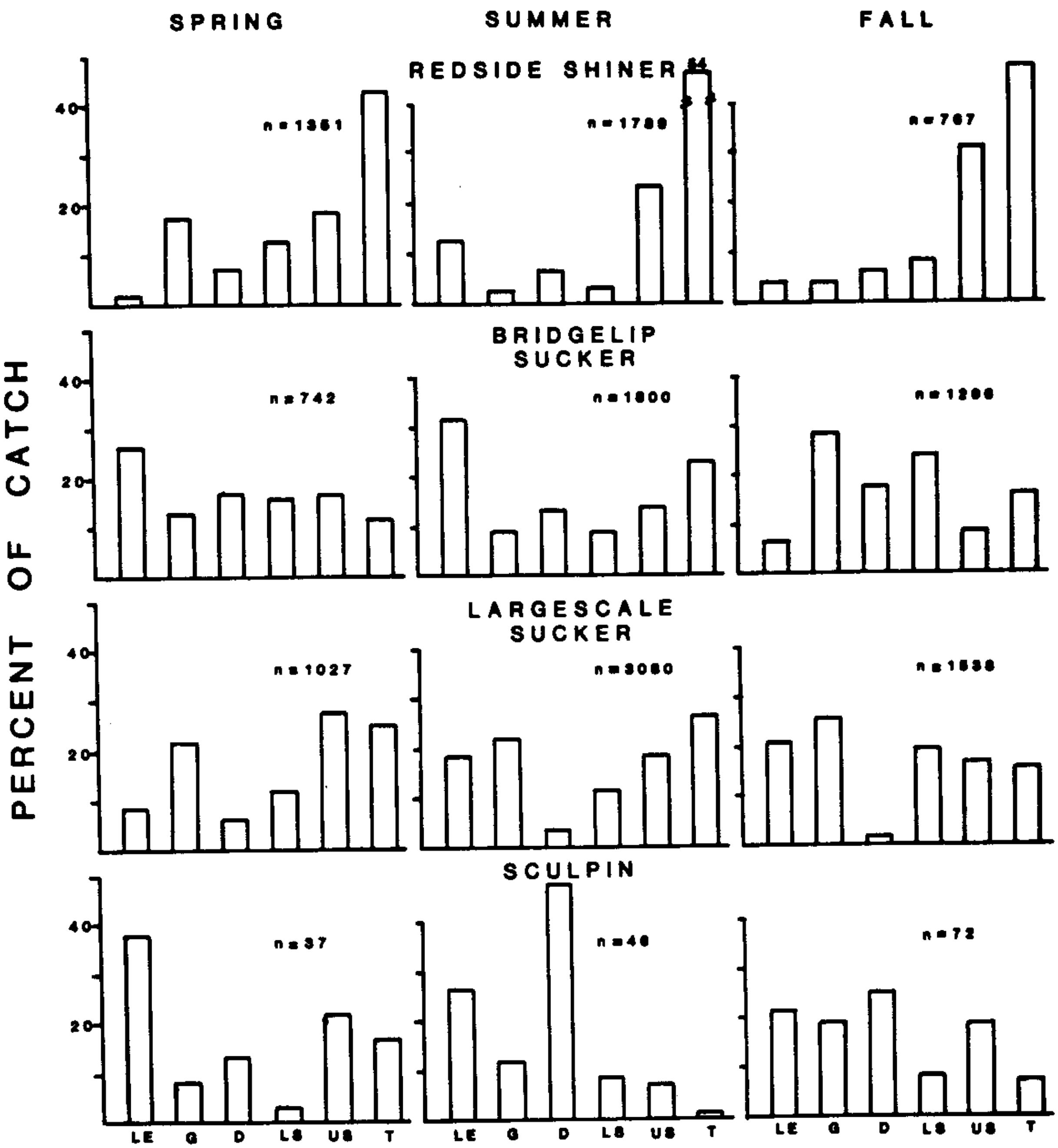

Figure 49. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at major sampling stations for redside shiner, bridgelip sucker, largescale sucker, and sculpin on Little Goose Reservoir, Washington, during 1979 and 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: LE-lower embayment; G-lower gulch; D-deepwater; LS-lower shoal; US-upper shoal; T-tailwater.

was found primarily at the lower embayment and deepwater stations. Chiselmouth and redside shiner were associated with lotic conditions of the tailwater and upper shoal stations.

Channel catfish and northern squawfish displayed seasonal habitat preferences. From our samples, both species were more abundant at the tailwater station during spring but were widely distributed throughout the reservoir during summer and fall. Carp, bridgelip sucker, largescale sucker, smallmouth bass, and sculpin displayed no definite habitat preferences as they were captured throughout the reservoir.

Habitat preferences of fishes in other lower Snake reservoirs were similar to those observed in Little Goose Reservoir (Figs. 50 and 51). Bridgelip sucker and redside shiner were the only species exhibiting noticeable differences in habitat preference. Bridgelip sucker occurred primarily at the deepwater station on Lower Granite Reservoir, whereas, redside shiner were found primarily at the embayment station on Lower Monumental Reservoir.

Fish Species Associations

Pearson product-moment correlations, calculated between sample frequencies of 16 fish species in Little Goose Reservoir, identified 39 significant species associations (Table 23). Most correlations were obtained for species occupying similar habitats. Sample frequencies of white crappie, black crappie, pumpkinseed, bluegill, and brown bullhead were significantly correlated with each other. Correlation coefficients for these embayment species were variable ($r = 0.30$ to 0.92) with white crappie and black crappie exhibiting the strongest association. Yellow perch and bridgelip sucker were significantly correlated with most species occurring in the embayment; however, their abundance was not associated with each other.

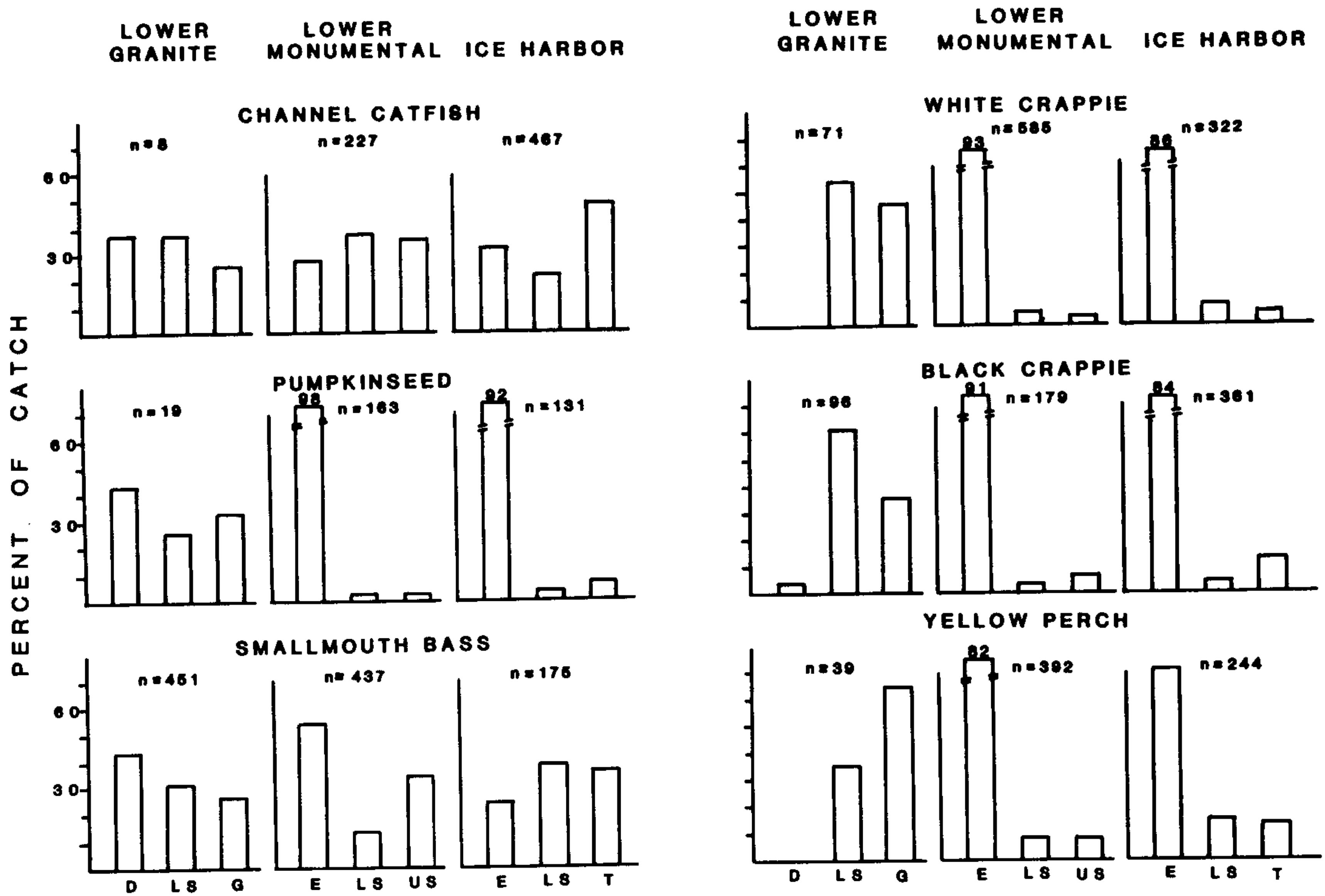

Figure 50. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at stations sampled for channel catfish, pumpkinseed, smallmouth bass, white crappie, black crappie, and yellow perch from Lower Granite, Lower Monumental, and Ice Harbor reservoirs, Washington, during 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: D-deepwater; G-gulch; LS-lower shoal; E-embayment; US-upper shoal; T-tailwater.

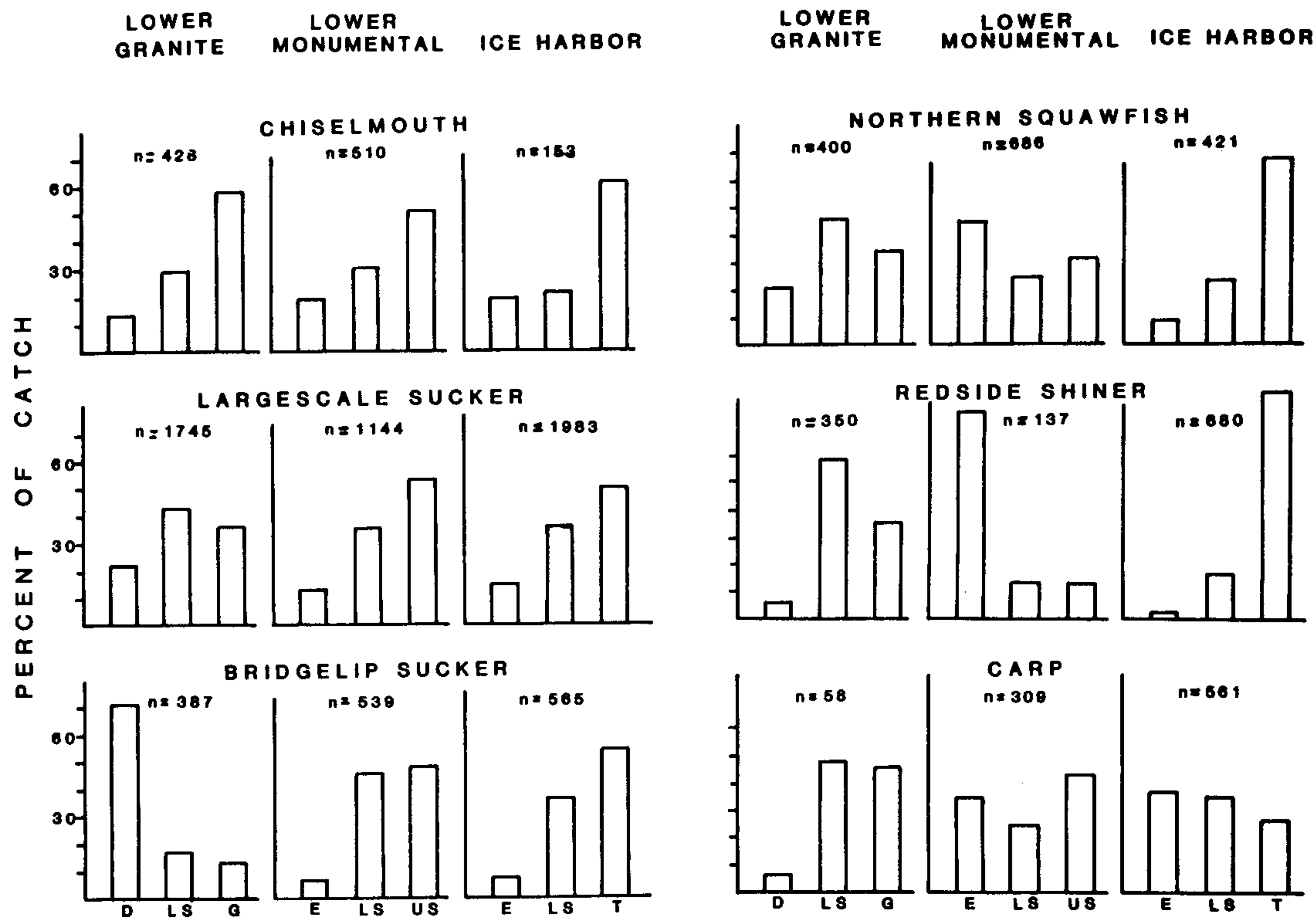

Figure 51. Seasonal habitat preferences (spring-summer-fall) based on percent of catch at stations sampled for chiselmouth, largescale sucker, bridgelip sucker, northern squawfish, redside shiner, and carp from Lower Granite, Lower Monumental, and Ice Harbor reservoirs, Washington, during 1980. Number of fish collected during each season is indicated (n). Station abbreviations are: D-deepwater; G-gulch; LS-lower shoal; E-embayment; US-upper shoal; T-tailwater.

Table 23. Species associations based on Pearson product-moment correlation coefficients ($P < 0.05$) of fishes age I and older from Little Goose Reservoir, Washington, for 1979 and 1980.

	white sturgeon	chiselmouth	carp	northern squawfish	redside shiner	bridgelip sucker	largescale sucker	yellow bullhead	brown bullhead	channel catfish	pumpkinseed	bluefill	smallmouth bass	white crappie	black crappie	yellow perch
white sturgeon	--															
chiselmouth	0.31	--														
carp			--													
northern squawfish		0.49	0.37	--												
redside shiner	0.59	0.61		0.36	--											
bridgelip sucker						--										
largescale sucker	0.49		0.36	0.31	0.39		--									
yellow bullhead								--								
brown bullhead						0.37			--							
channel catfish		0.34			0.36		0.39		0.60	--						
pumpkinseed								0.36	0.56	0.34	--					
bluegill						0.48		0.33	0.91	0.51	0.57	--				
smallmouth bass								0.41					--			
white crappie						0.49			0.87	0.42	0.30	0.89		--		
black crappie						0.48			0.84	0.42	0.44	0.89		0.92	--	
yellow perch									0.31			0.34		0.40	0.34	--

Species preferring lotic conditions of the tailwater and upper shoal stations were generally associated with each other. Correlation coefficients for white sturgeon, chiselmouth, northern squawfish, redside shiner, and largescale sucker were usually lower than those obtained for embayment species ($r = 0.31$ to 0.61). Abundance of channel catfish was associated with chiselmouth, redside shiner, and largescale sucker as well as all of the embayment species (white crappie, black crappie, pumpkinseed, bluegill, and brown bullhead).

Yellow bullhead, carp, and smallmouth bass were associated with few species. Pumpkinseed, bluegill, and smallmouth bass were associated with yellow bullhead. Carp were associated with northern squawfish and largescale sucker.

DISCUSSION

Because of the interrelationship between fish behavior and limnological characteristics in the lower Snake reservoirs, the Discussion section for Subobjective 2 was incorporated into the Discussion section for Subobjective 5.

SUMMARY

1) Intensive sampling on Little Goose Reservoir and seasonal sampling on Lower Granite, Lower Monumental, and Ice Harbor reservoirs from April, 1979 to November, 1980 with electrofishing gear, trap and gill nets, and beach seine provided information on relative abundance, survival, distribution, and movements of resident fishes.

2) Results of these fish collections yielded 31 species and over 52,000 age I and older fish.

3) Annual estimates of relative abundance of age I and older fish indicated that the majority of individuals of introduced species were more abundant in embayment habitats, whereas individuals of native species were more abundant at stations along the main river channel.

4) Smallmouth bass, pumpkinseed, and white crappie were more abundant in up-river reservoirs, whereas channel catfish and carp were more abundant in down-river reservoirs.

5) Habitat preferences of most resident fishes in lower Snake River reservoirs were similar among seasons with each habitat type generally having a characteristic species complement. Correlations between fish abundance and water velocity and morphometric factors were higher than for other habitat characteristics.

6) Annual estimates of survival for smallmouth bass, white crappie, black crappie, bluegill, pumpkinseed, and yellow perch in Little Goose Reservoir ranged between 28 and 62%. Population density and standing crop estimates of white crappie at the lower embayment

station (Deadman Bay) were 200 fish/hectare and 33.8 kg/hectare, respectively.

7) Movement of resident fishes, based on the recapture of tagged fish in Little Goose Reservoir, was extensive for certain species and limited for others. Individuals of bridgelip and largescale suckers, channel catfish, and white and black crappies traveled distances greater than 15 km. Movement of smallmouth bass, largemouth bass, white sturgeon, and brown bullhead was more restricted.

8) Future changes in game fish populations in lower Snake reservoirs will depend largely on the preservation of backwater habitats. These habitats are being degraded by sedimentation resulting in decreased spawning and rearing habitat.

rest of the digestive tract by a pyloric sphincter (i.e. smallmouth bass), or the entire stomach and intestine (i.e. largescale sucker) were exised. Stomachs containing food were preserved in 10% formalin for later analysis, while the number of empty stomachs were recorded. Stomachs of large fish were opened in formalin to accelerate preservation.

Contents of each stomach were examined in the laboratory. A variable power dissecting microscope was used to aid in the enumeration, sorting, and identification of food organisms to the lowest practical taxonomic level using Pennak (1978), Merrit and Cummins (1978), Needham and Needham (1978), Scott and Crossman (1973), and Simpson and Wallace (1980). Following vacuum filtration to remove surface moisture volumetric measurements of sorted stomach contents were determined by water displacement using various sizes of graduated cylinders and micropipettes. Average volumetric displacement of small food items was calculated from the displacement of a pooled sample. Volumes of food items infrequently encountered were estimated by multiplying the number of organisms by the average volume. In addition to enumeration and volumetric displacement, lengths of large food items (i.e. fish and crayfish) were measured (nearest mm).

Stomach contents of catostomids were analysed by subsampling (Borgeson 1963). Contents of individual fish were pooled with other samples collected from the same habitat and season into a volumetrically graduated glass container and the total volume recorded. The entire sample or a subsample was then diluted by a known volume of water until 100 to 300 total food items could be observed in one field of an inverted Wild microscope (280x). Food items were enumerated in five replicate 1 ml samples in which 5 random fields were counted. From these data, mean counts of various food items were calculated. Relative volumes of each food item were determined visually by comparing the relative size of a particular food item with the size of a prevalent diatom on the random fields. To eliminate variability which can arise in comparing relative sizes among different workers, a single analyst estimated the relative volumes.

The percent frequency of occurrence (F) and percent composition by number (N) and volume (V) of various food items were used to calculate an Index of Relative Importance (IRI) for each food item, where: IRI = (N+V)*F (Prince et al. 1978; Pinkas et al. 1971). Index values of specific (i.e. Chironomidae pupae), and major categories (i.e. aquatic insects) of food items were used to determine the overall and seasonal importance of various dietary components and qualitatively compare diets from one habitat to another. Only stomachs containing food were considered in calculating frequency of occurrence and stomach contents of catostomids were assigned a frequency of occurrence of one. Unidentifiable organic matter and debris, such as sand and gravel, were noted during stomach examination but were not used in the calculation of IRI values.

Diel Feeding

Channel catfish and white crappie were collected during June, July, and August, 1980, from the lower embayment station in Little Goose Reservoir (Fig. 2) to determine diel food habits. Using trapnets and gillnets, fish were sampled throughout a 48 hour period at 6 hour intervals beginning at 0600. Stomachs were collected and preserved as described earlier.

Index of relative importance values of specific and general categories of food items were calculated for each diel feeding period to determine changes in dietary composition during a 24 hour period. Mean total volumes of stomach contents for each diel period were compared statistically using the nonparametric two-way analysis of variance analog, the Friedmans test, to determine significant changes in feeding intensity with time.

Resident Fish Predation on Salmonid Smolts

Smallmouth bass, channel catfish, and northern squawfish were collected during April and May, 1980 on Little Goose Reservoir to determine the incidence of predation on juvenile chinook salmon and steelhead trout. Sampling (with trapnets, gillnets, and electrofishing gear) was concentrated primarily in the tailwater and upper shoal area below Lower Granite Dam (Fig. 2).

Collected fish and their stomachs were processed as described earlier. Smolts found in the stomach contents were identified, enumerated, and measured. The average number of smolts per stomach and incidence of predation based on the frequency of occurrence of smolts in the diet were calculated and compared among predators, sampling stations, and time periods.

Age and Growth

Linear Growth

Age and growth determinations were made on smallmouth bass, black crappie, white crappie, redside shiner, northern squawfish, largemouth bass, bluegill, pumpkinseed, yellow perch, white sturgeon, and brown bullhead collected from April to November, 1979 and 1980. Scales or spines were taken from fish collected at monthly intervals from Little Goose Reservoir and seasonally for comparative purposes from Lower

Granite, Lower Monumental, and Ice Harbor reservoirs. Fish used to satisfy other subobjectives (2 and 4) also were used for age and growth studies.

Scales, rays, or spines were consistently removed from the same location on the fish. Cycloid scales (northern squawfish and redside shiner) were removed from the left side between the lateral line and the anterior edge of the dorsal fin, whereas, ctenoid scales (centrarchids and yellow perch) were removed at the posterior extension of the pectoral fin below the lateral line (Lagler 1956). The left pectoral spine was removed from channel catfish and brown bullheads by laying the spine flat and parallel against the body in an unlocked position and rotating the spine with a pair of pliers in a clockwise direction until it became dislocated from the socket. For white sturgeon, a small section of the first fin ray, just above the articulation of the left pectoral fin, was removed with "horse-hoof" nippers (Coon 1978). All age structures were stored in coin envelopes, labeled with species, length (mm), and weight (g) of fish and location and date of capture.

Structures used for age and growth analyses were prepared in the laboratory. Regenerated or damaged age structures were discarded. Scales were washed to remove dried mucous and dirt and 6 to 10 scales per fish were used to make impressions on cellulose acetate slides using a heated hydraulic press (Greenbank and O'Donnel 1950; Campbell and Witt 1953). Ictalurid spines and sturgeon fin rays were secured at the distal end in a portable desk vise, and cross sections (approximately 0.5 mm) were cut with a jeweler's handsaw. Both sides of the section were polished with 400 grit wet-dry sandpaper, and then sections were mounted on glass slides with permamount. Cross sections were consistently cut immediately above the apex of the basal groove (Marzolf 1955).

Scales were magnified (81x) and examined on a scale projector. Following aging, a representative scale (based on size and shape) on each acetate slide was measured (mm) from the focus to the anterior scale margin and to each annulus along the vertical posterior-anterior axis of cycloid scales and along an imaginary line from the focus to the farthest scallop on the anterior margin of ctenoid scales. Scales were interpreted twice, each analysis independent of the previous, and a third time when disagreement occurred between the first and second interpretations.

Channel catfish spines were magnified using a microprojector and aged by counting the annular rings on a section. Measurements (mm) for growth and spine body length relationships were made from the lumen to each annulus along an imaginary line going from the lumen to the farthest most margin of the longest lobe of the section.

Brown bullhead spines and white sturgeon fin rays were viewed and aged under reflected light using a variable power binocular dissecting microscope. No growth measurements were made on spines or rays from these species.

Back-calculated lengths at each year of age were calculated from a model (log transformation of body and scale length or first to third degree polynomial) of the body-scale (body-spine) relationship which accounted for the most variation (highest r^2 value). Average lengths for each year of age by year class and increments of growth were calculated. These back-calculated lengths at each annulus were used to compute the von Bertalanffy and second degree polynomial growth models from which the length of the fish could be computed for any time (years) in the life of that fish. The von Bertalanffy growth model was:

$$l_t = l_\infty\,(1-e^{-k(t-t_0)})$$

where:

l_t = total length (mm) at time t (years)
l_∞ = ultimate length (mm) for the population
k = growth coefficient
t_0 = time when length would theoretically be 0.

The second degree polynomial growth model was computed using the equation:

$$l_t = a+b_1(\text{age})+b_2(\text{age}^2)$$

where: l_t is the length at time t; age is the age at time t, and a, b_1, and b_2 are constants derived from the regression analysis. Also, instantaneous growth models were developed for young-of-year fish captured by seining (subobjective 4) using the equation:

$$l_t = l_0(e^{g(t)})$$

where:

l_t = length at time t
l_0 = length at time 0
e = base natural logs
g = instantaneous growth coefficient

Allometric Growth

Length-weight relationships were calculated for selected species from the equation:

$$W = aL^b$$

Where: a and b are constants derived from regressing log of weight (W) against the log of total length (L).

Condition factors (k) were calculated for selected fishes using the equation:

$$k = W/L^3 \times 10^5$$

Where: W is the wet weight (g) and L is the total length (mm). Condition factors were calculated for males and females for various seasons and habitats by 25 mm length intervals. Body condition (k) was compared statistically between sexes, seasons, and habitats using the nonparametric two-way analysis of variance analog, the Friedman's test ($P<0.05$).

RESULTS

Food Habits

General Food Habits

Smallmouth Bass

A total of 484 smallmouth bass stomachs were collected from Little Goose Reservoir during 1979 and 1980 (Table 24). Bass examined for stomach contents range in size from 57 to 470 mm. Smaller bass ($\bar{x}$ = 173 mm) were collected from the deepwater area while, on the average, the largest bass ($\bar{x}$ = 254 mm) were found at the gulch area. Ninety-six (19.8%) of the 484 stomachs examined were empty and 388 (80.1%) contained food. The percentage of empty stomachs decreased from 23.1 in the spring to 17.6 and 9.5 in the summer and fall, respectively.

Crayfish, fish, and terrestrial and aquatic insects were the more important food items of smallmouth bass in Little Goose Reservoir (Fig. 52). Other food items of lesser importance were gammarids (*Gammarus* sp. and *Corophium* sp.); calonoid copepods (*Epichurus* sp.); cladocerans (*Daphnia* sp. and *Leptodora kindti*); and, Isopods. Miscellaneous debris, including wood, stones, and unidentified organic matter, also were present (0.5% of total volume).

Crayfish (*Pacifastucus leniusculus*) was the most important food item of smallmouth bass in Little Goose Reservoir (Figs. 53-56, and

Table 24. Characteristics of smallmouth bass examined for stomach analyses from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	Habitat	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
SPRING	Tailwater	81	2	2.5	253	187-352	221
	Shoal	59	18	30.5	247	132-442	255
	Gulch	30	11	36.7	254	57-467	361
	Deepwater	55	21	38.2	222	150-313	135
Total		225	52	23.1	244	57-467	228
SUMMER	Tailwater	62	16	25.8	228	112-350	171
	Shoal	47	2	4.3	220	112-430	188
	Embayment	74	16	21.6	189	88-421	115
	Gulch	19	5	26.3	218	103-470	254
	Deepwater	36	3	8.3	173	101-260	80
Total		238	42	17.6	205	88-470	150
FALL	Deepwater	21	2	9.5	173	112-226	78
GRAND TOTAL		484	96	19.8	222	57-470	183

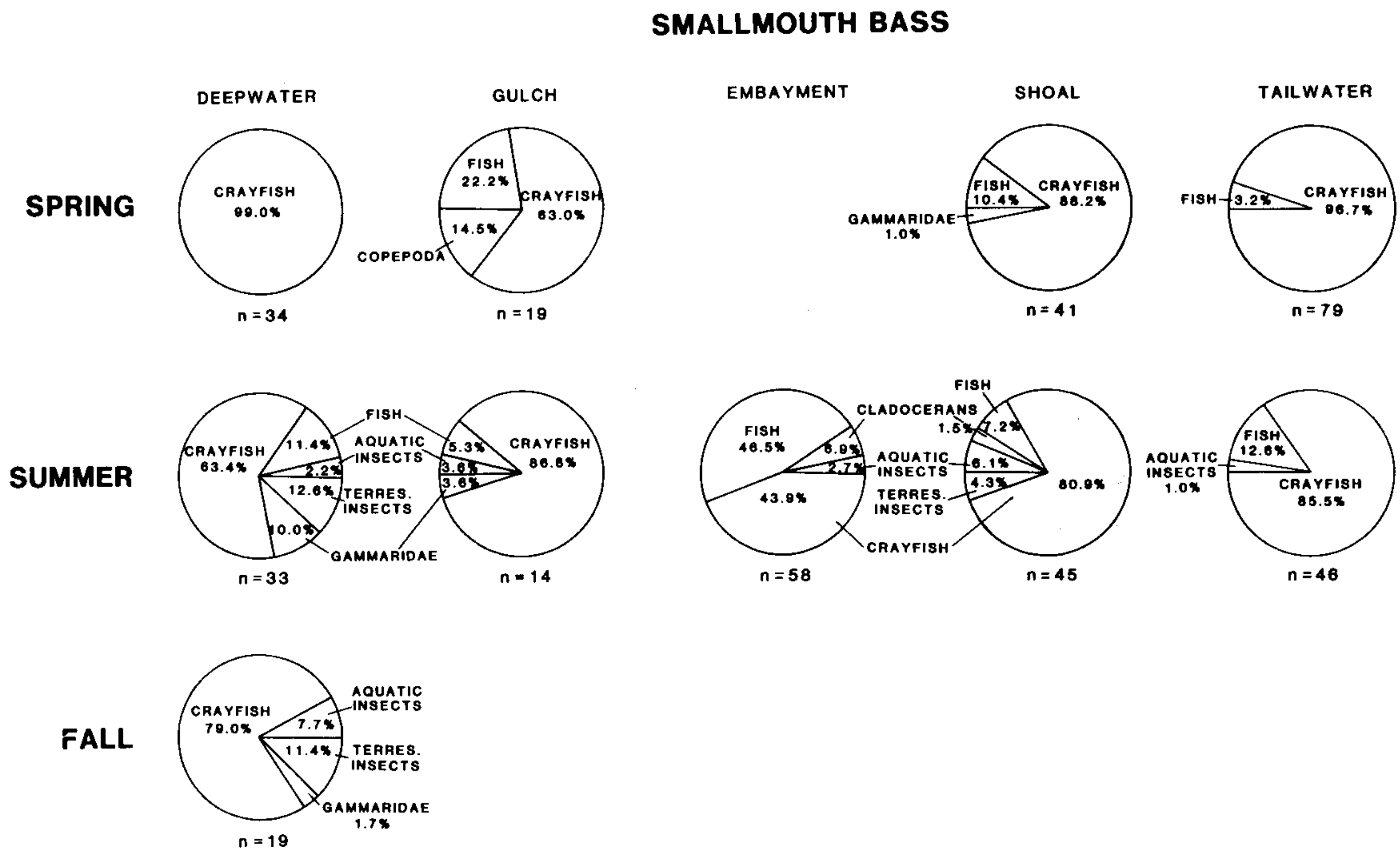

Figure 52. Percent of the index of relative importance (IRI) of major food items of smallmouth bass collected (spring-fall, 1979 and 1980) from Little Goose Reservoir (deepwater, gulch, embayment, shoal, and tailwater areas), Washington. Food items contributing less than 1% of the total IRI are not shown.

SPECIES - SMALLMOUTH BASS

HABITAT - TAILWATER

RANK	TOTAL IRI	FOOD ITEM	SEASONAL RELATIVE IMPORTANCE SPR — SUM
1	20871	CRAYFISH	
2	246	UNIDENT. FISH	
3	85	CHIRONOMID PUPAE	
4	78	SCULPIN	
5	45	REDSIDE SHINER	
6	36	TERRES. DIPTERA	
7	22	NO. SQUAWFISH	
8	19	BRIDGELIP SUCKER	

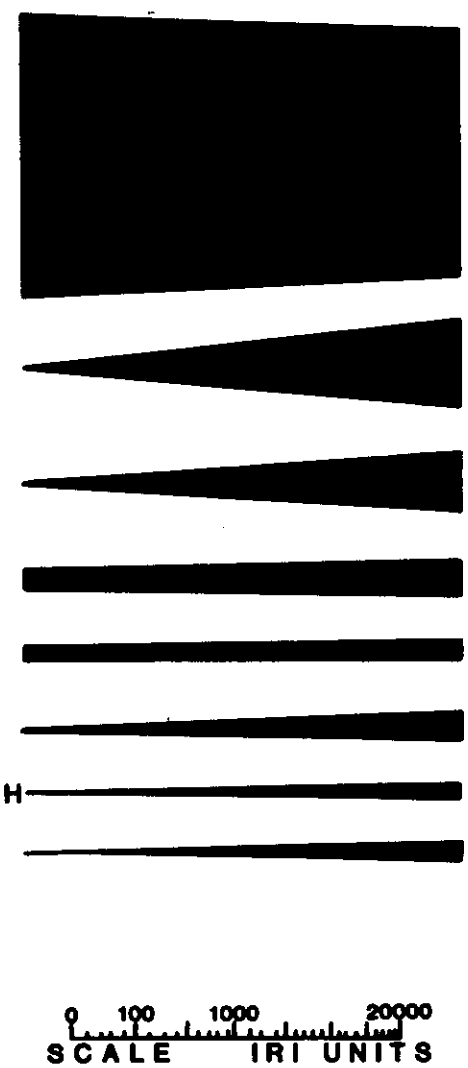

Figure 53. Index of relative importance (IRI) of food items of smallmouth bass collected (spring and summer, 1979 and 1980) from the tailwater habitat in Little Goose Reservoir, Washington.

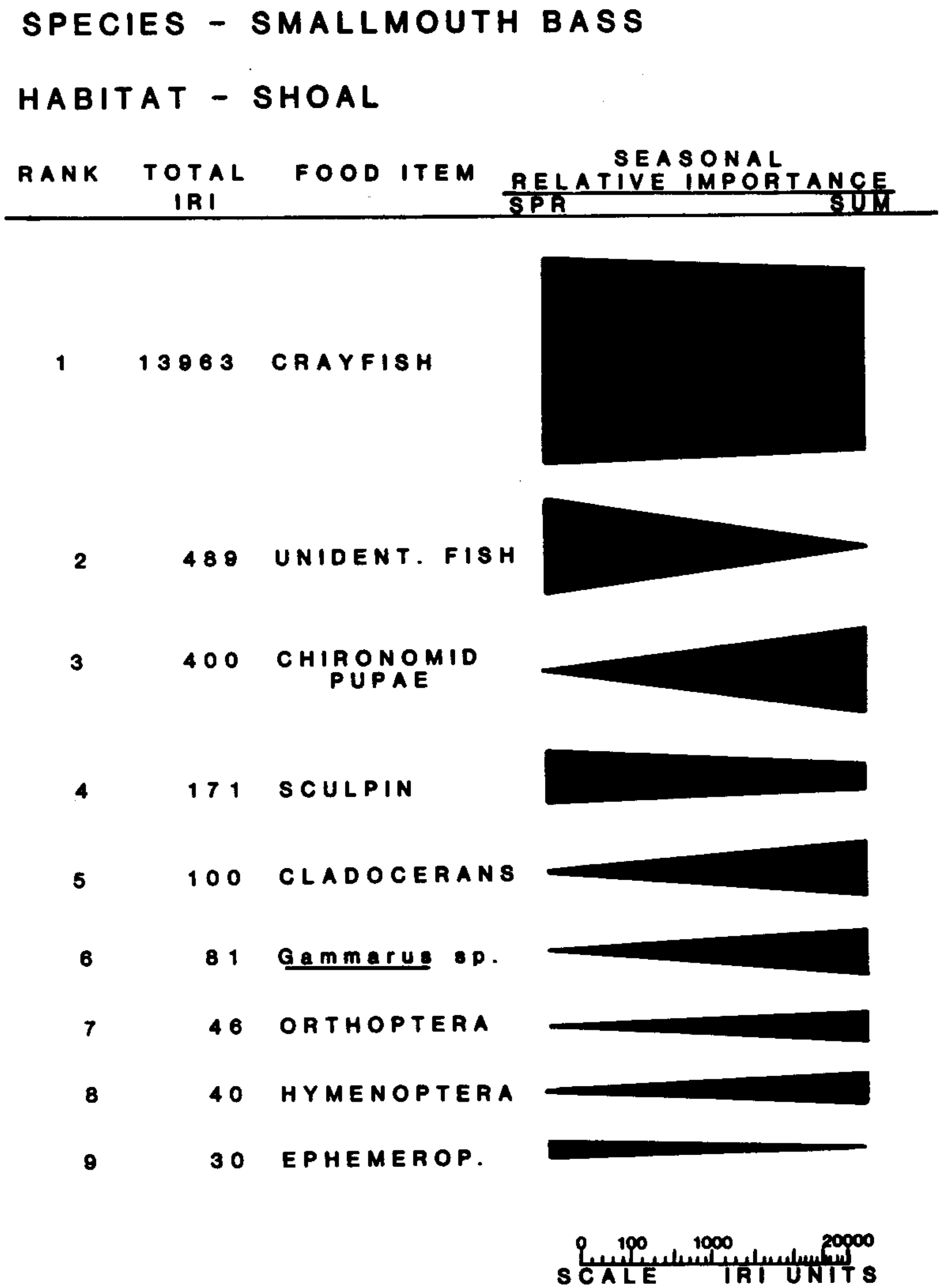

Figure 54. Index of relative importance (IRI) of food items of smallmouth bass collected (spring and summer, 1979 and 1980) from the shoal habitat in Little Goose Reservoir, Washington.

SPECIES - SMALLMOUTH BASS

HABITAT - GULCH

RANK	TOTAL IRI	FOOD ITEM	SEASONAL RELATIVE IMPORTANCE (SPR — SUM)
1	9065	CRAYFISH	
2	796	COPEPODA	
3	620	YELLOW PERCH	
4.5	324	SCULPIN	
4.5	324	CHINOOK SALMON	
6	235	*Gammarus* sp.	
7	222	CHIRONOMID PUPAE	
8	47	ORTHOPTERA	

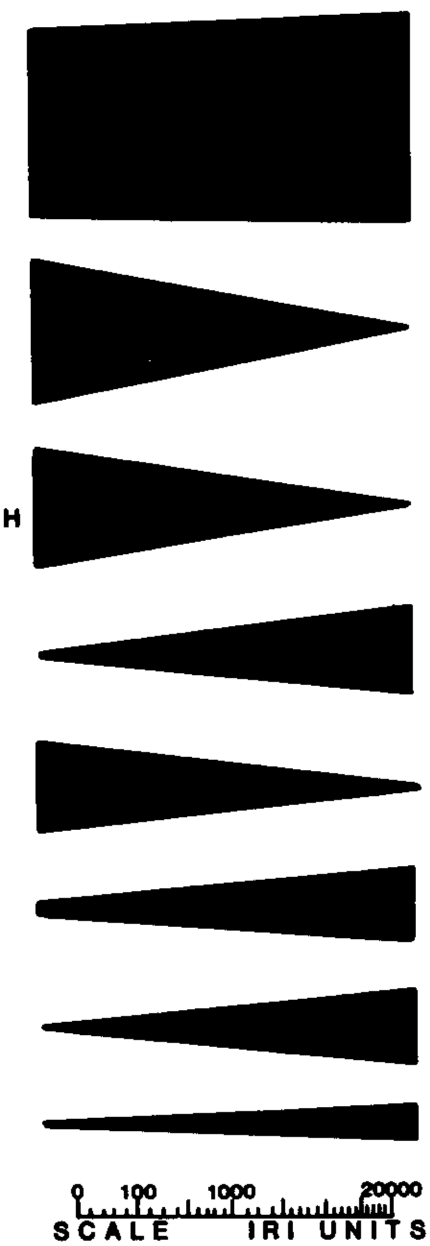

Figure 55. Index of relative importance (IRI) of food items of smallmouth bass collected (spring and summer, 1979 and 1980) from the gulch habitat in Little Goose Reservoir, Washington.

SPECIES - SMALLMOUTH BASS

HABITAT - DEEPWATER

RANK	TOTAL IRI	FOOD ITEM
1	26296	CRAYFISH
2	787	CHIRONOMID PUPAE
3	732	HYMENOPTERA
4	433	*Gammarus* sp.
5	419	ORTHOPTERA
6	378	SCULPIN
7	207	TERRES. COLEOPTERA
8	115	*Corophium* sp.
9	65	NO. SQUAWFISH
10	60	UNIDENT. FISH
11	28	ISOPODA

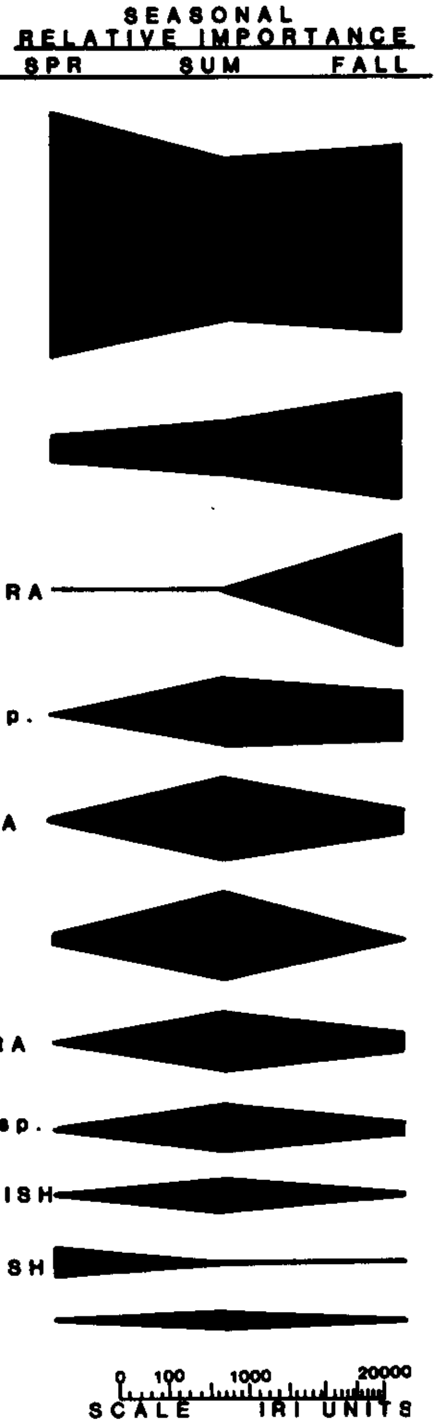

Figure 56. Index of relative importance (IRI) of food items of smallmouth bass collected (spring, summer, and fall, 1979 and 1980) from the deepwater habitat in Little Goose Reservoir, Washington.

Table 25). Crayfish accounted for 28% of the total number and 72% of total volume of food and occurred in 64% of the smallmouth bass stomachs.

Fish were the second most abundant food item consumed by smallmouth bass. Fish accounted for 7.8% of the total number, 25.4% of the total volume, and were found in 32% of the stomachs containing food. Unidentified fish accounted for 44% of the total number and 25.5% of the total volume of fish consumed. Of the identifiable fish, sculpin accounted for 53.2% of the total number and 49.5% of the total volume of the diet and were found in 20% of the stomachs containing food. Other fish eaten, in order of declining numerical abundance, were: white crappie; redside shiner; northern squawfish; catfish (Ictaluridae); bluegill; yellow perch; chinook salmon; bridgelip sucker; and, pumpkinseed. Collectively, these fishes represented 46.8% of the total number and 50.5% of the total volume of identifiable fish and were found in 6% of bass stomachs which contained food.

Fish eaten by smallmouth bass had a mean length of 53.5 mm (Table 26) and ranged in size from 13 to 140 mm. Largest fishes consumed were chinook salmon, bridgelip sucker, and northern squawfish.

Terrestial insects were of minor importance in the diet of smallmouth bass. Terrestial insects accounted for 14.3% of the total number, 1.8% of the total volume, and were found in 7% of the stomachs which contained food. Hymenoptera (ants), Orthoptera (grasshoppers), Coleoptera (beetles), and Diptera (flies) were the most abundant orders of terrestial insects represented in the diet of smallmouth bass.

Aquatic insects, also found in the diet of smallmouth bass from Little Goose Reservoir, were of minor importance. Overall, aquatic insects accounted for 20% of the total number, 0.3% of the total volume,

Table 25. Index of relative importance (IRI) of food items for smallmouth bass collected from the lower embayment during the summer in Little Goose Reservoir, Washington, during 1979 and 1980.

RANK	IRI	FOOD ITEM
1	2233	Crayfish
2	350	Cladocerans
3	323	Sculpin
4	130	Unidentified fish
5	74	white crappie
6	24	Chironomidae larvae
7	21	Chironomidae pupae
8	11	Bluegill
9	8	Ictaluridae
10	5	Redside shiner
11	4	Orthoptera

Table 26. Length (mm) of fish consumed by smallmouth bass in Little Goose Reservoir, Washington, 1979 and 1980.

		Length	
	No.	$\bar{X}$	Range
chinook salmon	2	94.5	94-95
northern squawfish	5	87.2	62-140
redside shiner	9	65.9	60-87
largescale sucker	1	47.0	-
bridgelip sucker	3	91.6	80-110
pumpkinseed	1	38.0	-
bluegill	3	33.5	25-48
white crappie	13	40.6	34-53
smallmouth bass	2	61.0	54-68
yellow perch	2	69.0	55-83
sculpin	27	64.2	45-90
unidentified fish	27	37.3	13-140
all fishes	95	53.5	13-140

and were found in 6.4% of the stomachs containing food. Chironomidae pupae and larvae and Ephemeroptera (mayfly) and Odonata (dragonfly) nymphs were the most important taxa of aquatic insects found in the diet of smallmouth bass. Except for chironomidae pupae, which was the most important taxa consumed, other invertebrates comprised a small portion of the diet of smallmouth bass.

Other invertebrates comprised a small portion of the diet of smallmouth bass. Gammarids, cladocerans, calonoid copepods, and isopods accounted for 28.6% of the total number, 0.2% of the total volume, and were found in 7.5% of the stomachs containing food.

Few seasonal and habitat differences were found in the diet of smallmouth bass from Little Goose Reservoir. Crayfish was generally the most important dietary item followed by fish (spring and summer) in all habitats sampled. Fish were the most abundant food item in smallmouth bass from the embayment station. No consistent seasonal and habitat trends existed in the abundance of lesser important food items in smallmouth bass.

Crayfish was the most important dietary item of smallmouth bass from Lower Granite and Lower Monumental during the summer. Crayfish was followed in importance by fish in Lower Granite and Lower Monumental reservoirs. In Ice Harbor Reservoir, however, fish was the most important food item of 31 smallmouth bass followed in importance by crayfish. Major and specific food items consumed by smallmouth bass at Lower Granite, Lower Monumental, and Ice Harbor reservoirs were similar to those found in the diet of bass from Little Goose Reservoir (Fig. 57).

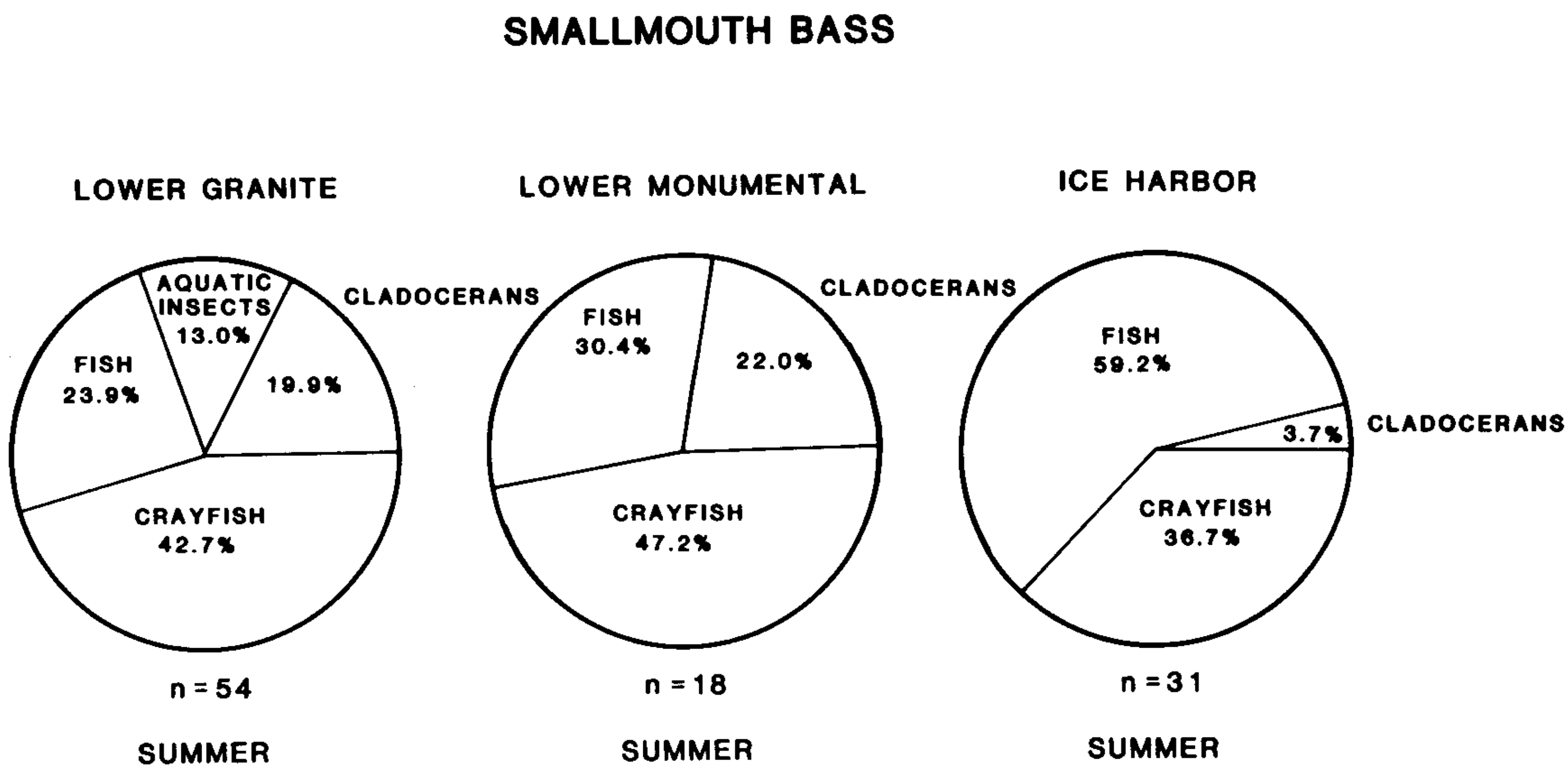

Figure 57. Percent of the index of relative importance (IRI) of major food items of smallmouth bass collected (summer, 1979 and 1980) from Lower Granite, Lower Monumental, and Ice Harbor reservoirs, Idaho - Washington. Food items contributing less than 1% of the total are not shown.

White Crappie

A total of 394 white crappie stomachs were collected from Little Goose Reservoir, during 1979 and 1980 (Table 27). Sixty-three (16%) of the stomachs were empty while 331 (84%) contained food. Crappies sampled had a mean length of 216 mm and ranged in size from 110 to 334 mm. The percentage of empty stomachs decreased from 24% in the spring to 11% in the summer and then increased to 38% in the fall.

Cladocerans, fish and aquatic insects were the most important food items in the diet of white crappie in Little Goose Reservoir (Figs. 58 and 59). Other food items of lesser importance were gammarids and calonoid copepods.

Cladocerans (Daphnia schodleri, D. galeata, and Leptodora kindti) were the single most important food item of white crappie (Fig. 60). Cladocerans represented 98.1% of the total number and 43.2% of the total volume of food items and were found in 82.8% of white crappie stomachs. Daphnia sp. and Leptodora kindti accounted for 87.7 and 12.3% of the total number of cladocerans, respectively.

Fish were the second most important dietary component in the diet of white crappie. Fish represented 0.2% of the total number and 46.2% of the total volume of food items and occurred in 13.3% of the stomachs which contained food. Fish consumed by crappies had a mean length of 40 mm and ranged in size from 10 to 67 mm. Unidentified fish accounted for 78.2% of the total number and 52.9% of the total volume of fish eaten. Of the identifiable fish in white crappie stomachs, individuals of the family Catostomidae were the most abundant species, accounting for 13% of the total number and 33.1% of the total volume of all fish consumed. Other fishes found in the stomachs of white crappie, in order of numerical abundance, were Centrarchidae, bluegill, and black crappie.

Table 27. Characteristics of white crappies examined for stomach analyses from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	Habitat	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
SPRING	Shoal	24	1	4.2	236	188-285	173
	Embayment	61	19	31.1	205	110-303	127
Total		85	20	23.5	214	110-303	140
SUMMER	Gulch	48	13	27.1	226	160-297	147
	Embayment	224	16	7.1	213	110-334	141
Total		272	29	10.7	215	110-334	142
FALL	Embayment	37	14	37.8	233	195-263	178
Total		37	14	37.8	233	195-263	178
GRAND TOTAL		394	63	16.0	216	110-334	145

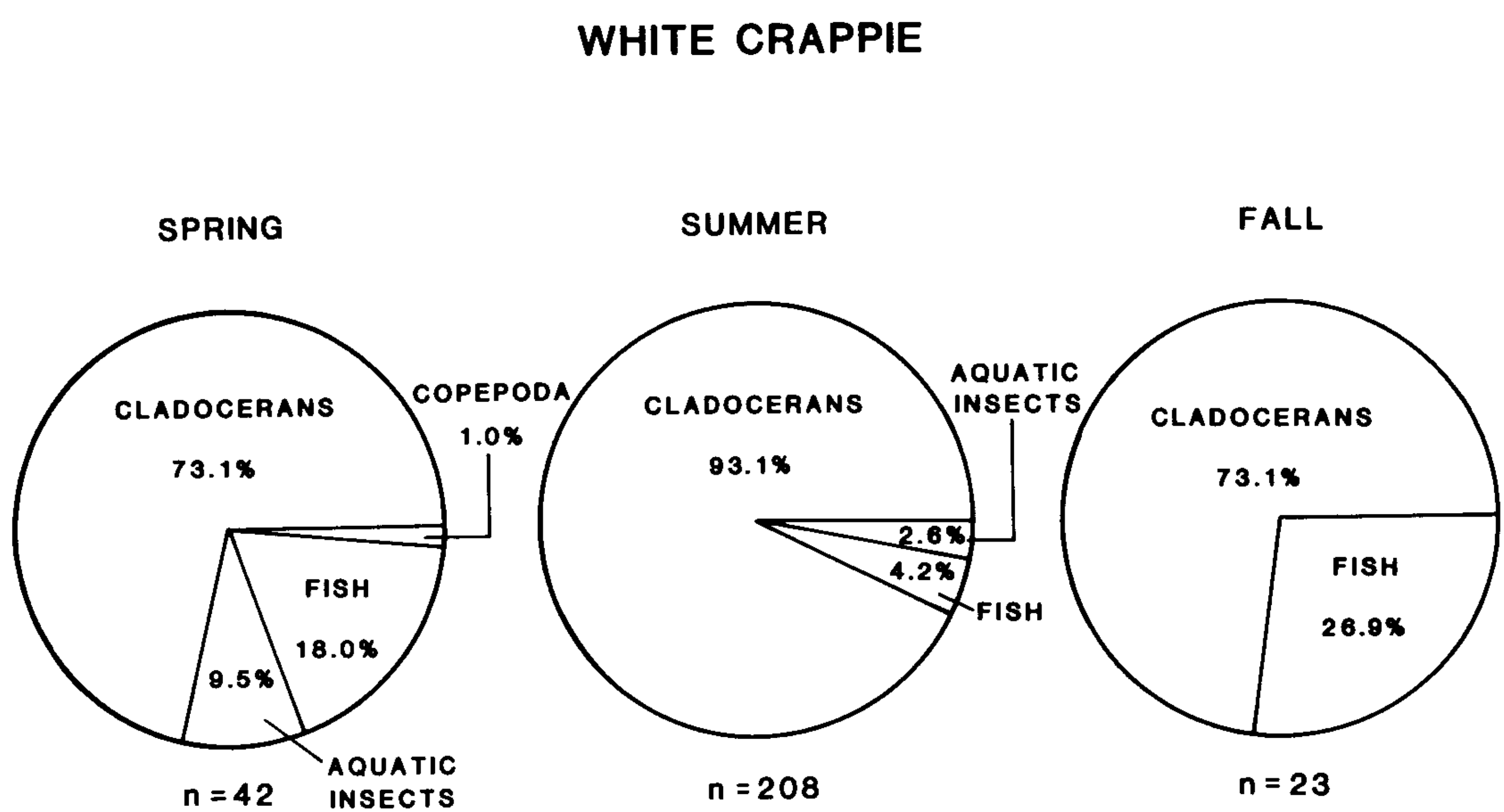

Figure 58. Percent of the index of relative importance (IRI) of major food items of white crappie collected (spring, summer, and fall, 1979 and 1980) from the lower embayment in Little Goose Reservoir. Food items contributing less than 1% of the total IRI are not shown.

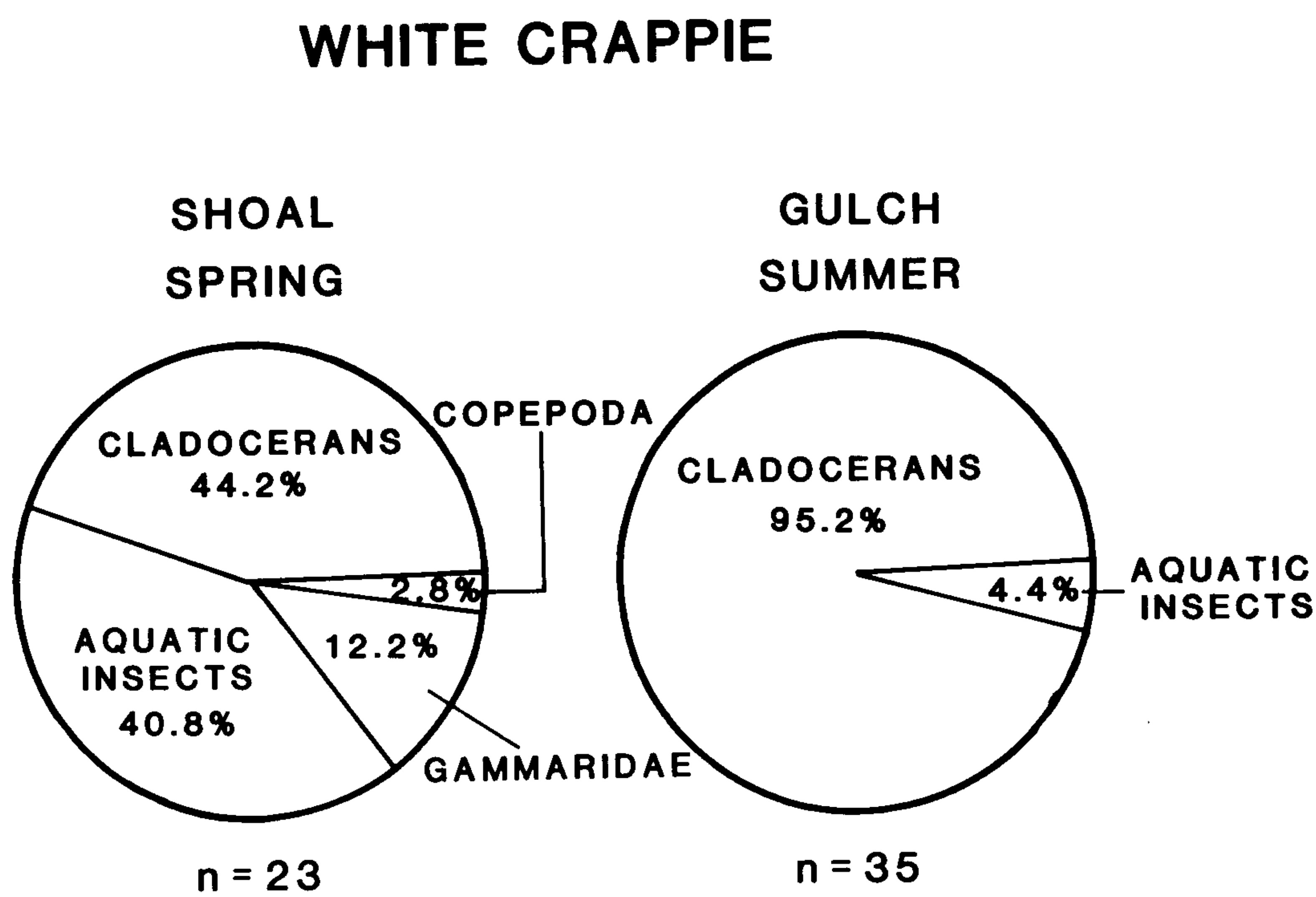

Figure 59. Percent of the index of relative importance (IRI) of major food items of white crappie collected (spring and summer, 1979 and 1980) from shoal and gulch habitats in Little Goose Reservoir, Washington. Food items contributing less than 1% of the total IRI are not shown.

Ephemeroptera and Odonata nymphs only were found in stomachs of fish collected from the embayment station during the spring and Hemiptera only occurred in stomachs during spring and summer.

Stomach contents of 83 white crappie from Lower Granite, Ice Harbor, and Lower Monumental reservoirs were similar to those from white crappie from Little Goose Reservoir. Cladocerans, fish and aquatic insects were the most important food items (Fig. 61).

Black Crappie

A total of 118 black crappie stomachs were examined from Little Goose Reservoir during 1979 and 1980 (Table 28). These fish had a mean length of 208 mm and ranged in size from 92 to 384 mm. Fifty-two (44.1%) of these stomachs were empty and 66 (55.9%) contained food. The percentage of empty stomachs decreased from 73.9% in the spring to 14.3% in the summer and increased to 47.8% in the fall, respectively.

Cladocerans, aquatic insects, and fish were the most important food items in the diet of black crappie in Little Goose Reservoir (Fig. 62). Also, calonoid copepods and gammarids were found in the stomach contents but were of minor importance.

Cladocerans (D. schodleri, D. galeata, and Leptodora kindti) were generally the most important food item of black crappie (Fig. 62). Overall, cladocerans represented 97.6% of the total number and 65.8% of the total volume of food items and occurred in 68.2% of the stomachs. Daphnia sp. and Leptodora kindti accounted for 88.5 and 11.5% of the total number of cladocerans, respectively.

Aquatic insects were the second most important food item of black crappie. Aquatic insects represented 1.6% of the total number and 16.1% of the total volume of food items and were found in 43.9% of the stomachs.

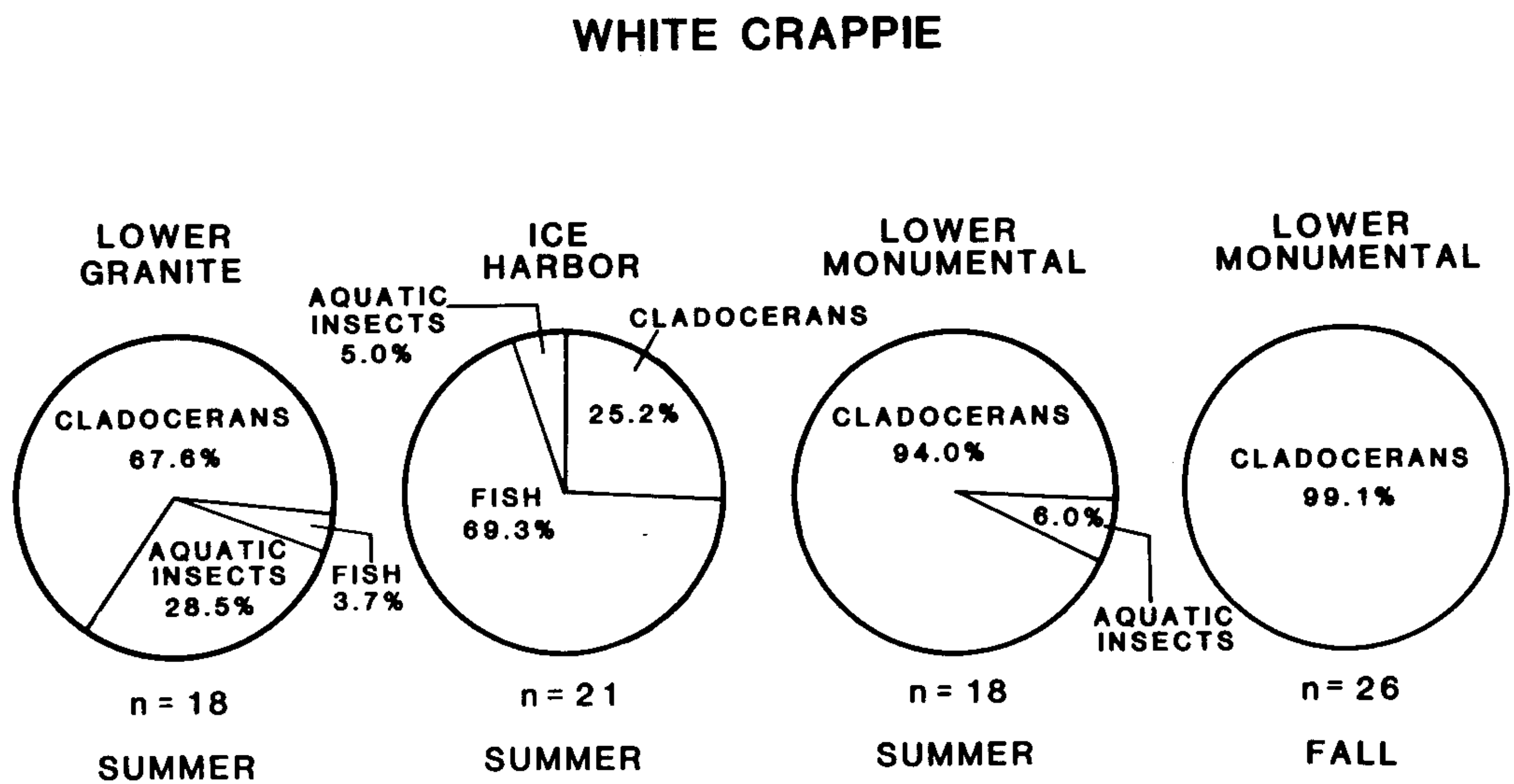

Figure 61. Percent of the index of relative importance (IRI) of major food items of white crappie collected (summer and fall, 1979 and 1980) from Lower Granite, Ice Harbor, and Lower Monumental reservoirs, Washington - Idaho. Food items contributing less than 1% of the total IRI are not shown.

SPECIES - WHITE CRAPPIE

HABITAT - EMBAYMENT

RANK	TOTAL IRI	FOOD ITEM
1	26878	CLADOCERANS
2	3910	UNIDENT. FISH
3	374	CHIRONOMID PUPAE
4	117	CATOSTOMIDAE
5	105	CHIRONOMID LARVAE
6	75	COPEPODA
7	27	UNIDENT. CENTRARCHIDAE
8	20	EPHEMEROP.
9	11	HYMENOPTERA

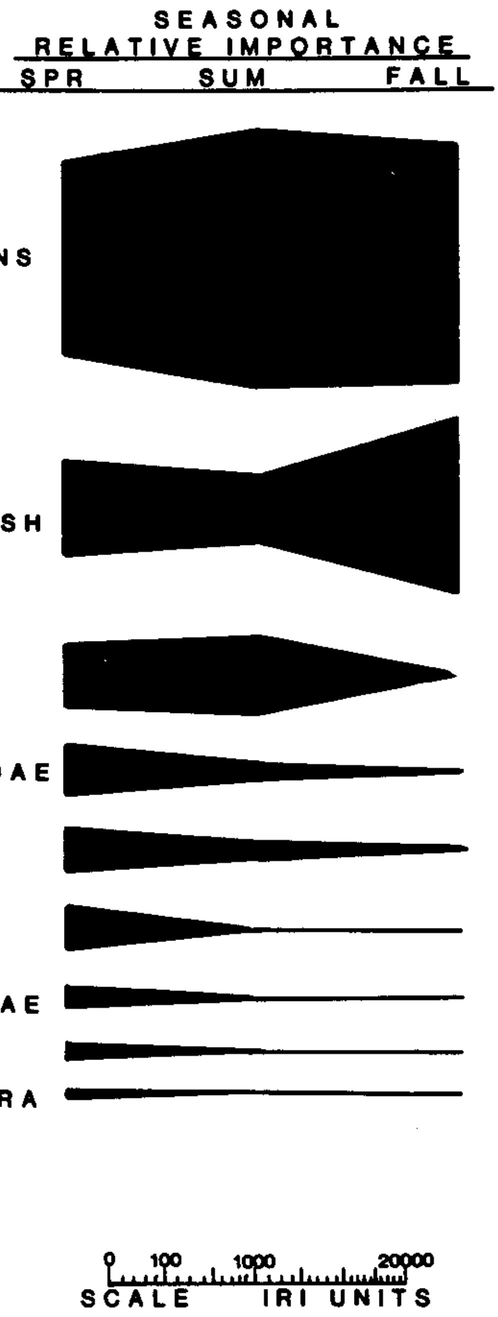

Figure 60. Index of relative importance (IRI) of food items of white crappie collected spring-fall, 1979 and 1980, from the lower embayment in Little Goose Reservoir, Washington.

Aquatic insects were the third most important food item in the diet of white crappie. Aquatic insects represented 1% of the total number and 6.5% of the total volume. Aquatic insects were found in 63.1% of the stomachs which contained food. In order of numerical abundance, chironomidae (pupae and larvae), Ephemeroptera, Odonata, Hemiptera, and Odonata were the more important taxa of aquatic insects in the diet of white crappie. Chironomidae pupae and larvae accounted for 70.5% and 27.4% of the total number and 70 and 22% of the total volume of aquatic insects found in the diet, respectively. Unidentified aquatic insects represented 0.3% of the total number and 4.4% of the total volume of aquatic insects in the stomach contents. Other dietary items found in white crappie stomachs were gammarids and calonid copepods. However, these were generally of lesser importance relative to the cladocerans, fish, and aquatic insects.

Dietary items of white crappie varied among seasons and habitats. Cladocerans were relatively more important in the diet during the summer and of lesser importance in spring and fall. Also, cladocera were relatively more important in the diet of white crappie from the gulch station in the summer than in the embayment and shoal areas and of least importance to crappies from the shoal area during spring. Fish were relatively more important in the diet of white crappie during the fall, followed by the spring. Aquatic insects were highest in relative importance in the diet of fish in the shoal habitat during the spring and least important in the embayment area in the fall when no aquatic insects were found in the diet. Aquatic insect pupae increased in relative importance from spring to summer and then decreased in the fall, whereas larvae steadily decreased in relative importance from spring to fall.

Table 28. Characteristics of black crappies examined for stomach analyses from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
Spring	46	34	73.9	216	196-246	153
Summer	49	7	14.3	199	92-384	139
Fall	23	11	47.8	213	174-256	180
Total	118	52	44.1	208	92-384	152

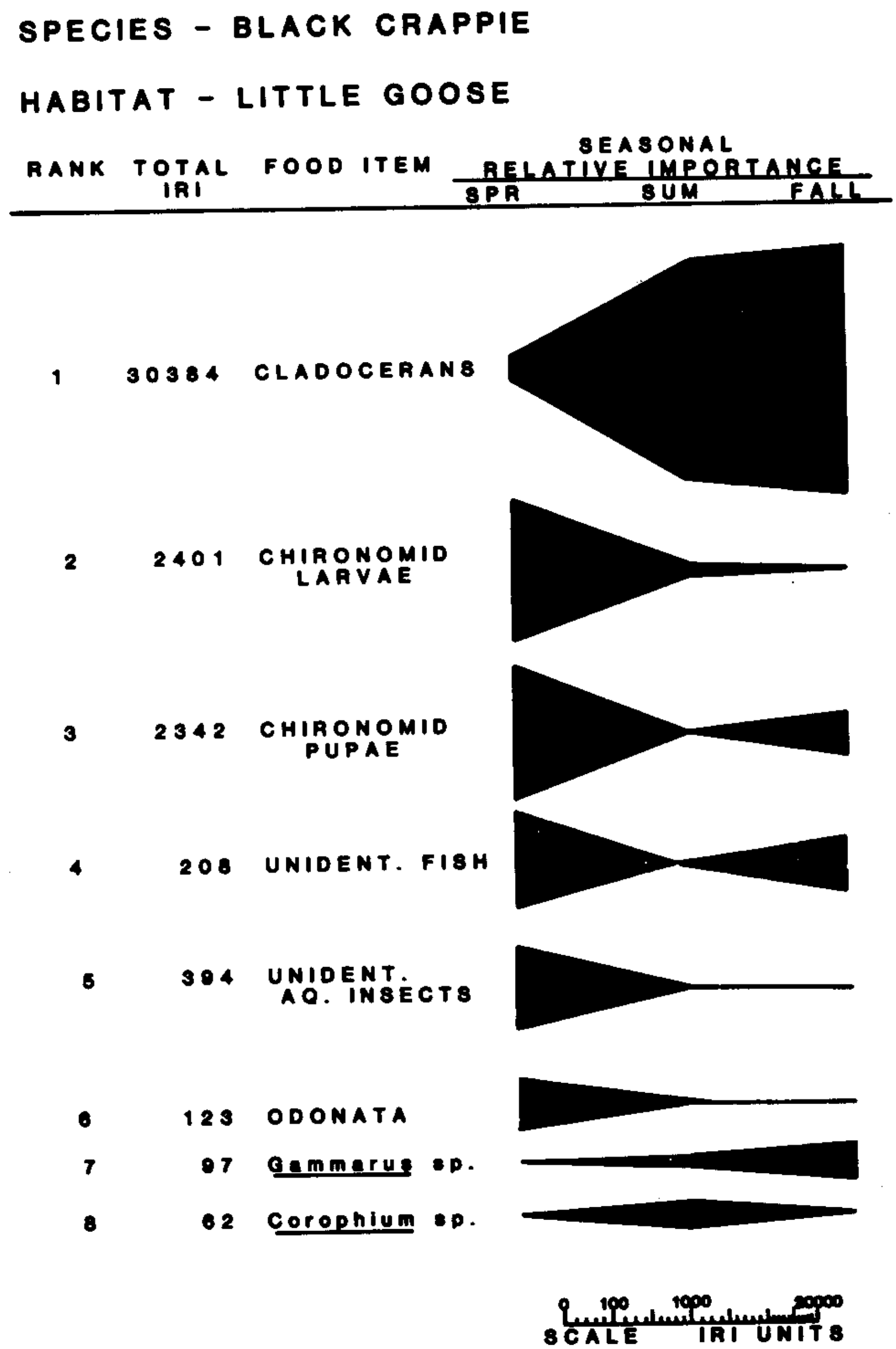

Figure 62. Index of relative importance (IRI) of food items of black crappie collected (spring, summer, and fall, 1979 and 1980) from Little Goose Reservoir, Washington.

Chironomidae (pupae and larvae) and Odonata (nymphs) were the only taxa of aquatic insects found in the stomachs of black crappie. Collectively, Chironomid pupae and larvae accounted for 56.2 and 41.6% of the total number of aquatic insects, respectively.

Fish were a minor food item in the diet of black crappie (Fig. 62). Overall, fish accounted for 0.02% of the total number and 13.9% of the total volume of food items and occurred in 7.8% of the stomachs containing food.

Few seasonal differences in the diet of black crappie were found (Fig. 62). Cladocera were relatively more important in their diets in the fall than summer and of negligible importance in the spring. Aquatic insects were the most important food item in the spring. Fish were of greatest importance during the spring and least importance in the summer.

Channel Catfish

A total of 452 channel catfish stomachs were collected from Little Goose Reservoir during 1979 and 1980 (Table 29). Catfish ranged in size from 92 to 649 mm. The smallest catfish ($\bar{x}$ = 317) were collected from the embayment habitat while, on the average, the largest catfish ($\bar{x}$ = 527) were captured at the tailwater area. Of these, 149 (33%) stomachs were empty and 303 (67%) contained food. The percentage of empty stomachs during spring and summer were 17.8 and 37.3%, respectively.

Fish, aquatic insects, crayfish, wheat, and cladocerans were the most important food items in the diet of channel catfish in Little Goose Reservoir (Fig. 63). Other food items included fish eggs, gammarids, and algae. Miscellaneous debris including wood, stones, and unidentified organic matter, also were present (3.8% of total volume).

Table 29. Characteristics of channel catfish examined for stomach analyses, from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	Habitat	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
SPRING	Tailwater	57	7	12.3	527	397-570	1800
	Shoal	26	3	11.5	523	365-635	1873
	Embayment	10	4	40.0	439	260-523	878
	Gulch	8	4	50.0	548	486-563	1880
Total		101	18	17.8	519	260-635	1734
SUMMER	Tailwater	38	26	68.4	509	410-600	1420
	Shoal	47	17	36.2	476	300-649	1332
	Embayment	232	74	31.9	317	92-635	606
	Gulch	34	14	41.2	462	120-549	1198
Total		351	131	37.3	373	92-649	849
GRAND TOTAL		452	149	33.0	406	92-649	1047

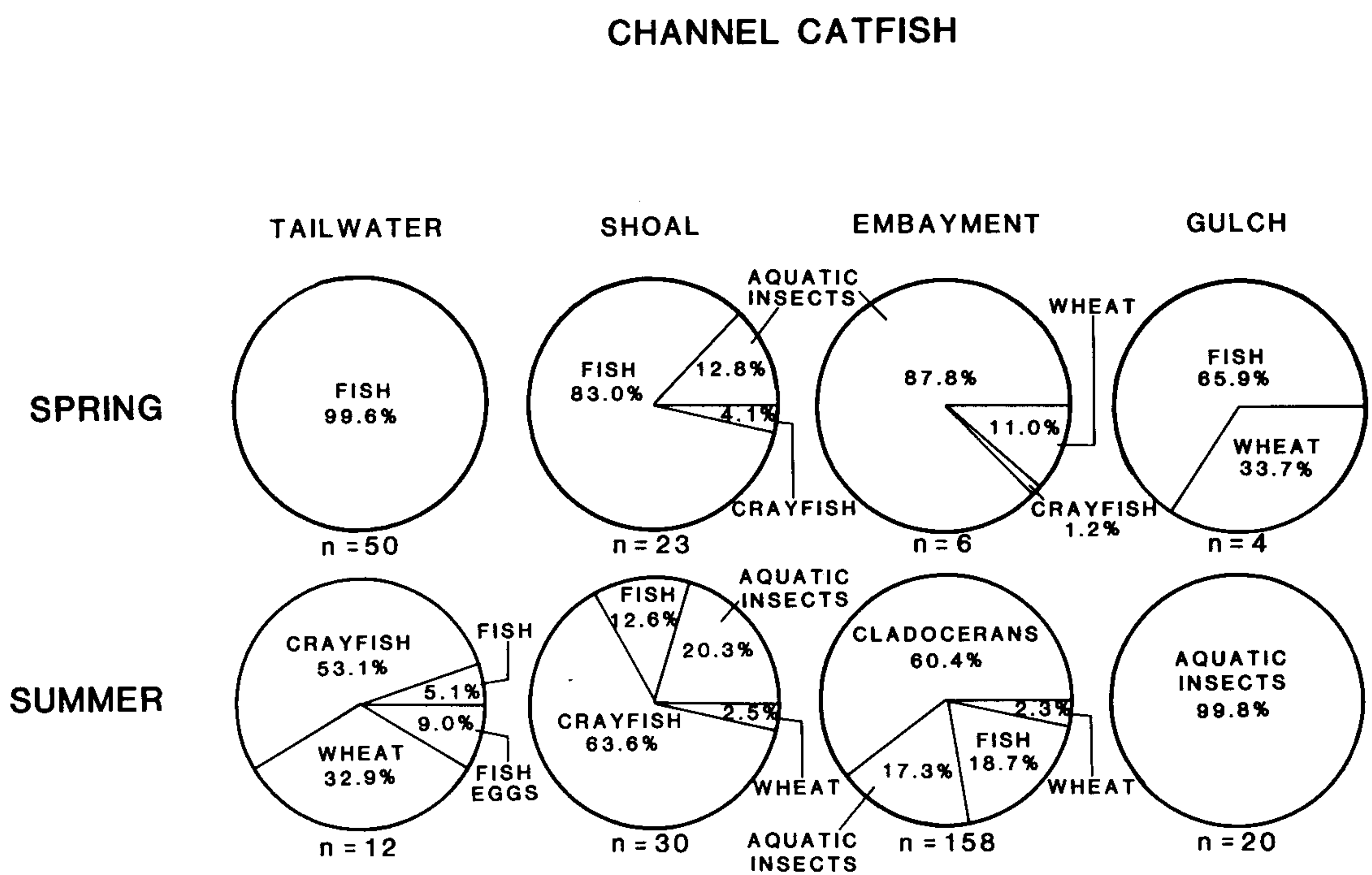

Figure 63. Percent of the index of relative importance (IRI) of major food items of channel catfish collected (spring and summer, 1979 and 1980) from Little Goose Reservoir (tailwater, shoal, embayment, and gulch habitats), Washington. Food items contributing less than 1% of the total IRI are not shown.

Fish were an important dietary component of channel catfish (Figs. 64-67). Fish accounted for 0.4% of the total number and 80.4% of the total volume of food items and occurred in 28.1% of the stomachs containing food. Fish eaten had a mean length of 143 mm and ranged in size from 50 to 270 mm (Table 30). Unidentified fish represented 25% of the total number and 19.8% of the total volume of fish found in the diet. Other more abundant fish consumed by catfish, in order of numerical abundance, were chinook salmon, steelhead trout, Pacific lanprey, pumpkinseed, and yellow perch.

The relative importance of aquatic insects was highly variable (Figs. 64-67). Overall, aquatic insects accounted for 28% of the total number and 4.3% of the total volume of food items and were found in 21.1% of the stomachs containing food. Chironomidae (larvae and pupae) was the only taxa of aquatic insect in the diet. Pupae were most common and represented 93.3% of the total number and 96% of the total volume of Chironomidae. Generally, pupae increased in relative importance from spring to summer whereas larvae decreased in importance.

Crayfish (Pacifastacus leniusculus) were an important dietary component of channel catfish in up-reservoir areas (Figs. 64 and 65). Overall, crayfish accounted for 0.2% of the total number and 5.4% of the total volume of food items and occurred in 17.5% of the stomachs which contained food.

A variety of other fauna and floral organisms were found in channel catfish stomachs (Figs. 64-67). Wheat accounted for 2.2% of the total number and 4.3% of the total volume of food items and occurred in 8.5% of the stomachs containing food. Cladocerans were more abundant than wheat and represented 58.3% of the total number and 0.4% of the total

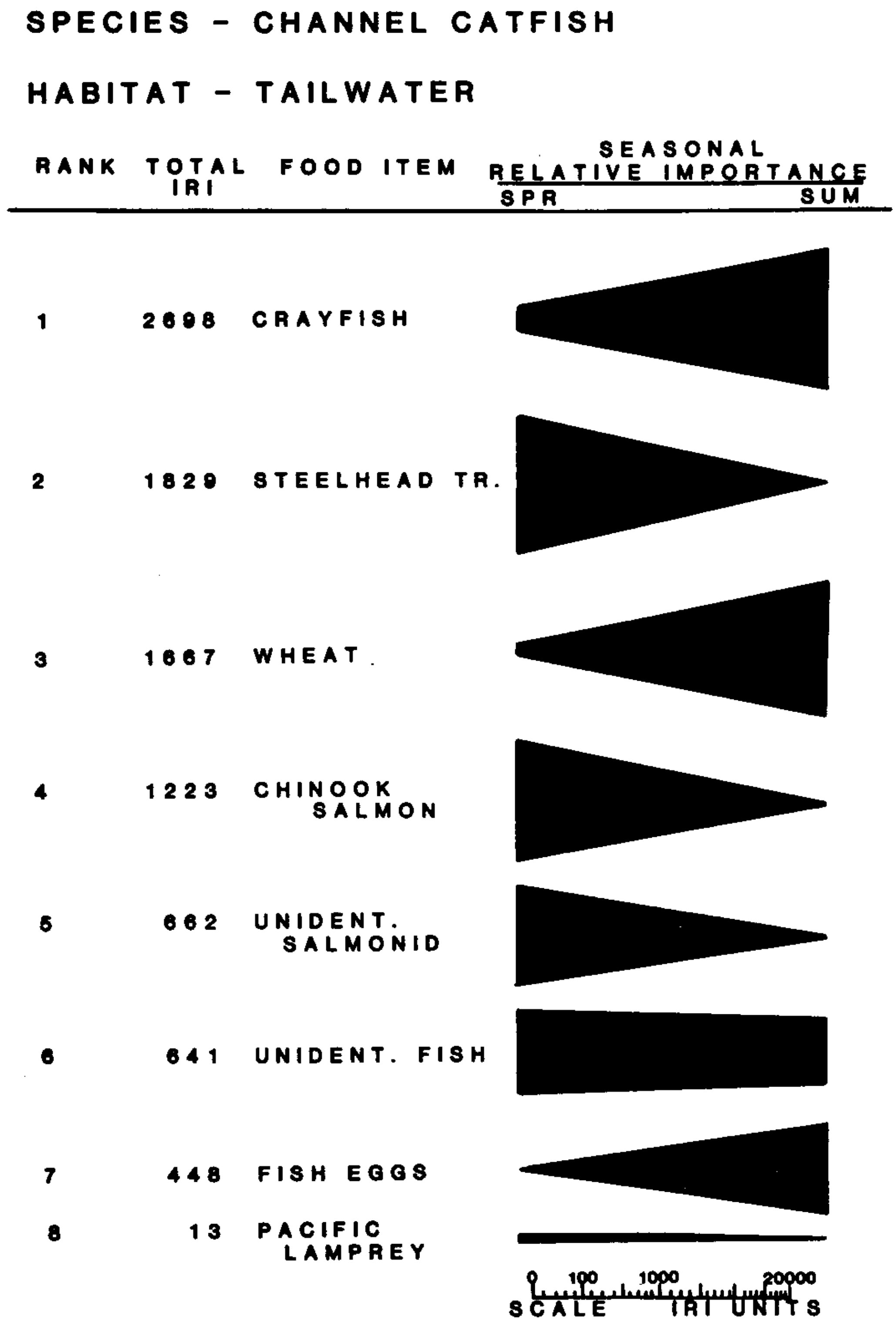

Figure 64. Index of relative importance (IRI) of food items for channel catfish collected (spring and summer, 1979 and 1980) from the tailwater habitat in Little Goose Reservoir, Washington.

SPECIES - CHANNEL CATFISH

HABITAT - SHOAL

RANK	TOTAL IRI	FOOD ITEM
1	3721	CRAYFISH
2	1410	CHIRONOMID PUPAE
3	707	UNIDENT. FISH
4	479	CHINOOK SALMON
5	475	STEELHEAD TR.
6	160	CHIRONOMID LARVAE
7	142	WHEAT
8	102	UNIDENT. SALMONID
9	99	LARGESCALE SUCKER
10	26	*Corophium* sp.
11	20	FILAMENTOUS GREEN ALGAE

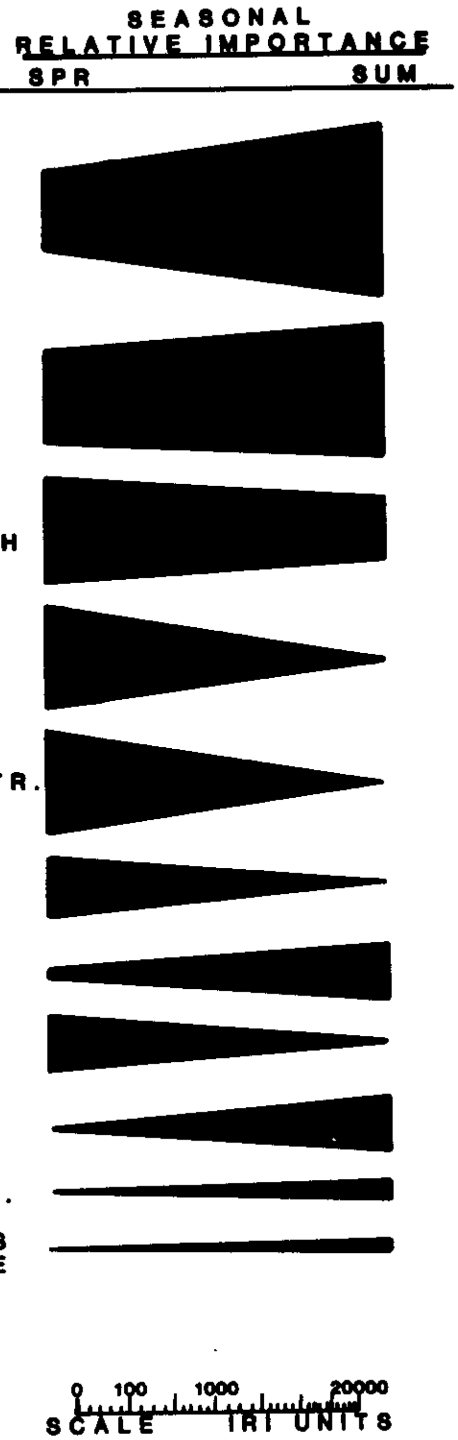

Figure 65. Index of relative importance (IRI) of food items for channel catfish collected (spring and summer, 1979 and 1980) from the shoal habitat in Little Goose Reservoir, Washington.

SPECIES - CHANNEL CATFISH

HABITAT - EMBAYMENT

RANK	TOTAL IRI	FOOD ITEM
1	7062	CHIRONOMID LARVAE
2	2576	CLADOCERANS
3	979	WHEAT
4	555	CHIRONOMID PUPAE
5	141	UNIDENT. FISH
6	112	CRAYFISH
7	33	FISH EGGS
8	30	WHITE CRAPPIE
9	17	YELLOW PERCH
10	9	FILAMENTOUS GREEN ALGAE

SEASONAL RELATIVE IMPORTANCE

SPR SUM

Figure 66. Index of relative importance (IRI) of food items for channel catfish collected (spring and summer, 1979 and 1980) from the lower embayment station in Little Goose Reservoir, Washington.

SPECIES - CHANNEL CATFISH

HABITAT - GULCH

RANK	TOTAL IRI	FOOD ITEM	SEASONAL RELATIVE IMPORTANCE (SPR – SUM)
1	13480	CHIRONOMID PUPAE	
2	4914	UNIDENT. FISH	
3	2510	WHEAT	
4	34	CHIRONOMID LARVAE	
5	18	FISH EGGS	

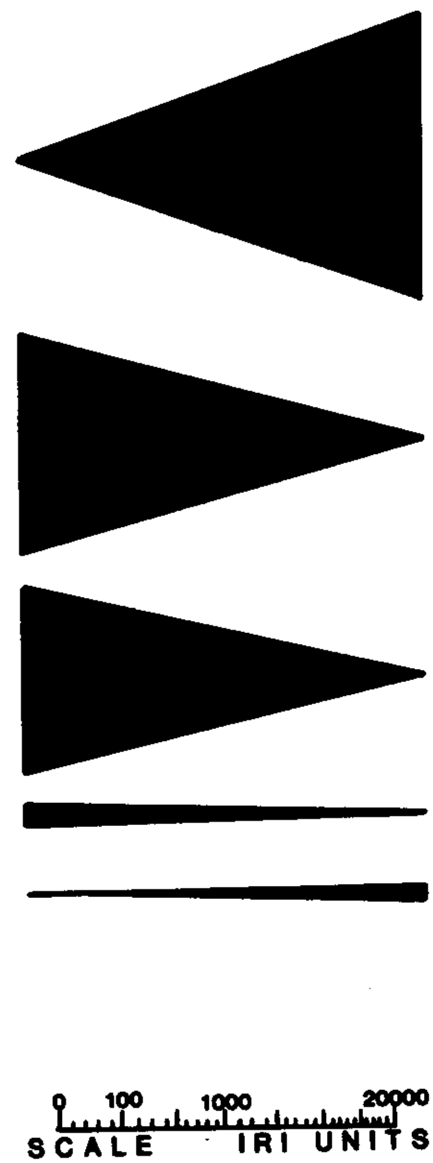

Figure 67. Index of relative importance (IRI) of food items for channel catfish collected (spring and summer, 1979 and 1980) from the gulch habitat in Little Goose Reservoir, Washington.

Table 30. Length (mm) of fish consumed by channel catfish in Little Goose Reservoir, Washington, 1979 and 1980.

		Length	
	No.	$\bar{X}$	Range
chinook salmon	47	108	65-195
steelhead trout	31	165	110-238
unidentified salmonid	21	120	86-160
northern squawfish	1	270	-
pumpkinseed	3	105	90-120
white crappie	2	126	112-140
yellow perch	3	169	120-248
sculpin	2	116	53-178
unidentified fish	14	103	50-250
all fishes	124	143	50-270

volume of food items and were found in 19.8% of the stomachs containing food. Leptodora kindti and Daphnia sp. represented 71 and 29% of the total number of cladocera consumed, respectively. Although fish eggs, gammarids, and filamentous green algae were present in the stomachs of channel catfish, they were of minor importance.

The relative importance of food items of channel catfish varied widely among seasons and habitats (Figs. 63-67). Fish were the most important food item consumed in the spring, but decreased in relative importance, whereas crayfish and aquatic insects were more important in the summer. At the lower embayment, no fish were found in the stomach contents during the spring, but fish were second in importance to cladocerans in the summer. Fish were of greatest importance in the spring and summer in the tailwater, shoal, gulch, and embayment habitat, respectively. Aquatic insects were of highest importance in the embayment and gulch areas. Aquatic insects decreased in relative importance from spring to summer in the lower embayment as cladocerans became more important, but increased in relative importance in the shoal and gulch areas as fish declined in importance during summer. Aquatic insects did not occur in the stomach contents of catfish collected from the tailwater area. Crayfish was the most important food item during the summer, but was of negligible importance in the spring relative to fish. Wheat was found in the stomach contents of catfish collected from the tailwater, shoal, embayment, and gulch areas. Cladocerans (Daphnia schodleri, D. galeata, and Leptodora kindti) were the most important dietary component from the lower embayment during summer.

Redside Shiner

A total of 251 redside shiner stomachs were collected from Little Goose Reservoir during 1979 and 1980 (Table 31). These fish had a mean length of 171 mm and ranged in size from 90 to 205 mm. Seventy-five (29.9%) of the stomachs were empty and 176 (70.1%) contained food. The percentage of empty stomachs decreased from 39.3 to 25.0 to 9.8 from spring to fall, respectively.

Cladocerans, aquatic insects, and terrestrial insects were the more important food items in the diet of redside shiner in Little Goose Reservoir (Fig. 68). Other food items of lesser importance were: wheat, gammarids, filamentous green algae, and arachnids. Miscellaneous debris, including unidentified organic matter, wood, and detritus, also were present (15.4% of total volume).

Cladocerans (*Daphnia schodleri* and *D. galeata*) were the most important food item in the diet of redside shiner (Figs. 69 and 70). Cladocerans accounted for 89.4% of the total number and 20.6% of the total volume of food items and were found in 29.6% of the stomachs which contained food. *Daphnia* sp. comprised all of the cladocera found in the diet.

Aquatic insects were the second most important food item of redside shiners collected from the upper (shoal and tailwater) and lower (gulch, lower embayment, deepwater) reservoir during spring, summer, and fall (Figs. 69 and 70). Aquatic insects represented 6% of the total number and 20.1% of the total volume of food items and were found in 26.1% of the stomachs which contained food. Chironomidae (pupae and larvae), hemiptera, odonata, and tricoptera were the most important taxa of aquatic insects found in the stomach contents (in order of numerical

Table 31. Characteristics of redside shiners examined for stomach analyses from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	Location	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
SPRING	Lower Reservoir	123	58	47.2	173	90-205	51
	Upper Reservoir	27	1	3.7	159	102-188	43
Total		150	59	39.3	170	90-205	50
SUMMER	Lower Reservoir	28	5	27.8	174	140-197	60
	Upper Reservoir	22	5	22.7	153	121-189	42
Total		40	10	25.0	162	121-197	50
FALL	Lower Reservoir	46	1	2.2	183	152-205	59
	Upper Reservoir	15	5	33.3	162	130-191	44
Total		61	6	9.8	178	130-205	55
GRAND TOTAL		251	75	29.9	171	90-205	51

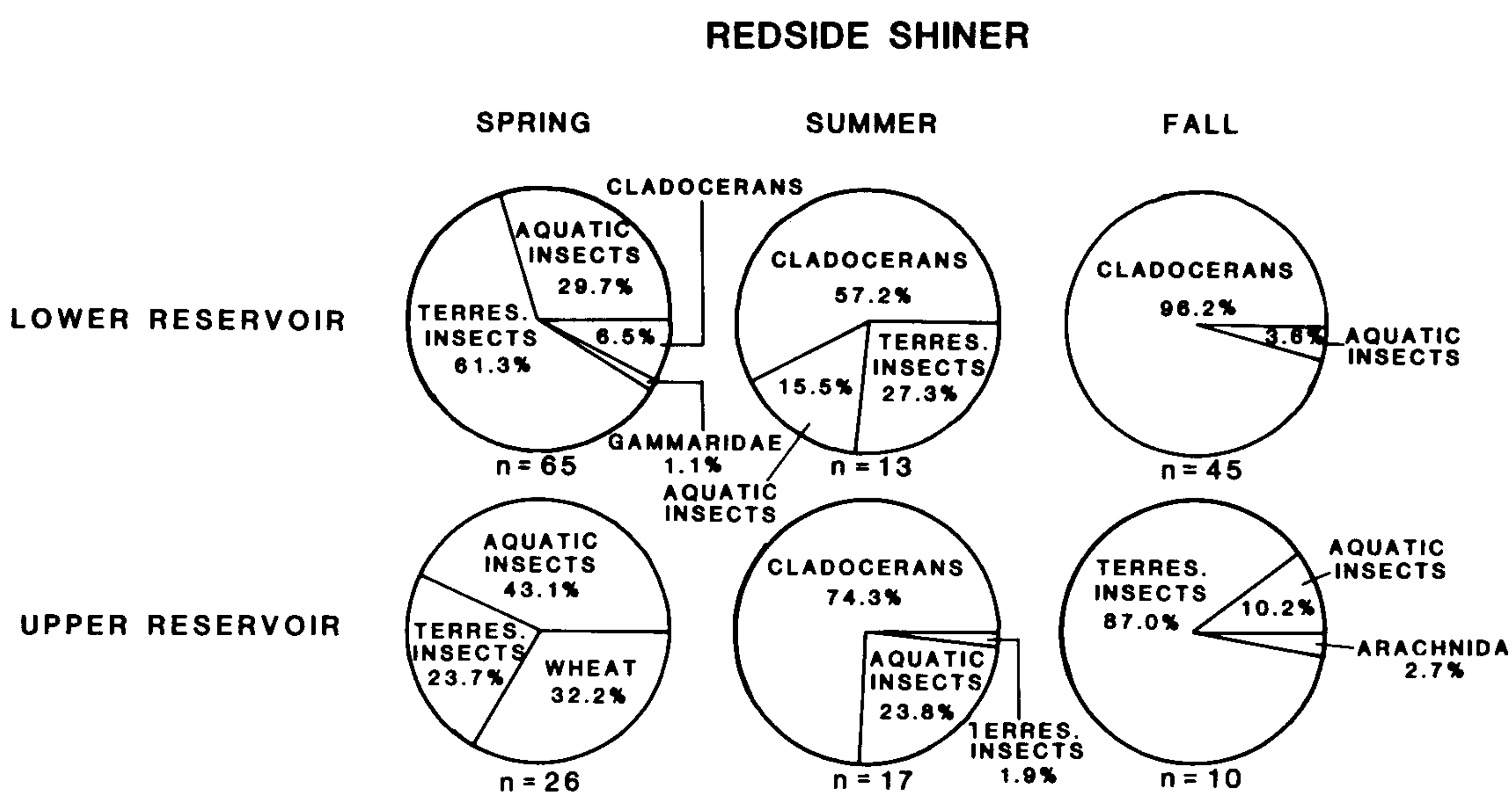

Figure 68. Percent of the index of relative importance (IRI) of major food items of redside shiners collected (spring-fall, 1979 and 1980) from lower (embayment, gulch, and deepwater areas) and upper (tailwater and shoal areas) reservoir zones in Little Goose Reservoir, Washington. Food items contributing less than 1% of the total IRI are not shown.

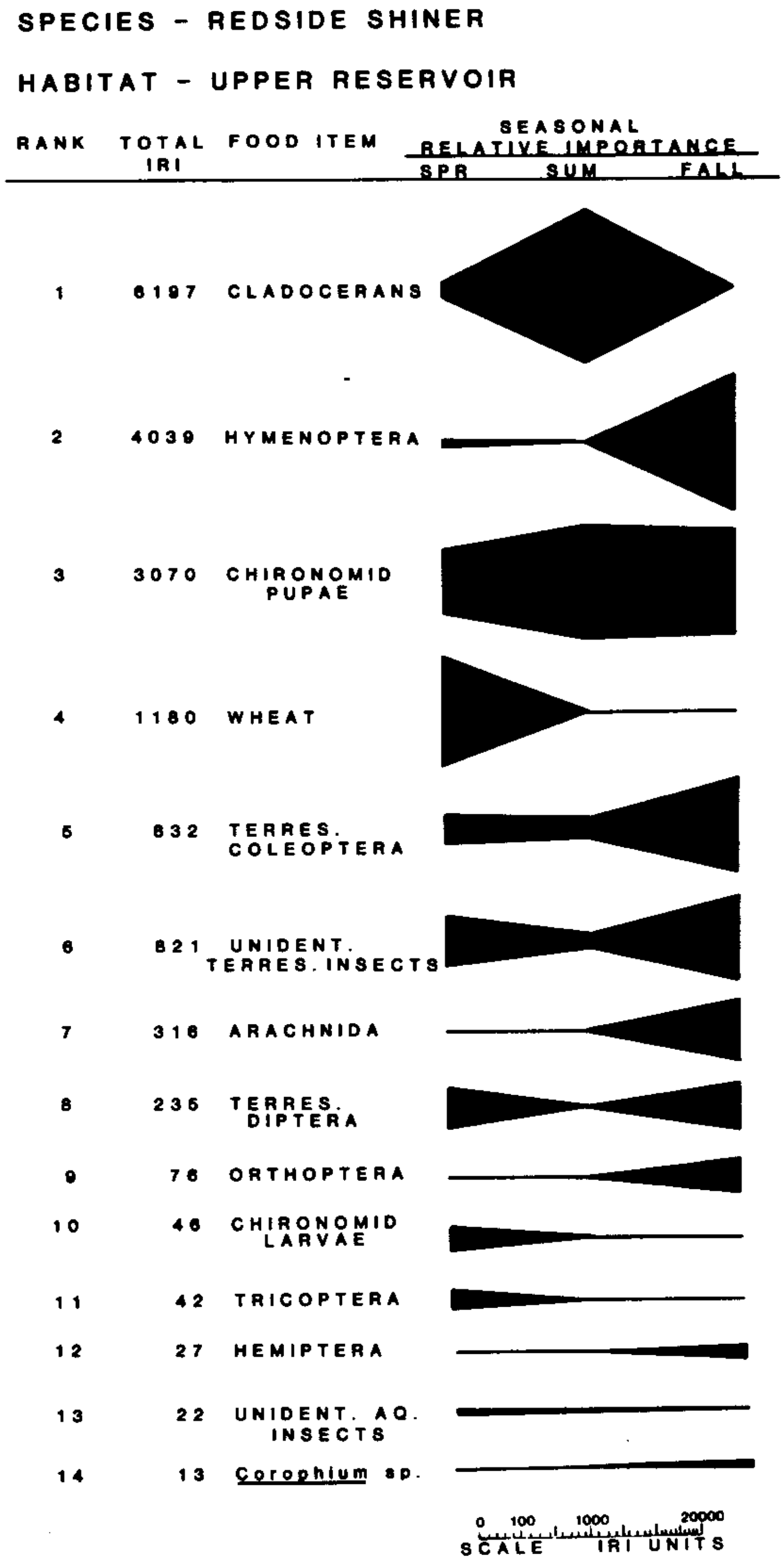

Figure 69. Index of relative importance (IRI) of food items of redside shiners collected (spring, summer, and fall, 1979 and 1980) from the upper reservoir (shoal and tailwater) zone in Little Goose Reservoir, Washington.

SPECIES - REDSIDE SHINER

HABITAT - LOWER RESERVOIR

RANK	TOTAL IRI	FOOD ITEM
1	18381	CLADOCERANS
2	861	HYMENOPTERA
3	587	UNIDENT. TERRES. INSECTS
4	581	TERRES. COLEOPTERA
5	466	CHIRONOMID PUPAE
6	254	CHIRONOMID LARVAE
7	216	FILAMENTOUS GREEN ALGAE
8	40	*Gammarus* sp.
9	31	WHEAT
10	19	ARACHNIDA
11	18	UNIDENT. AQ. INSECTS
12	12	ODONATA

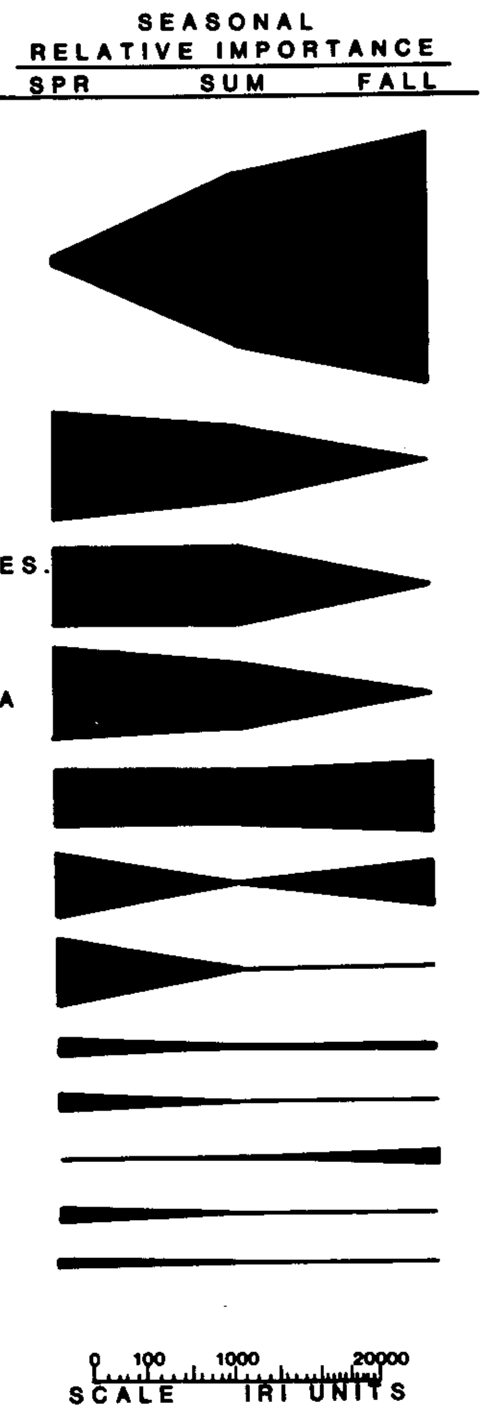

Figure 70. Index of relative importance (IRI) of food items of redside shiners collected (spring, summer, and fall, 1979 and 1980) from the lower reservoir (deepwater, lower embayment, and gulch areas) zone in Little Goose Reservoir, Washington.

abundance). Chironomidae pupae and larvae accounted for 78.8 and 16.8% of the total number of aquatic insects, respectively. Pupae increased in relative importance from spring to fall in the upper and lower reservoir, whereas larvae decreased in relative importance.

Terrestrial insects of sporadic importance were the most important dietary component of redside shiners in the lower reservoir during spring and the upper reservoir during fall (Figs. 69 and 70). Terrestrial insects represented 3.6% of the total number and 20.6% of the total volume of food items and occurred in 20.5% of the stomachs which contained food. Hymenoptera (ants), Coleoptera (beetles), Diptera (flies), and Orthoptera (grasshoppers) were the major taxa of terrestrial insects in the diet. Ants, beetles, and dipterans accounted for 48.4, 24.0, and 13.1% of the total number of terrestrial insects consumed, respectively.

Collectively, wheat, gammarids, filamentous green algae and arachnids accounted for 1.1% of the total number and 27.9% of the total volume of food items.

Stomach contents of 25 redside shiners collected during summer and fall from Ice Harbor Reservoir were similar to those for shiners in Little Goose Reservoir. Cladocerans (Daphnia sp.) were the most important dietary component followed by terrestrial and aquatic insects (Fig. 71).

Northern Squawfish

A total of 185 northern squawfish stomachs were collected from Little Goose Reservoir during 1979 and 1980 (Table 32). Fish sampled had a mean length of 292 mm and ranged in size from 98 to 558 mm. Sixty-four (34.6%) of the stomachs were empty and 121 (65.4%) contained food. The percentage of empty stomachs decreased from approximately 37% in the spring and summer to 13% in the fall.

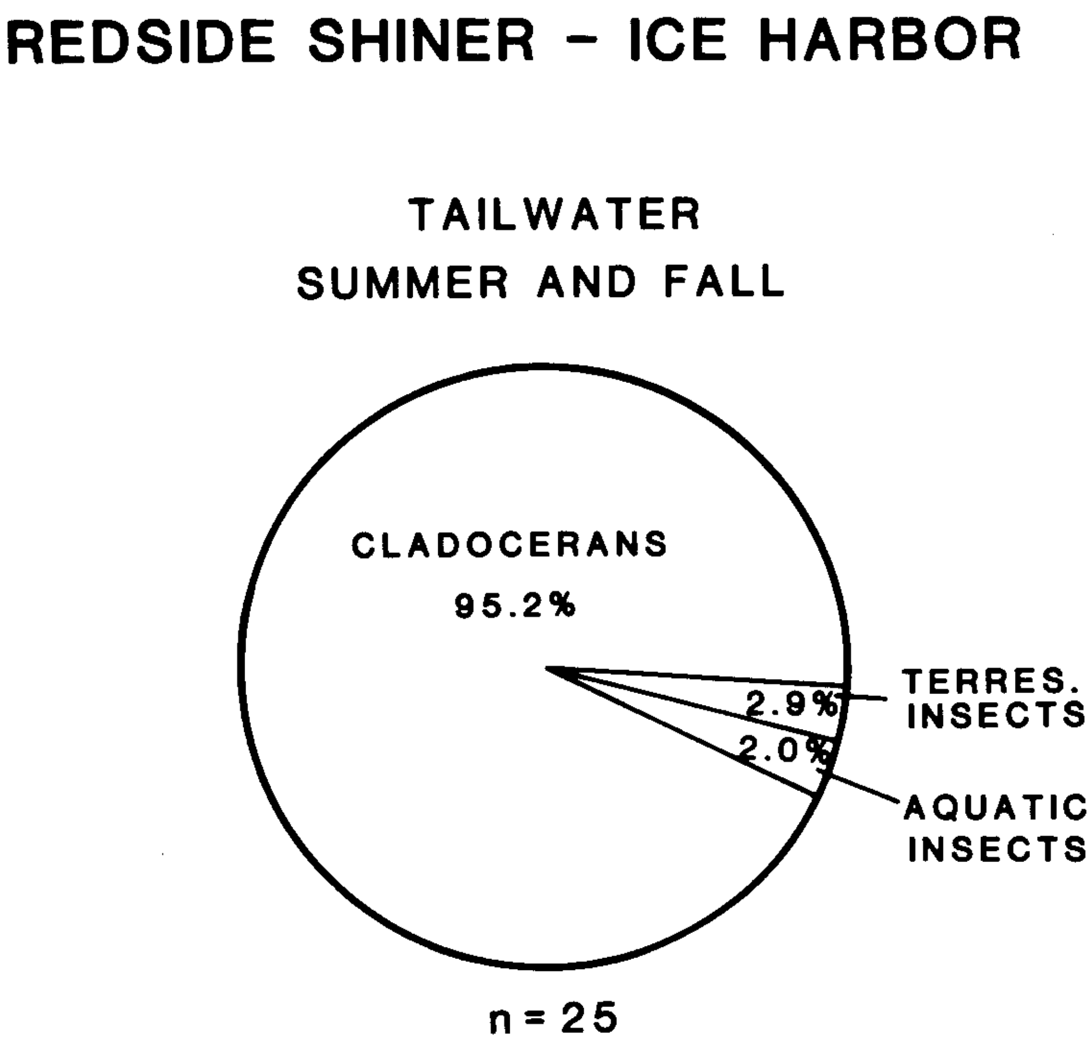

Figure 71. Percent of the index of relative importance (IRI) of major food items of redside shiners collected (summer and fall, 1979 and 1980) from Ice Harbor Reservoir, Washington. Food items contributing less than 1% of the total IRI are not shown.

Table 32. Characteristics of northern squawfish examined for stomach analyses from Little Goose Reservoir, Washington, during 1979 and 1980.

Season	Location	No.	EMPTY STOMACHS No.	EMPTY STOMACHS %	Length(mm) $\bar{X}$	Length(mm) Range	Mean Weight(g)
SPRING	Lower Reservoir	38	24	63.2	334	166-558	450
	Shoal	26	7	26.9	258	98-465	298
	Tailwater	22	1	4.5	369	334-427	532
Total		86	32	37.2	320	98-558	425
SUMMER	Lower Reservoir	55	27	51.9	246	114-510	247
	Shoal	21	2	9.5	329	242-426	124
Total		76	29	38.2	269	114-510	213
FALL	Lower Reservoir	11	0	0	359	275-525	515
	Shoal	12	3	25.0	177	140-367	54
Total		23	3	13.0	264	140-525	274
GRAND TOTAL		185	64	34.6	292	98-558	319

Fish, cladocerans, crayfish, aquatic insects, terrestrial insects, and wheat were the more important food items in the diet of northern squawfish (Fig. 72). Food items of lesser importance were: mussels, gammarids, filamentous green algae, and fish eggs. Unidentified organic matter also was present (9.7% of total volume).

Food habits of northern squawfish varied seasonally and from one habitat to another (Figs. 73 and 74). Fish and wheat were the dominant food items in the lower reservoir (gulch, lower embayment, deepwater) during the spring, whereas, cladocerans and crayfish were the major food items in the stomach contents of fish collected at the shoal area. Fish was the only food item found in the stomachs of squawfish collected in the spring at the tailwater station (Table 33). During summer, cladocerans and crayfish were major food items in the lower reservoir while crayfish dominated the food items of squawfish collected from the shoal area. In the fall, cladocerans and crayfish were major food items in squawfish from the lower reservoir, while aquatic and terrestrial insects were major food items in squawfish collected in the shoal area.

Fish were of highest relative importance in the diet of northern squawfish during the spring at the tailwater, lower reservoir, and shoal areas (Figs. 73 and 74; Table 33). Fish accounted for 0.9% of the total number and 74.5% of the total volume of food items and occurred in 18.2% of the stomachs which contained food. Fish consumed by northern squawfish, in order of numerical abundance, were: Pacific lamprey, unidentified salmonids, steelhead trout, chinook salmon, and steelhead trout.

Cladocerans (Daphnia schodleri, D. galeata, and Leptodora kindti) were the second most important dietary component of squawfish (Figs. 73 and 74). Cladocerans represented 87.2% of the total number and 1.7% of

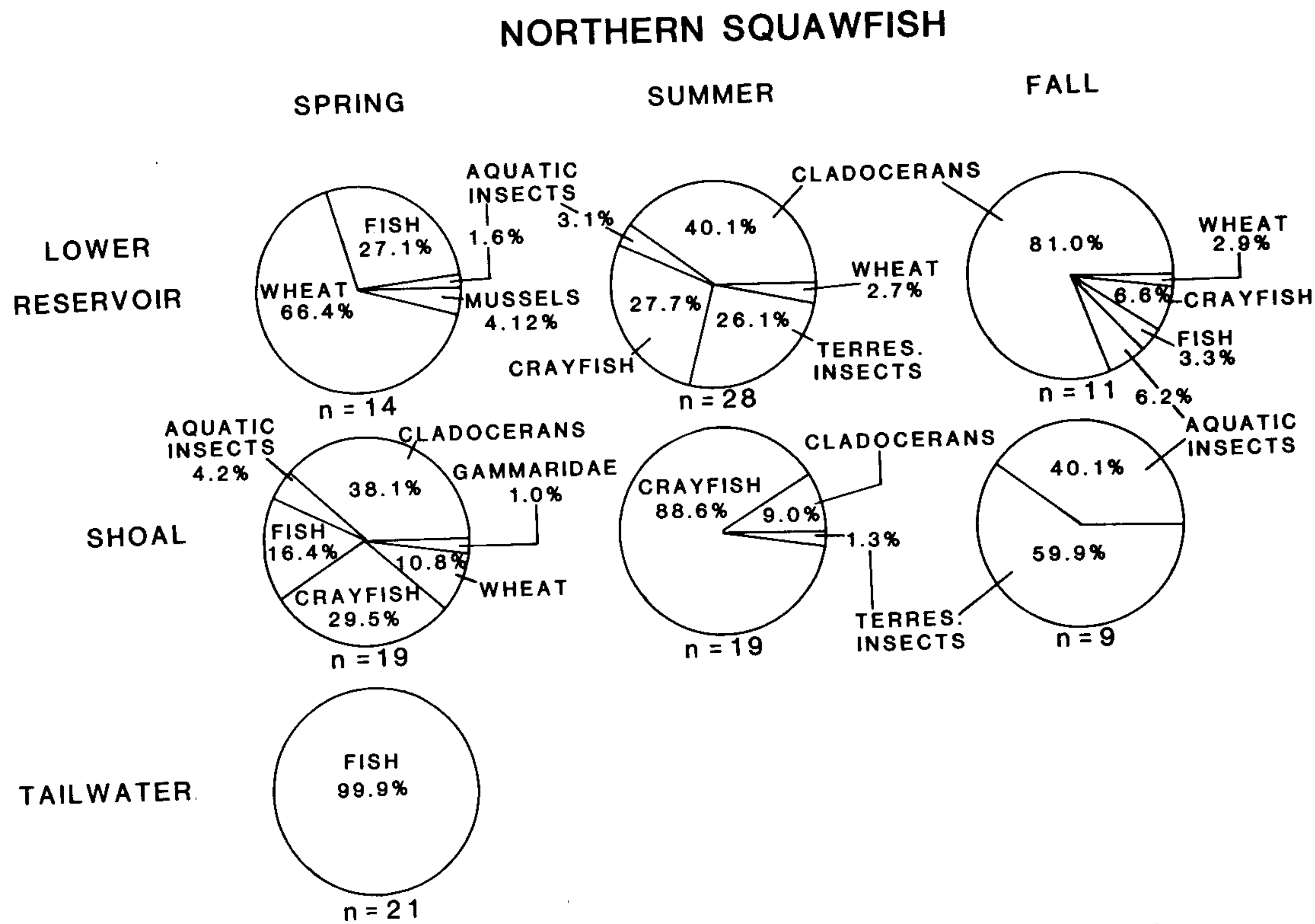

Figure 72. Percent of the index of relative importance (IRI) of major food items of northern squawfish collected (spring-fall, 1979 and 1980) from Little Goose Reservoir (lower reservoir, shoal, and tailwater habitats), Washington. Food items contributing less than 1% of the total IRI are not shown.

SPECIES - NORTHERN SQUAWFISH

HABITAT - SHOAL

RANK	TOTAL IRI	FOOD ITEM
1	5262	CRAYFISH
2	4450	CHIRONOMID PUPAE
3	4217	HYMENOPTERA
4	1165	TERRES. COLEOPTERA
5	1158	CLADOCERANS
6	433	ORTHOPTERA
7	316	CHIRONOMID LARVAE
8	290	UNIDENT. FISH
9	277	UNIDENT. TERRES. INSECTS
10	242	WHEAT
11	17	UNIDENT. AQ. INSECTS
12	11	*Corophium* sp.

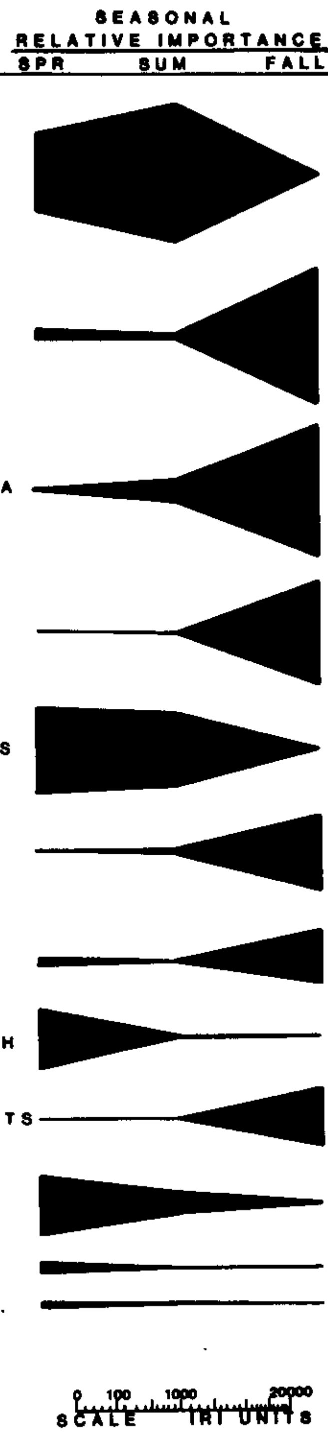

Figure 73. Index of relative importance (IRI) of food items of northern squawfish collected (spring, summer, and fall, 1979 and 1980) from the shoal habitat in Little Goose Reservoir, Washington.

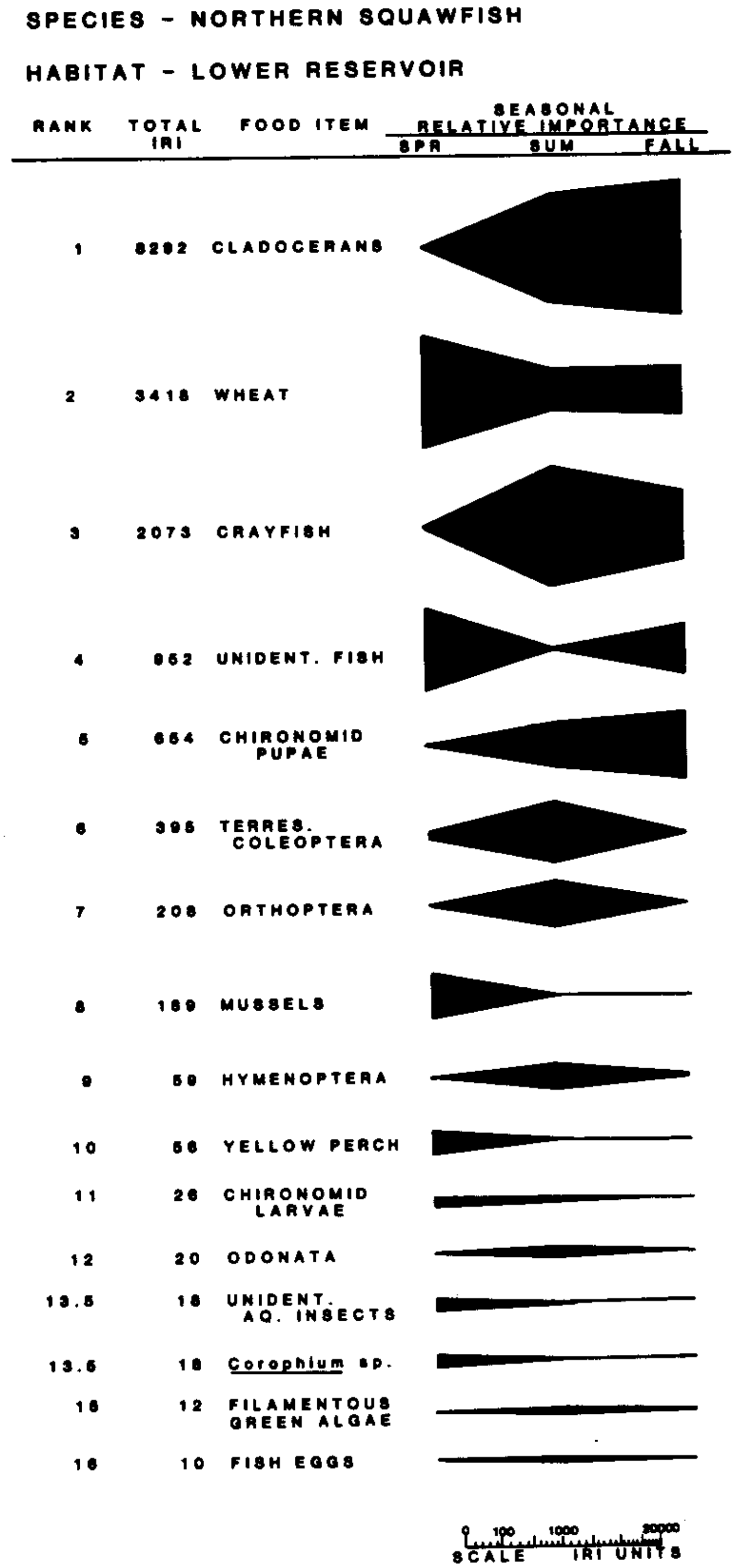

Figure 74. Index of relative importance (IRI) of northern squawfish collected (spring, summer, and fall, 1979 and 1980) from the lower reservoir (lower embayment, gulch, and deepwater habitats) zone in Little Goose Reservoir, Washington.

Table 33. Index of relative importance (IRI) of food items for northern squawfish collected from the tailwater area during the spring in Little Goose Reservoir, Washington, 1979 and 1980.

Rank	IRI	Food Item
1	96	unidentified fish
2	67	steelhead trout
3	21	unidentified salmonid
4.5	10	yellow perch
4.5	10	crayfish
6	7	chinook salmon
7	4	pacific lamprey

the total volume of food items and were found in 12.4% of the stomachs containing food. Daphnia sp. and Leptodora kindti represented 91.2 and 8.8% of the cladocera in the stomach contents, respectively.

Crayfish (Pacifastacus leniusculus) was the most important food item in the diet of northern squawfish collected in the shoal area (Fig. 73). Crayfish accounted for 0.7% of the total number and 10.7% of the total volume of food items and occurred in 21.5% of the stomachs which contained food. In the lower reservoir and shoal habitat, crayfish increased in relative importance from spring to summer then decreased in importance in the fall.

Aquatic insects were of minor importance in the diet of northern squawfish from Little Goose Reservoir, except in the shoal area during fall (Fig. 73). Aquatic insects represented 4.7% of the total number and 0.8% of the total volume of food items and occurred in 17.4% of the stomachs which contained food. Chironomidae (pupae and larvae) were the major taxa of aquatic insects found in the stomach contents of squawfish. Pupae and larvae accounted for 90.8 and 6.0% of the total number of insects occurring in the stomachs.

As with aquatic insects, terrestrial insects were of sporadic importance in the diet of northern squawfish in Little Goose Reservoir (Figs. 73 and 74). Terrestrial insects represented 1.7% of the total number and 1.4% of the total volume of food items and occurred in 17.4% of the stomachs containing food. Coleoptera (beetles), Hymenoptera (ants), Orthoptera (grasshoppers), and unidentified insects accounted for 31.7, 25.6, 23.2, and 19.5% of the terrestrial insects in the stomach contents, respectively.

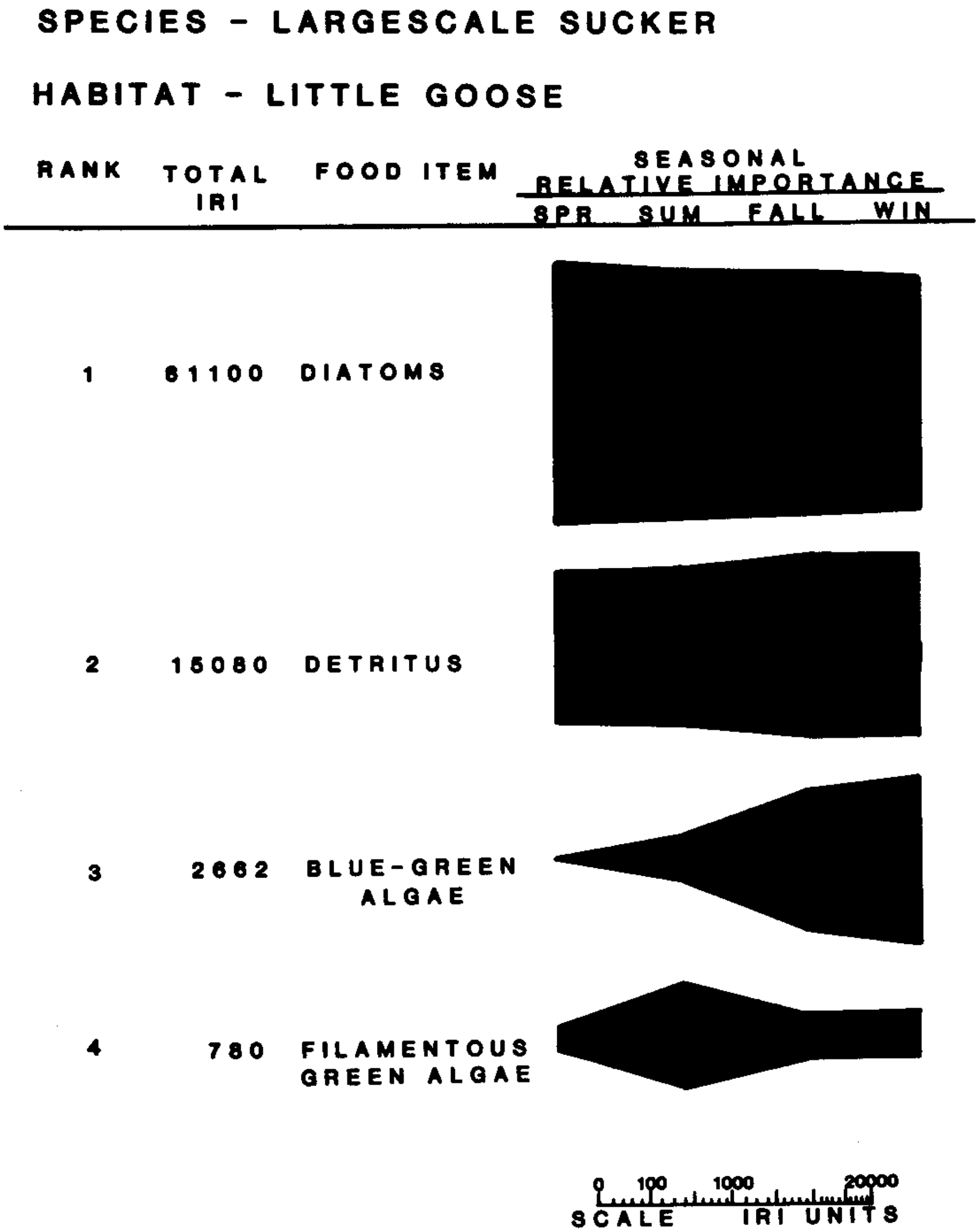

Figure 76. Index of relative importance (IRI) of food items of largescale suckers collected from Little Goose Reservoir, Washington, during 1979 and 1980.

Few seasonal and habitat differences were found in the diet of largescale suckers in Little Goose Reservoir (Figs. 75 and 76). Diatoms were most important in the diet during spring and decreased slightly in relative importance from spring to winter. In contrast to diatoms, detritus increased in relative importance in largescale sucker stomachs from spring to winter. Blue-green algae were of minor importance during the spring and summer, but increased in relative importance during fall and winter.

Bridgelip Sucker

A total of 39 stomachs from bridgelip suckers with food items were examined from Little Goose Reservoir during summer, 1979 and 1980. Our sample of bridgelip suckers had a mean length of 291 mm and ranged from 141 to 455 mm.

Diatoms, detritus, filamentous green algae, and blue-green algae were the more important food items in the diet of bridgelip suckers (Fig. 77). Diatoms (Fragilaria sp. and Melosira sp.) were the most important food item in the summer. Diatoms accounted for 98.2% of the total number and 47.8% of the total volume of food items. As in large-scale sucker stomachs, detritus was the second most important food item of bridgelip suckers and represented 49.6% of the total volume of food items. Collectively, filamentous green and blue-green algae accounted for 1.6% of the total number and 2.5% of the total volume of food items.

Diel Food Habits

White crappie

White crappie were collected at 6 hour intervals during the summer of 1980 from the lower embayment of Little Goose Reservoir. Five (3.9%) of the stomachs were empty and 123 (96.1%) contained food. The percentage

Wheat was the most important food item in the diet of northern squawfish during the spring in the lower portion of Little Goose Reservoir but of overall minor importance. Wheat accounted for 4.6% of the total number and 9.1% of the total volume of food items and occurred in 6.6% of the stomachs which contained food.

Mussels, gammarids, filamentous green algae, and fish eggs represented 0.1% of the total number and 3.7% of the total volume of food items and occurred in 10.7% of northern squawfish stomachs with food.

Largescale Sucker

A total of 122 largescale sucker stomachs examined from Little Goose Reservoir contained food during 1979 and 1980. These suckers had a mean length of 393 mm and ranged in size from 129 to 732 mm.

Diatoms, detritus, blue-green algae, and filamentous green algae were the more important food items in the diet of large-scale suckers in Little Goose Reservoir (Figs. 75 and 76). Diatoms (*Cymbella* sp., *Melosira* sp., *Surirella* sp., and *Fragilaria* sp.) were the single most important food items of largescale suckers. Diatoms accounted for 96.4% of the total number and 58.4% of the total volume of stomach contents. Detritus (silt, sand, and unidentified organic matter) was the second most abundant dietary component of largescale suckers. Detritus represented 37.6% of the total volume of food items. Blue-green algae were the third most important food item. Blue-green algae represented 3.2% of the total number and 2.2% of the total volume of food items. Filamentous green algae were of minor importance in the diet of largescale suckers. Green algae accounted for 0.4% of the total number and 1.8% of the total volume of food items.

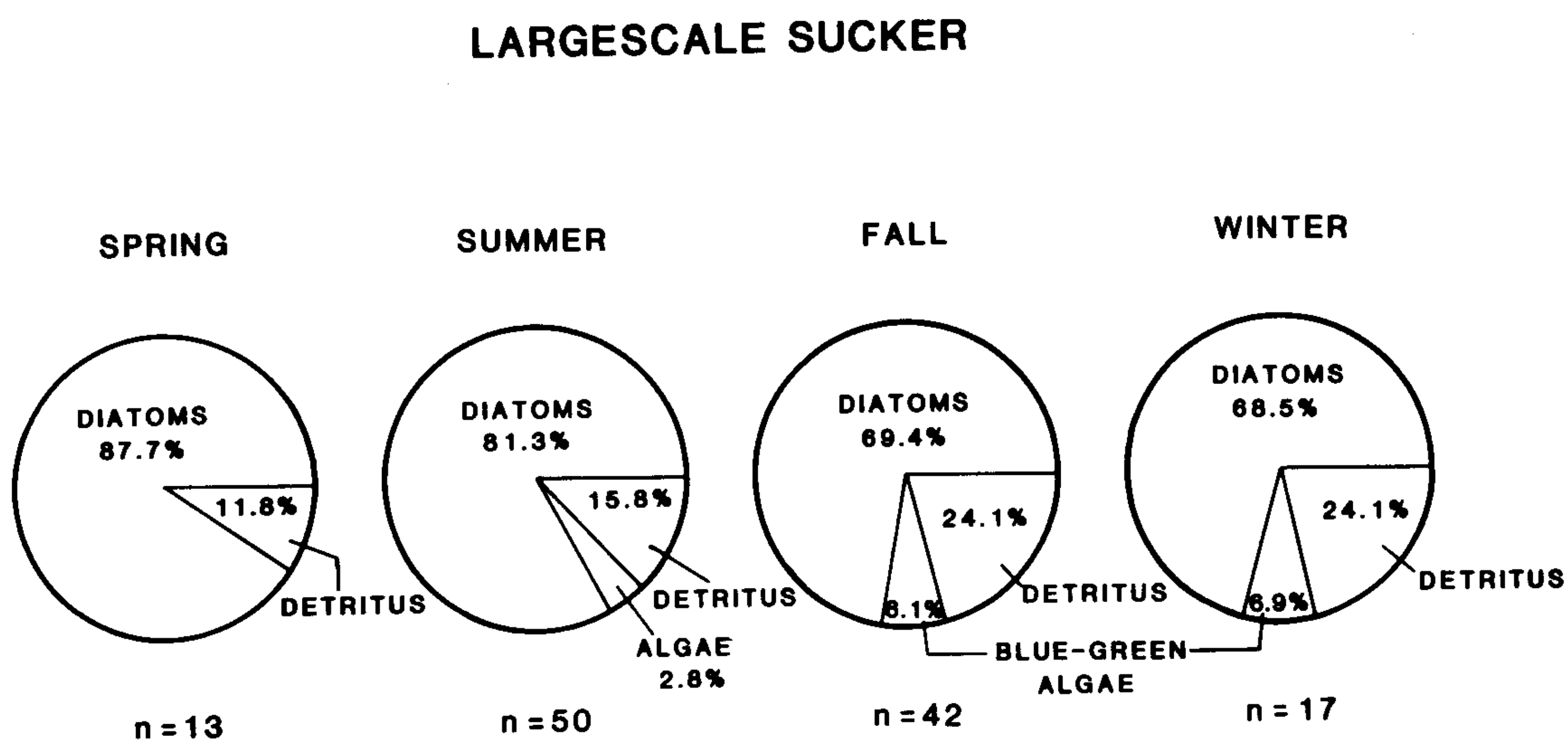

Figure 75. Percent of the index of relative importance (IRI) of major food items of largescale suckers collected (spring-winter, 1979 and 1980) in Little Goose Reservoir, Washington. Food items contributing less than 1% of the total IRI are not shown.

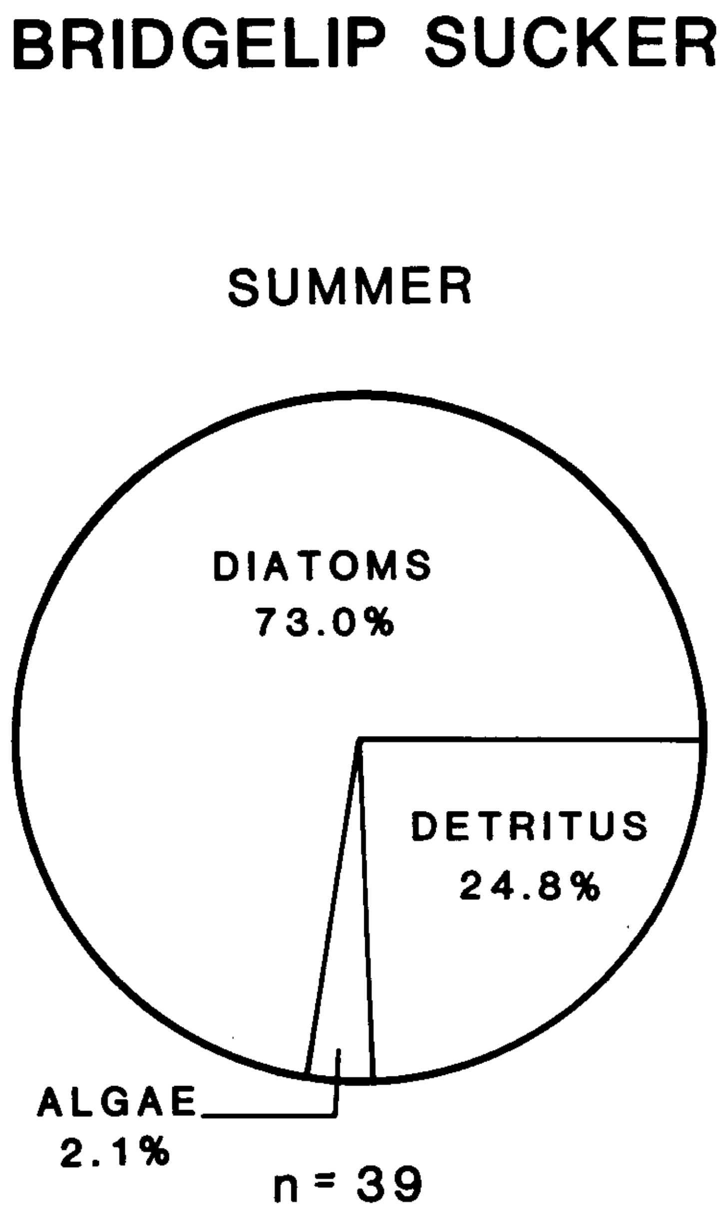

Figure 77. Percent of index of relative importance (IRI) of major food items of bridgelip suckers collected (summer, 1979 and 1980) in Little Goose Reservoir, Washington. Food items contributing less than 1% of the total IRI are not shown.

of empty stomachs for the 6 hour periods were: 0600-1200--4%; 1200-1800--5.3%; 1800-2400--4.2%; and 2400-0600 hours--0%.

Major and specific food items of white crappie did not vary throughout the 24-hour period (Fig. 78). Cladocerans consistently comprised a major proportion of the diet. Based on total number, 96.5 to 99.4% and 25 to 54.6% of the total volume of food items were cladocerans. Cladocerans were followed in importance by fish and aquatic insects.

Although various stomach items remained similar throughout the 24 hour period, mean volume varied. White crappie contained the highest mean volume of food items from 0600-1200 and 1200-1800 hours. The least was found during the night (1800-2400 and 2400-0600). Mean volume of food items consumed from 0600-1200 was significantly higher ($P<0.05$) than that from 1800-2400.

Channel Catfish

A total of 152 channel catfish stomachs were collected at the lower embayment in Little Goose Reservoir during June, July, and August, 1980. Thirty-six (23.8%) of these stomachs were empty and 116 (76.2%) contained food. The percentage of empty stomachs increased from 0600-1200 to 2400-0600 hours: 0600-1200--17.3%; 1200-1800--22.2%; 1800-2400--28.6%; and 2400-0600--30.6%.

The relative importance of food items in the diet of channel catfish varied throughout a 24 hour period (Fig. 79). From 0600-1200 and 1800-2400 cladocerans were the most important food item in the diet (68.2-56.2% of the total number and 2.0-0.6% of the total volume) followed by fish and aquatic insects. Although aquatic insects were the most important overall food item (65.0% of the total number and 35.9% of the total volume), cladocerans and aquatic insects from 2400-0600 were approximately

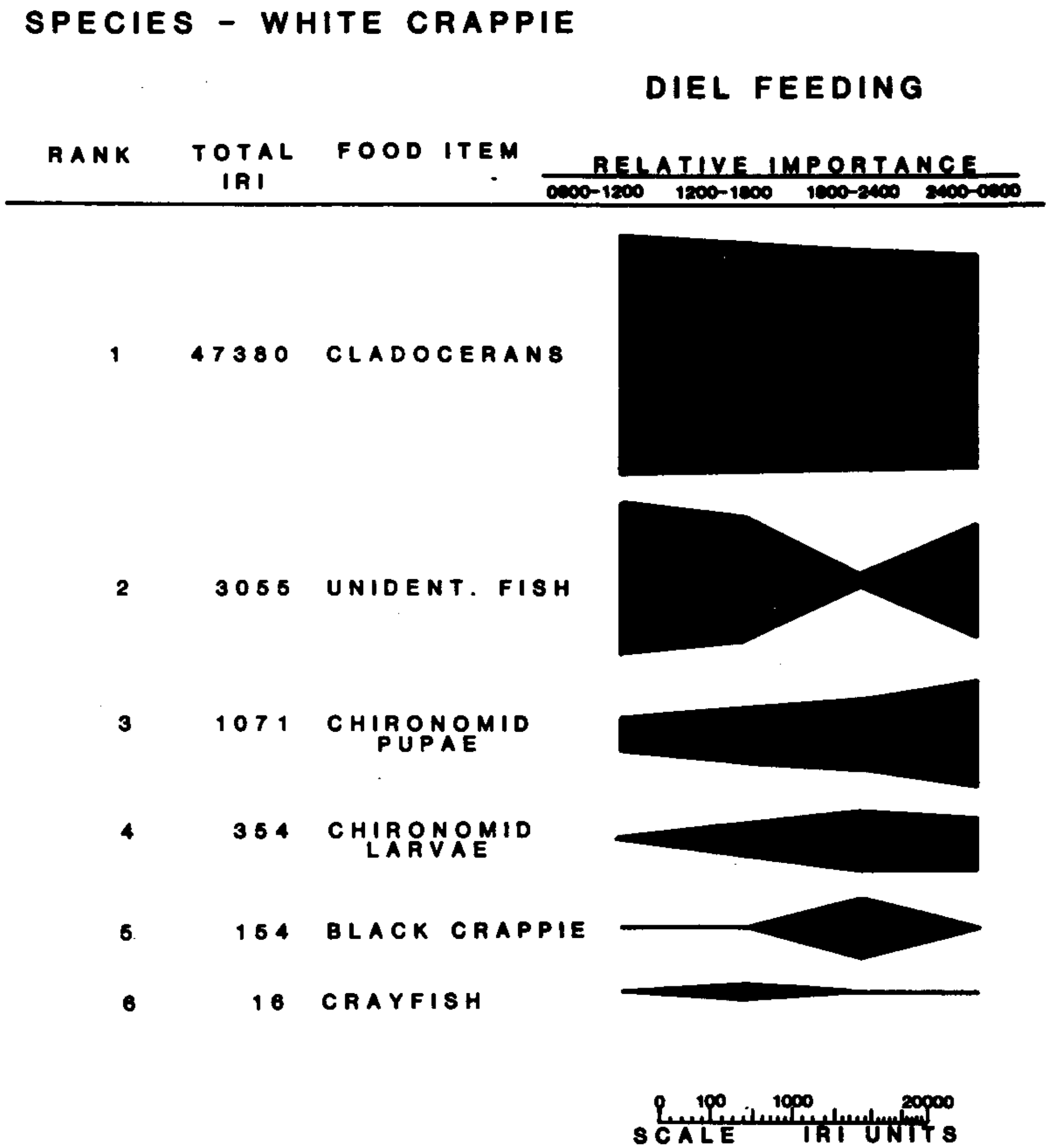

Figure 78. Index of relative importance (IRI) of food items of white crappie collected during 1980 at 6 hour intervals (0600-1200, 1200-2400, and 2400-0600) from the lower embayment in Little Goose Reservoir, Washington.

SPECIES - CHANNEL CATFISH

DIEL FEEDING

RANK	TOTAL IRI	FOOD ITEM
1	10095	CLADOCERANS
2	7718	CHIRONOMID PUPAE
3	1389	UNIDENT. FISH
4	1109	WHEAT
5	317	CRAYFISH
6	165	YELLOW PERCH
7	147	CHIRONOMID LARVAE
8.5	109	PUMPKINSEED
8.5	109	WHITE CRAPPIE
10	95	FILAMENTOUS GREEN ALGAE
11	50	REDSIDE
12	44	STEELHEAD TR.
13	20	BLUEGILL
14	16	SCULPIN

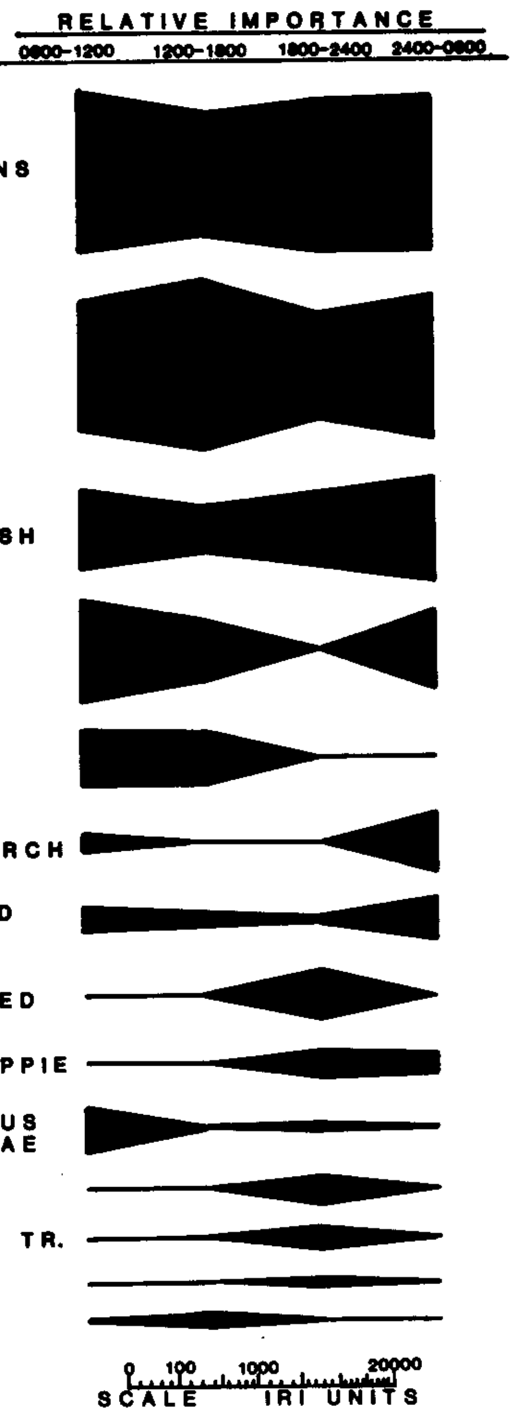

Figure 79. Index of relative importance (IRI) of food items of channel catfish collected at 6 hour intervals (0600-1200, 1200-1800, 1800-2400, and 2400-0600) from the lower embayment in Little Goose Reservoir, Washington, 1980.

equal in relative importance. Fish increased in relative importance from 0600-1200 to 2400-0600 hours.

Mean volume of food items consumed throughout a 24 hour period was similar. Channel catfish manifested the highest average volume of stomach contents from 1800-2400 and 2400-0600 hours although these were not statistically significant ($P<0.05$).

Resident Fish Predation on Juvenile Salmonid Smolts

<u>Smallmouth Bass</u>

A total of 184 smallmouth bass were collected from Little Goose Reservoir during April and May 1980 to assess the intensity of their predation on emigrating juvenile chinook salmon and steelhead trout. Bass examined for smolts had a mean length of 249 mm and ranged in size from 135 to 467 mm. During April and May, 31 (16.8%) of the stomachs were empty and 153 (83.2%) contained food.

Based on the presence of smolts in smallmouth bass stomachs, the intensity of smallmouth bass predation on salmonid smolts was minor. Two chinook salmon and no steelhead trout were found in smallmouth bass stomachs. Our results indicate the incidence of predation by smallmouth bass on chinook salmon (based upon the frequency of occurrence of chinook salmon in the diet) was less than 2%.

<u>Channel Catfish</u>

A total of 83 channel catfish were collected from tailwater and shoal areas of Little Goose Reservoir during the smolt migration. Catfish examined for smolts in their stomachs had a mean length of 526 mm and ranged in size from 365 to 635 mm. Ten (12.0%) of the catfish stomachs were empty while 73 (88%) contained food.

Chinook salmon and steelhead trout were the most abundant food items of channel catfish collected in tailwater and shoal areas during spring (Fig. 80). In the tailwater area, salmonids accounted for 66.5% of the total number and 85.5% of the total volume of food items in channel catfish in April and May, 1980. Steelhead trout and chinook salmon were found in approximately equal numbers in the diet, but because of their larger size, steelhead trout contributed a greater proportion of the total volume. In the shoal area, salmonids accounted for 22.8% of the total number and 73.4% of the total volume of food items. Chinook salmon were the most abundant salmonid in the stomach contents, while chinook salmon and steelhead trout contributed approximately equal volumes.

The incidence of predation by channel catfish on salmonid smolts varied between the tailwater and shoal area. At the tailwater, chinook salmon, steelhead trout, and unidentified salmonids were found in 54% 38% and 16% of the stomachs containing food, respectively. At the shoal area chinook, steelhead, and unidentified salmonids occurred in 13, 13, and 8.7% of the stomachs, respectively. Of those channel catfish which contained salmon, an average of 3.2 and 4.3 chinook were found. Also, an average of 3.0 and 3.3 steelhead trout were found in channel catfish stomachs (of fish containing steelhead) at the tailwater and shoal areas, respectively.

Northern Squawfish

Twenty-one of the 44 northern squawfish stomachs examined from the tailwater area of Little Goose Reservoir during April and May, 1980 contained food. Squawfish examined for smolts had a mean length of 369 mm and ranged in length from 344 to 427 mm.

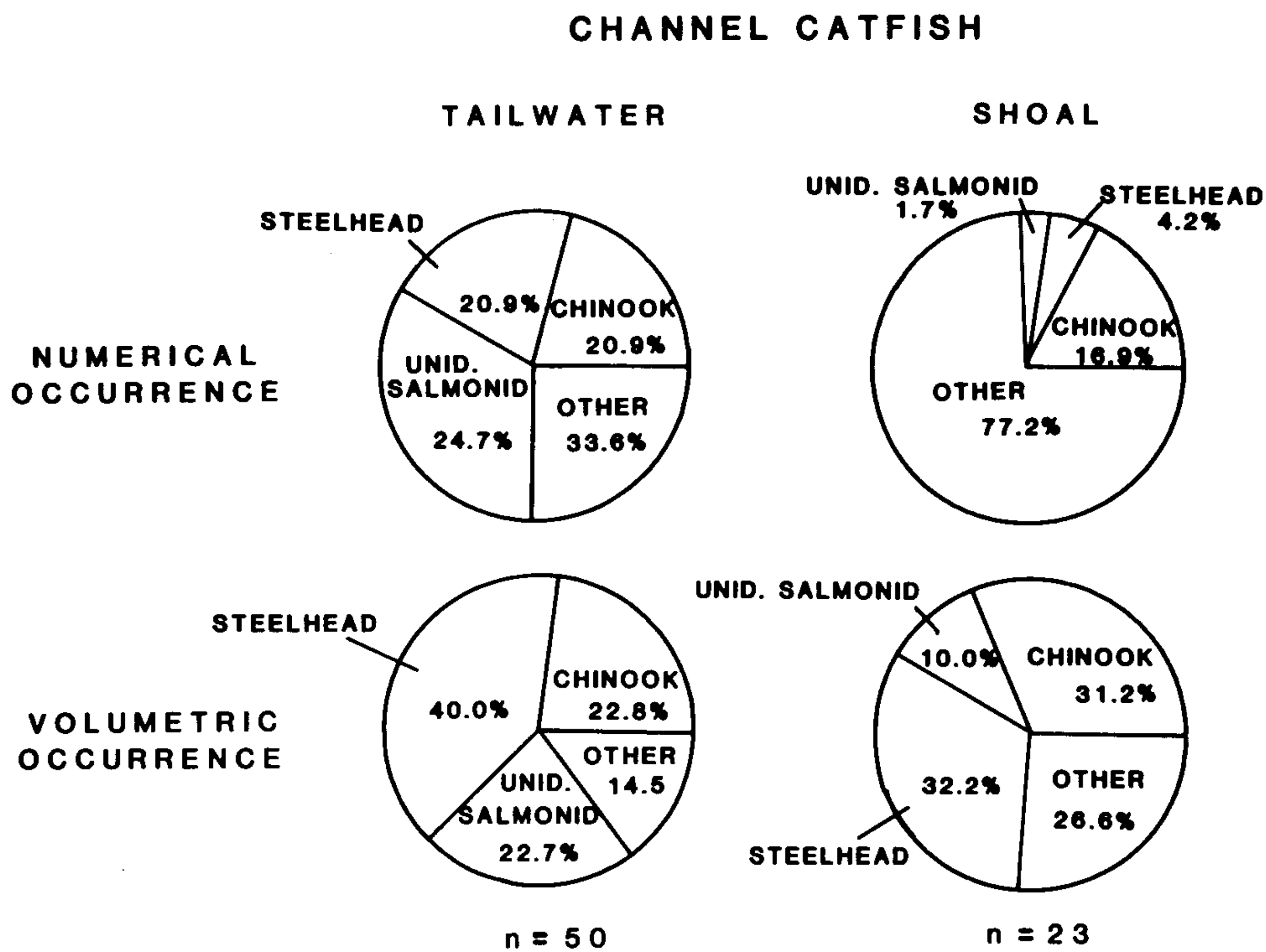

Figure 80. Numerical and volumetric occurrence (%) of salmonids and other food items in the diet of channel catfish collected April and May, 1980, from the tailwater and shoal habitats in Little Goose Reservoir, Washington.

Salmonid smolts were the most abundant food item in the diet of northern squawfish in April and May, 1980 (Fig. 81). Salmonids represented 30% of the total number and 67.1% of the total volume of food items. Based on the 21 stomachs examined, the incidence of predation on steelhead trout, chinook salmon, and unidentified salmonids was 19, 9.5%, and 14.3%, respectively.

Age and Growth

Smallmouth Bass

Age determinations were made on scales from 494 smallmouth bass (39-500 mm) from Little Goose Reservoir. The oldest scale examined had 13 annuli. The time of annulus formation occurred about June 14 to July 10. Younger, immature fish deposited an annulus during mid June, whereas older fish laid down an annulus in late June or early July.

Mean back-calculated lengths for all year classes ranged from 71 mm at age I to 497 mm at age XIII (Table 34). The model that provided the "best" fit between scale length and body length was:

$$\log BL = \log 0.5344 + 0.77066 (\log SL) \quad r^2 = 0.98$$

where:

BL = total length (mm)
SL = scale length (mm)

Smallmouth bass grew an average 71 to 54 mm a year during the first 5 years of growth and approximately 25 mm thereafter. The largest growth increments occurred during the first 2 years when the average increments of growth were 71 and 61 mm, respectively.

Growth of smallmouth bass generally was similar among year classes and reservoirs. We observed no trends in back-calculated mean lengths among year classes (Table 34). Back-calculated mean lengths at each

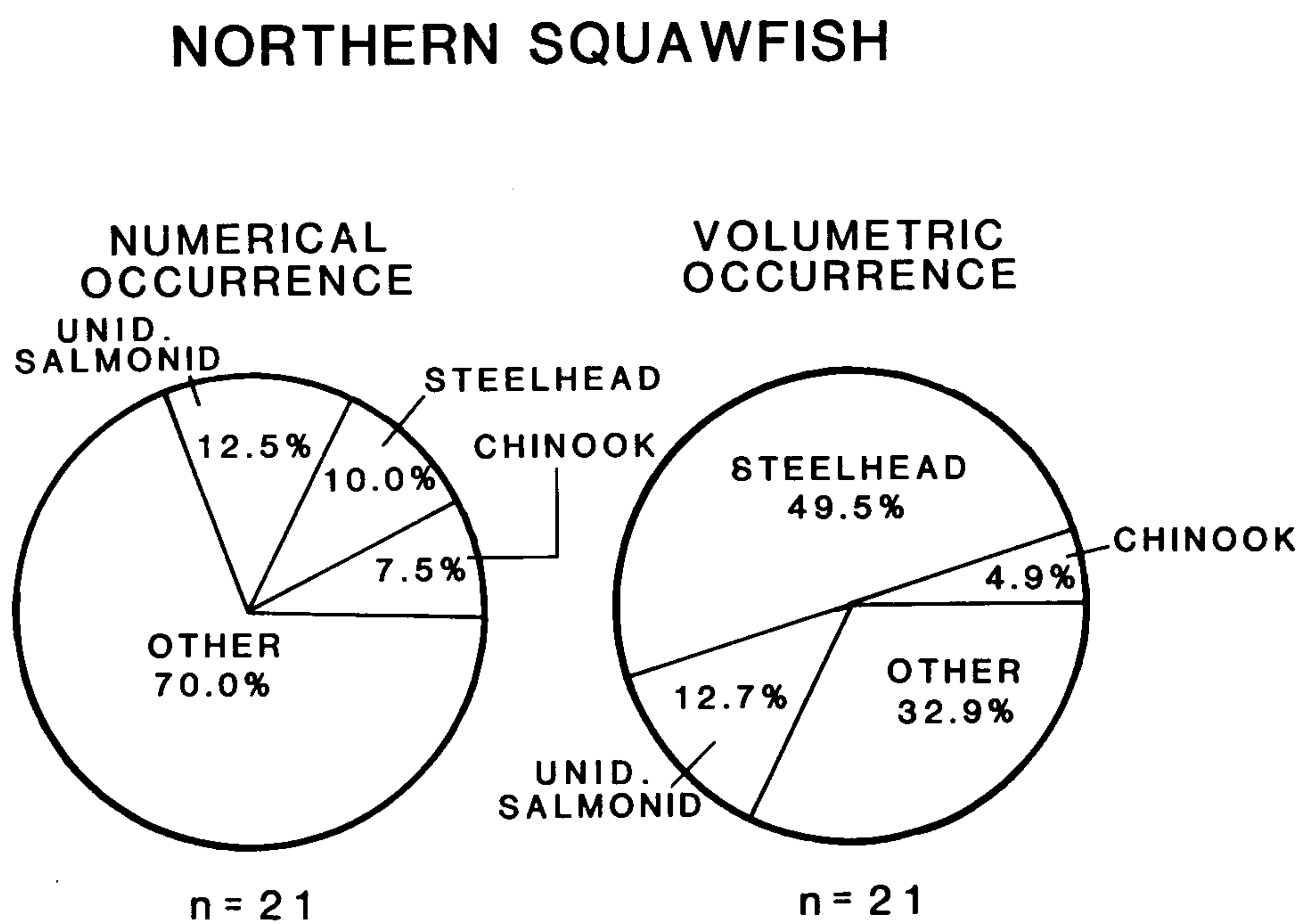

Figure 81. Numerical and volumetric occurrence (%) of salmonids and other food items in the diet of northern squawfish collected during April and May, 1980, from the tailwater habitat in Little Goose Reservoir, Washington.

Table 34. Backcalculated total lengths at annulus formation and annual increments of growth for smallmouth bass collected in 1979 and 1980 from Little Goose Reservoir.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
1979	143	-	86												
1978	4	31	57	134											
1977	28	47	68	124	191										
1976	32	98	61	131	181	236									
1975	19	19	62	133	199	249	293								
1974	8	6	60	130	195	259	308	358							
1973	8	8	68	141	192	240	295	328	348						
1972	4	15	73	145	200	245	295	338	365	387					
1971	5	7	74	145	210	259	297	328	363	386	400				
1970	2	2	75	146	204	260	298	328	352	378	394	422			
1969	2	2	65	124	178	233	276	323	357	388	418	420	422		
1968	0	2	83	174	262	331	364	385	405	422	439	451	465	477	
1967	1	1	69	162	229	302	338	374	404	422	446	456	469	479	497
Weighted Mean			71	132	190	244	298	336	363	390	411	434	454	478	497
Increment of growth			71	61	58	54	54	38	27	27	21	23	20	24	19
Number			494	347	288	209	92	65	51	39	19	10	6	4	1

annulus from Lower Granite, Lower Monumental, and Ice Harbor Reservoirs were similar to those for smallmouth bass from Little Goose Reservoir (Table 35). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of smallmouth bass from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 612\ (1-e^{-0.1258(t-(-0.0442)})$

Polynomial -- $l_t = 13.69+65.53(t)-2.205(t^2)$ $r^2 = 0.997$

where:

l_t = total length (mm) at time t.

Young-of-year smallmouth bass grew at an exponential rate from 9 August to 4 October, 1980. The instantaneous growth model was:

$l_t = 30.7\ (e^{0.0108(t)})$

where:

l_t = total length (mm) at time t (days)

Smallmouth bass in Little Goose Reservoir demonstrated allometric growth, increasing in length at a faster rate than growth in weight (Fig. 82). Condition factors for 1979 and 1980 and all seasons combined were not significantly different ($P<0.05$) between male ($k = 1.30$) and female ($k = 1.30$) bass. Body condition did vary seasonally and fish caught in the fall ($k = 1.36$) exhibited significantly higher ($P<0.05$) condition factors than those caught in the spring ($k = 1.27$) and summer ($k = 1.26$). Condition factors of bass caught in the tailwater ($k = 1.30$) and embayment ($k = 1.28$) were significantly higher ($P<0.05$) than that for smallmouth bass caught in the gulch ($k = 1.21$) habitat. Although condition factors of bass from the tailwater and embayment habitats were higher, condition factors were not statistically different than those from the shoal area ($k = 1.26$).

Table 35. Back-calculated total lengths (mm) at annulus formation for smallmouth bass collected in 1979 and 1980 from lower Snake reservoirs, Washington for 1979 and 1980.

		Mean Length				
Reservoir	Number	I	II	III	IV	V
Little Goose	494	71	132	190	244	298
Lower Granite	107	71	124	184	235	283
Lower Monumental	53	72	132	188	242	-
Ice Harbor	80	70	134	192	243	277

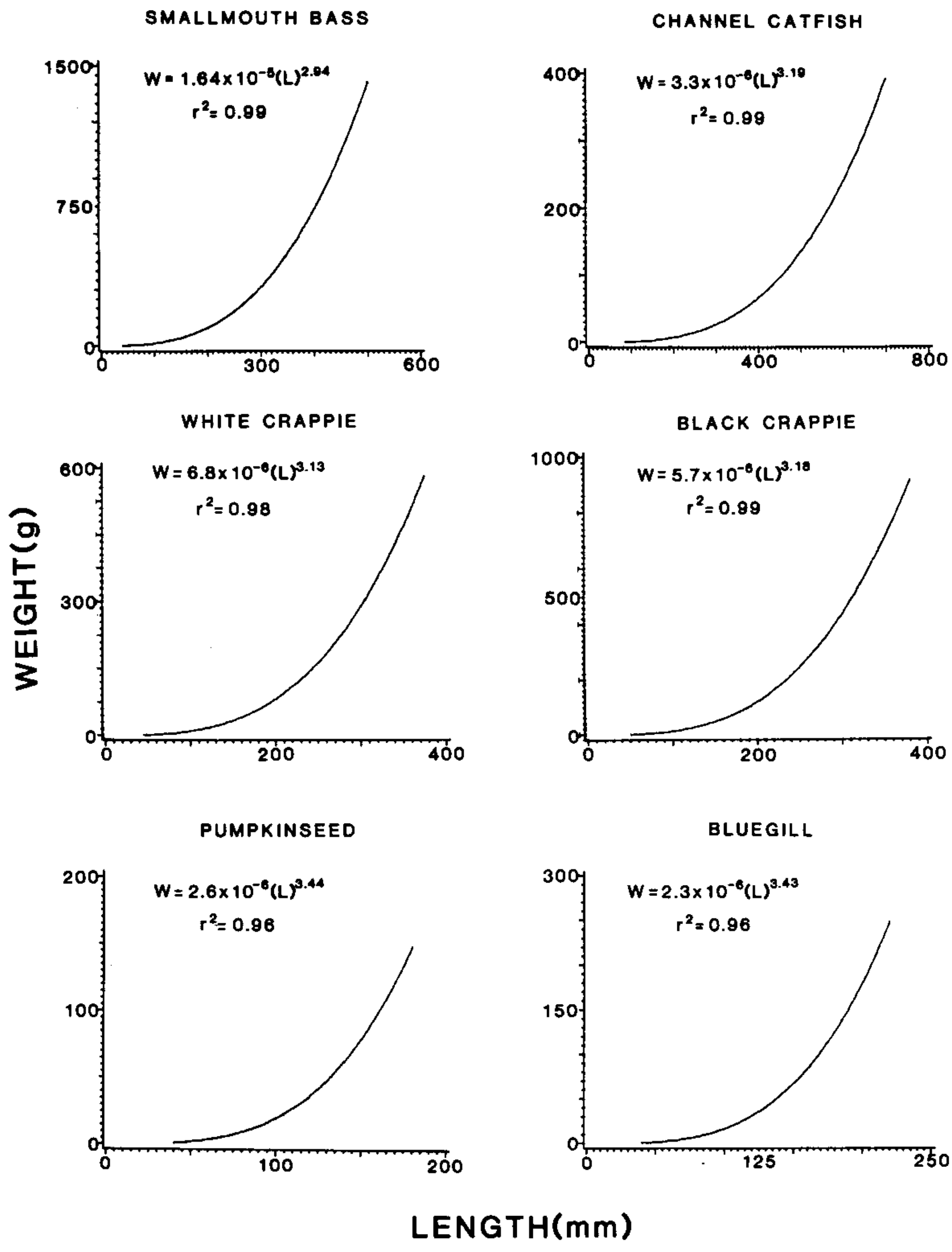

Figure 82. Length-weight relationships for smallmouth bass, channel catfish, white crappie, black crappie, pumpkinseed, and bluegill collected from Little Goose Reservoir, Washington, 1979 and 1980.

Largemouth Bass

Age determinations were made on scales from 11 largemouth bass (180-434 mm) from Little Goose Reservoir. The oldest fish examined had 7 annuli.

Back-calculated mean lengths for all year classes ranged from 85 mm at age I to 443 mm at age VII (Table 36). The model that provided the "best" fit between scale length and body length was:

$B_l = 35.7 + 0.69(SL) \quad r^2 = 0.95$

where:

BL = total length (mm)
SL = scale length (mm)

Growth increments of largemouth bass during the first 6 years of growth in Little Goose Reservoir were similar among years and averaged 85 to 60 mm a year. The longest increment of growth occurred during the first and third year (85 mm).

The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of largemouth bass from Little Goose Reservoir were:

von Bertalanffy - $l_t = 816\ (1-e^{-0.1178(t-0.16469)})$

Polynomial - $l_t = -8.86 + 90.27(t) - 3.51(t^2) \quad r^2 = 0.996$

where:

l_t = total length at time t.

White Crappie

Age determinations were made on scales from 385 white crappie (44-345 mm) from Little Goose Reservoir. The oldest scale examined had 8 annuli. Immature fish deposited an annulus in June, whereas older fish laid down an annulus in July.

Table 36. Backcalculated total length at annulus formation and annual increments of growth for largemouth bass collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII
1979	1	--	98						
1978	0	3	73	139					
1977	1	1	102	164	224				
1976	1	1	90	147	236	310			
1975	1	1	77	144	226	281	367		
1974	0	0	--	--	--	--	--	--	
1973	0	1	79	143	243	298	346	418	443
Weighted Mean			85	147	232	292	357	418	443
Increment of growth			85	62	85	60	65	61	25
Number			11	10	6	4	2	1	1

Mean back-calculated lengths for all year classes ranged from 72 mm at age I to 334 mm at age VIII (Table 37). The model that provided the "best" fit between scale length and body length was:

$$\log BL = \log 0.5345 + 0.7262 (\log SL) \quad r^2 = 0.97$$

where:

BL = total length (mm)
SL = scale length (mm)

White crappie grew an average 85 to 61 mm per year during the first 3 years of growth and 35 to 11 mm thereafter. The largest growth increments occurred during their first 2 years, when the average increments were 72 and 85 mm, respectively.

Growth of white crappie generally was similar among year classes and reservoirs. No trends in growth were found in either back-calculated mean lengths among year classes (Table 37) or among Lower Granite, Lower Monumental, and Ice Harbor reservoirs (Table 38).

The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of white crappie from Little Goose Reservoir were:

von Bertalanffy - $l_t = 346 (1-e^{-0.3655(t-0.62218)})$

Polynomial - $l_t = 24.55 + 69.24(t) - 4.09(t^2) \quad R^2 = 0.962$

where:

l_t = total length (mm) at time t.

Young-of-year white crappie grew at an exponential rate from 9 August to 6 November, 1980. The instantaneous growth model that described growth during this period was:

$$l_t = 23.1 (e^{0.0104(t)})$$

where:

Table 37. Backcalculated total lengths at annulus formation and annual increments of growth for white crappie collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII	VIII
1979	124	--	79							
1978	11	17	78	172						
1977	53	82	69	152	225					
1976	39	8	63	166	215	243				
1975	7	1	63	146	205	239	267			
1974	7	5	67	165	218	248	265	286		
1973	21	7	67	159	208	239	257	268	294	
1972	2	1	75	150	219	255	276	294	317	334
Weighted Mean			72	157	218	242	261	272	299	334
Increments of growth			72	85	61	24	19	11	27	35
Number			385	250	180	59	44	36	10	1

Table 38. Back-calculated total lengths (mm) at annulus formation for white crappie collected in 1979 and 1980 from lower Snake reservoirs, Washington, for 1979 and 1980.

		Mean length					
Reservoir	Number	I	II	III	IV	V	VI
Little Goose	385	72	157	218	242	261	272
Lower Granite	30	67	145	212	238	-	-
Lower Monumental	106	69	161	225	247	262	268
Ice Harbor	33	66	147	217	246	-	-

l_t = total length (mm) at time t (days)

White crappie from Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than growth in length (Fig. 82). Overall condition factors for all seasons did not vary significantly ($P>0.05$) between male ($k = 1.3$) and female ($k = 1.3$) crappie. Condition factors did vary seasonally, however, and white crappie caught in the fall ($k = 1.42$) exhibited significantly higher ($P<0.05$) condition factors than those in the spring ($k = 1.30$). Body condition of fish caught in the summer ($k = 1.32$) was not significantly different from those collected in the fall or spring. Condition factors of crappie caught in the embayment ($k = 1.33$), gulch ($k = 1.29$), shoal ($k = 1.31$), and tailwater ($k = 1.25$) also were similar ($P>0.05$).

Black Crappie

Age determinations were made on scales from 185 black crappie (52-406 mm) from Little Goose Reservoir. The oldest scale examined had 9 annuli. Immature fish laid down an annulus in June, whereas older fish laid down an annulus in July.

Mean back-calculated lengths for all year classes ranged from 73 mm at age I to 304 mm at age XI (Table 39). The model that provided the "best" fit between scale length and body length was:

$$\log BL = \log 0.3718 + 0.7679 (\log SL) \quad r^2 = 0.97$$

where:

BL = total length (mm)
SL = scale length (mm)

Black crappie grew an average of 74 mm a year during the first 2 years of growth and from 45 to 14 mm thereafter.

Table 39. Backcalculated total length at annulus formation and annual increments of growth for black crappie collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII	VIII	IX
1979	76	-	83								
1978	5	2	62	161							
1977	18	34	74	152	202						
1976	29	11	60	144	186	218					
1975	0	2	51	114	166	202	229				
1974	1	1	62	135	192	231	255	234			
1973	3	0	48	126	171	214	246	259	--		
1972	0	1	69	168	241	276	292	305	313	324	
1971	0	2	65	156	212	242	259	272	286	296	304
Weighted Grand Average			73	147	192	221	251	265	290	305	304
Increment of growth			73	74	45	29	30	14	25	15	
Number			185	104	84	21	10	7	3	3	2

Growth of black crappie generally was similar among year classes and reservoirs. We found no trends in growth among year classes based on back-calculated mean lengths (Table 39). Back-calculated mean lengths at each annulus for black crappie from Lower Granite, Lower Monumental, and Ice Harbor Reservoirs were similar to those for black crappie from Little Goose Reservoir (Table 40). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of black crappie from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 321\ (1-e^{-0.3552(t-0.4667)})$

Polynomial -- $l_t = 23.24 + 64.29(t) - 3.7(t^2)$ $R^2 = 0.991$

where:

l_t = total length (mm) at time t.

Black crappie in Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than the growth in length (Fig. 82). Condition factors for all seasons combined did not differ significantly ($P>0.05$) between male ($k = 1.50$) and female $k = 1.51$) crappie. Condition factors did differ seasonally, however, as crappie caught in the fall ($k = 1.53$) exhibited a significantly higher ($P<0.05$) condition factor than fish caught in the summer ($k = 1.45$). Mean condition factor of fish caught in the spring ($k = 1.47$) was not significantly different, however, from that for crappie caught in the fall or summer. Also, mean condition factors of crappie caught from the embayment ($k = 1.46$) gulch ($k = 1.47$), and tailwater ($k = 1.50$) were not significantly different ($P>0.05$).

Bluegill

Age determinations were made on scales from 285 bluegill (23-215 mm) from Little Goose Reservoir. The oldest scale examined had 7 annuli. The time of annulus formation was approximately mid July to mid August.

Table 40. Back-calculated total lengths (mm) at annulus formation for black crappie collected in 1979 and 1980 from the lower Snake reservoirs, Washington, for 1979 and 1980.

		Mean length			
Reservoir	Number	I	II	III	IV
Little Goose	185	73	147	192	221
Lower Granite	34	70	139	190	214
Lower Monumental	24	75	153	208	228
Ice Harbor	46	76	144	193	215

Mean back-calculated lengths for all year classes ranged from 35 mm at age I to 211 mm at age VII (Table 41). The model that provided the "best" fit between scale length and body length was:

$BL = 14.31 + 0.4671\ (SL)\quad r^2 = 0.99$

where:

BL = total length (mm)
SL = scale length (mm)

Bluegill grew an average 51 to 35 mm a year during the first 3 years of growth and decreased from 30 to 18 mm thereafter. The largest increment of growth (51 mm) occurred during the third year of growth.

Growth of bluegill was variable among year classes, but we found no trends in back-calculated mean lengths among year classes (Table 41). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of bluegill from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 294\ (1-e^{-0.1914(t-0.3447)})$

Polynomial -- $l_t = -18.86+54.76(t)-3.17(t^2)\qquad R^2 = 0.996$

where:

l_t = total length (mm) at time t.

Young-of-year bluegill grew at an exponential rate from 23 August to 6 November, 1980. The instantaneous growth model that described their first year growth was:

$l_t = 18.1\ (e^{0.0058(t)})$

where:

l_t = total length (mm) at time t (days)

Bluegill from Little Goose Reservoir exhibited allometric growth, increasing in weight at a faster rate than growth in length (Fig. 82). Condition factors for all seasons did not vary significantly ($P>0.05$)

Table 41. Backcalculated total lengths at annulus formation and annual increments of growth for bluegill in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII
1979	172	--	37						
1978	0	5	41	82					
1977	3	47	30	64	126				
1976	5	22	33	79	126	166			
1975	6	22	32	76	114	142	174		
1974	1	0	32	61	92	137	174		
1973	0	2	33	62	97	146	173	193	211
Weighted Mean			35	71	122	152	174	193	211
Increment of growth			35	36	51	30	22	19	18
Number			285	113	105	53	25	2	2

between male ($k = 2.25$) and female ($k = 2.13$) bluegill. Also, body condition did not vary significantly ($P>0.05$) among spring ($k = 1.96$), summer ($k = 2.14$), and fall ($k = 2.22$). Condition factors of bluegill were not significantly different ($P>0.05$) between embayment ($k = 2.14$) and gulch ($k = 2.10$) areas.

Pumpkinseed

Age determinations were made on scales from 245 pumpkinseed (48-173 mm) in Little Goose Reservoir. The oldest fish examined was 6 years old. Time of annulus formation was approximately late July or early August.

Mean back-calculated lengths for all year classes ranged from 44 mm at age I to 166 mm at age VI (Table 42). The model that provided the "best" fit between scale length and body length was:

$$BL = 15.6 + 0.4346\ (SL) \quad r^2 = 0.96$$

where:

BL = total length (mm)
SL = scale length (mm)

Pumpkinseed grew an average 44 to 33 mm a year during the first 3 years of growth and 20 to 17 mm thereafter. The longest increment of growth (44 mm) occurred during their first year.

Growth of pumpkinseed generally was similar among year classes. No trends were found in back-calculated mean lengths among year classes (Table 42).

The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of pumpkinseed from Little Goose Reservoir were:

Table 42. Backcalculated total lengths at annulus formation and annual increments of growth for pumpkinseed collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI
1979	166	--	46					
1978	0	6	38	77				
1977	1	18	39	71	117			
1976	9	22	38	77	105	130		
1975	13	7	42	86	111	128	144	
1974	1	2	37	76	113	134	151	166
Weighted Mean			44	77	110	129	146	166
Increment of growth			44	33	33	19	17	20
Number			245	79	72	45	10	2

von Bertalanffy -- $l_t = 244\ (1-e^{-0.18457(t-0.0959)})$

Polynomial -- $l_t = 6.9+40.0(t)-2.30(t^2)$ $R^2 = 0.997$

where:

l_t = total length (mm) at time t (days).

Pumpkinseed in Little Goose Reservoir manifested allometric growth, increasing in weight at a faster rate than the growth in length (Fig. 82). Condition factors for all seasons and years combined did not vary significantly ($P>0.05$) between male ($k = 2.37$) and female ($k = 2.35$) fish. Condition factors did vary seasonally, however. Fish collected in the fall ($k = 2.36$) exhibited significantly ($P<0.05$) higher condition factors than pumpkinseed caught in the spring ($k = 2.24$). Body condition of fish caught in the summer ($k = 2.24$) was not significantly different than that for fish caught in the spring or fall. Condition factors of pumpkinseed caught in the embayment ($k = 2.31$) were significantly higher ($P<0.05$) than that for fish caught in the gulch habitat ($k = 2.22$).

Yellow Perch

Age determinations were made on scales from 150 yellow perch (30-274 mm) from Little Goose Reservoir. The oldest fish examined had 6 annuli. Time of annulus formation was from late May to early June.

Mean back-calculated lengths for all year classes ranged from 36 mm at age I to 218 mm at age VI (Table 43). The model that provided the "best" fit between scale length and body length was:

$\log BL = \log 0.4112 + 0.76119\ (\log SL)$ $r^2 = 0.98$

where:

BL = total length (mm)
SL = scale length (mm)

Yellow perch grew an average 36 and 56 mm a year during the first 2

Table 43. Backcalculated total lengths at annulus formation and annual increments of growth for yellow perch collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI
1979	22	--	38					
1978	9	20	36	96				
1977	4	8	34	86	116			
1976	2	4	35	89	131	180		
1975	35	24	35	93	129	164	206	
1974	6	12	36	90	129	166	193	218
1973	4	0	39	98	129	172	195	216
Weighted Mean			36	92	128	165	200	218
Increment of growth			36	56	36	37	35	18
Number			150	119	95	85	46	16

years of growth and approximately 36 mm thereafter to their 6th year. After the 6th year, growth declined to 18 mm.

Growth of yellow perch was generally similar among year classes. No trends in growth were found in back-calculated mean lengths among year classes (Table 43). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of yellow perch from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 311(1-e^{-0.2196(t-0.4657)})$

Polynomial -- $l_t = -19.6+60.56(t)-3.46(t^2)$ $R^2 = 0.998$

where:

l_t = length at time t (mm).

Yellow perch in Little Goose Reservoir demonstrated allometric growth, increasing in weight faster than the growth in length (Fig. 83). Overall condition factors for all seasons were significantly higher ($P<0.05$) between female (k = 1.32) and male (k = 1.22) perch. Condition factors did not differ significantly ($P>0.05$) between spring (k = 1.19), summer (k = 1.21), and fall (k = 1.24). Mean condition factor of perch caught in the embayment (k = 1.30) was significantly higher ($P<0.05$) than those collected in the gulch (k = 1.10) and shoal (k = 1.08) areas.

Channel Catfish

Age determinations were made on spines from 247 channel catfish (104-810 mm) in Little Goose Reservoir. The oldest spine examined had 16 annuli. The time of annulus formation occurred about mid July to mid August.

Mean back-calculated lengths for all year classes ranged from 66 mm at age I to 665 mm at age XVI (Table 44). The model that provided the "best" fit between spine diameter and body length was:

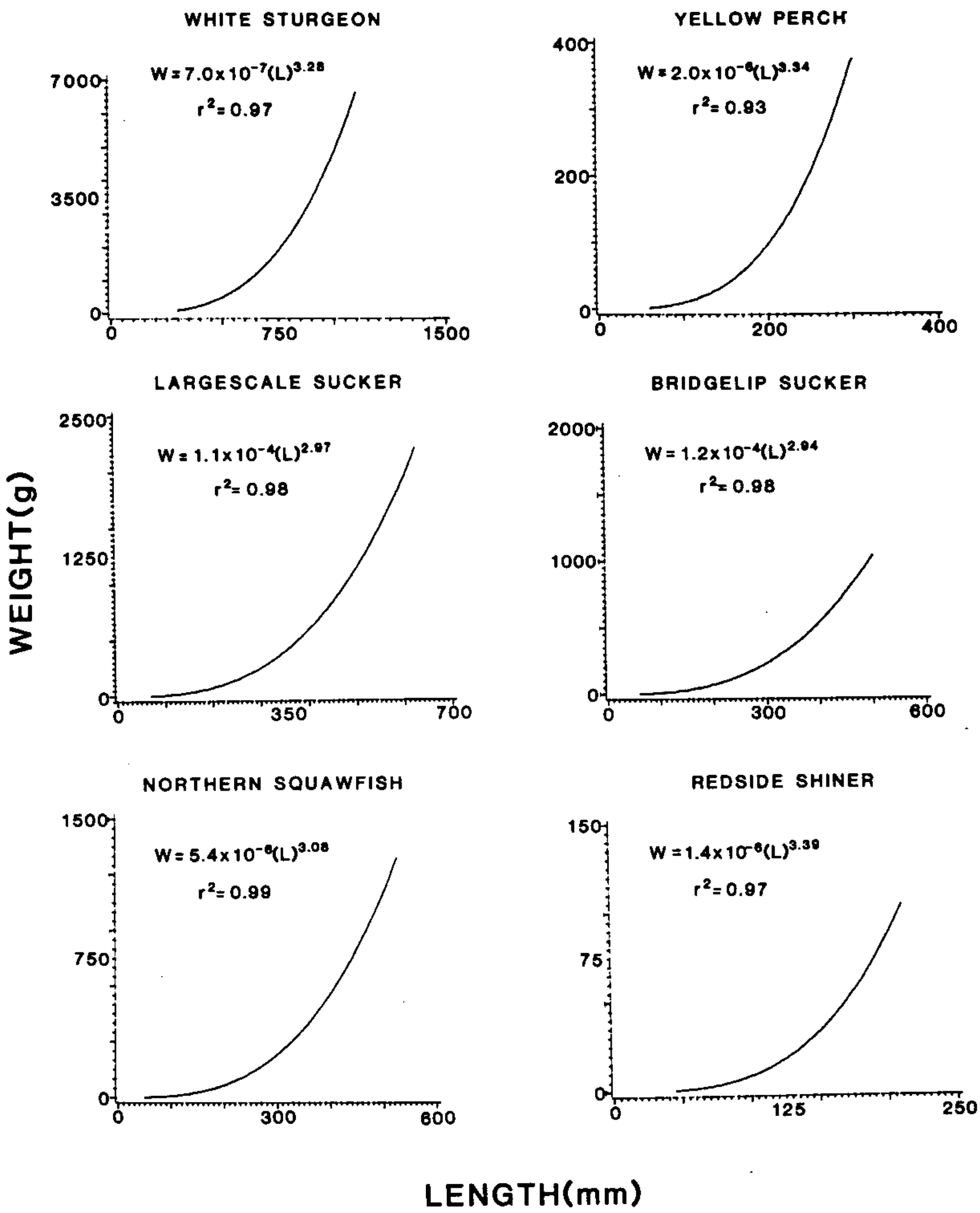

Figure 83. Length-weight relationships for white sturgeon, yellow perch, largescale sucker, bridgelip sucker, northern squawfish, and redside shiner collected from Little Goose Reservoir, Washington, 1979 and 1980.

Table 44. Backcalculated total lengths at annulus formation and annual increments of growth for channel catfish collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
1979	1	--	73															
1978	0	18	76	180														
1977	2	41	42	107	226													
1976	4	13	62	147	221	313												
1975	2	8	56	120	222	301	383											
1974	10	19	70	129	199	296	361	425										
1973	2	16	74	135	213	285	365	426	481									
1972	13	60	70	138	218	285	346	410	452	497								
1971	5	20	74	129	205	273	329	377	429	463	477							
1970	0	3	69	120	169	232	287	335	391	439	477	503						
1969	1	4	68	111	156	195	257	304	345	381	409	430	458					
1968	0	0	-	-	-	-	-	-	-	-	-	-	-	-				
1967	1	3	102	160	198	244	287	321	351	368	403	426	450	472	448			
1966	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
1965	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1964	0	1	73	146	246	321	390	438	485	520	536	582	593	613	629	644	655	665
Weighted Mean			66	133	213	284	345	401	442	476	460	457	469	500	493	644	655	665
Increment of growth			66	67	80	71	61	56	41	34			12	31			15	10
Number			247	246	226	181	166	148	127	98	33	13	9	5	4	1	1	1

$$\log BL = \log 0.3199 + 1.0329 (\log SL) \quad r^2 = 0.85$$

where:

BL = total length (mm)
SL = spine diameter (mm)

Channel catfish grew an average 80 to 56 mm a year during the first 6 years of growth and 41 to 10 mm thereafter. The maximum average growth increment (80 mm) occurred during the third year.

Growth of channel catfish was variable among year classes and among reservoirs. Generally, back-calculated mean lengths from the 1979 to 1969 year classes decreased (Table 44). Back-calculated mean lengths at each annulus for fish from Lower Monumental Reservoir were similar to those of channel catfish from Little Goose Reservoir, whereas mean lengths of catfish from Ice Harbor Reservoir were smaller at each age (Table 45). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of channel catfish from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 540\ (1-e^{-0.2069(t-0.0407)})$

Polynomial -- $l_t = -50.98 + 107.80(t) - 5.55(t^2) \quad R^2 = 0.993$

where:

l_t = total length (mm) at time t.

Channel catfish in Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than the growth in length (Fig. 82). Condition factors for all seasons combined were not significantly different (P>0.05) between male (k = 1.10) and female (k = 1.11) catfish. Also, condition factors of fish caught in the spring (k = 1.05) were not significantly different (P>0.05) from those for catfish caught in the summer (k = 1.05). Condition factors of channel catfish collected from the embayment (k = 1.08), gulch (k = 1.09), shoal (k =

Table 45. Back-calculated total lengths (mm) at annulus formation for channel catfish collected in 1979 and 1980 from lower Snake reservoirs, Washington, for 1979 and 1980.

		Mean length											
Reservoir	Number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Little Goose	247	66	133	213	284	345	401	442	476	460	457	469	500
Lower Monumental	28	75	140	212	275	329	389	427	463	457	520	512	504
Ice Harbor	31	51	98	159	199	249	283	312	365	360	383	425	455

1.09), and tailwater (k = 1.09) habitats were not significantly different ($P>0.05$).

Redside Shiner

Age determinations were made on scales from 242 redside shiners (44-222 mm) from Little Goose Reservoir. The oldest scale examined had 6 annuli. Time of annulus formation was approximately from late June to early July.

Mean back-calculated lengths for all year classes ranged from 59 mm at age I to 182 mm at age VI (Table 46). The model that provided the "best" fit between scale length and body length was:

$$\log BL = \log 0.4915 + 0.7888 (\log SL) \quad r^2 = 0.95$$

where:

BL = total length (mm)
SL = scale length (mm)

Redside shiners grew an average 59 to 34 mm a year during the first 3 years of growth and 17 mm thereafter. The largest growth increment (59 mm) occurred during the first year.

Growth of redside shiners generally was similar among year classes and reservoirs. No trends in growth were found in back-calculated mean lengths among year classes (Table 46). Back-calculated mean lengths at each annulus from Lower Granite, Lower Monumental, and Ice Harbor Reservoirs were similar to those for redside shiners from Little Goose Reservoir (Table 47). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of redside shiners from Little Goose Reservoir were:

$$\text{von Bertalanffy -- } l_t = 202\ (1-e^{-0.4801(t-0.2897)})$$

$$\text{Polynomial -- } l_t = -2.0 + 69.6(t) - 6.64(t^2) \qquad R^2 = 0.995$$

Table 46. Backcalculated total length at annulus formation and annual increments of growth for redside shiner collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V
1979	75	--	64				
1978	3	25	56	104			
1977	12	22	57	112	149		
1976	48	40	57	118	150	168	
1975	11	3	55	108	138	158	175
1974	1	2	58	103	139	166	192
Weighted Mean			59	114	148	165	182
Increments of growth			59	55	34	17	17
Number			242	164	127	57	5

Table 47. Back-calculated total lengths (mm) at annulus formation for redside shiner collected during 1979 and 1980 from the lower Snake reservoirs, Washington.

		Mean length			
Reservoir	Number	I	II	III	IV
Little Goose	242	59	114	148	165
Lower Granite	35	59	118	153	168
Ice Harbor	37	56	114	148	165

where:

l_t = total length (mm) at time t.

Young-of-year redside shiners grew exponentially from 9 August to 6 November, 1980. The instantaneous growth model that described daily growth was:

$$l_t = 30.8\ (e^{0.0072(t)})$$

where:

l_t = total length (mm) at time t (days)

Redside shiners in Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than growth in length (Fig. 83). Female shiners (k = 1.10) exhibited significantly higher ($P<0.05$) condition factors than males (k = 0.97). No seasonal differences in condition factors were found (spring, k = 1.05; summer, k = 0.97; and fall, k = 0.94). Condition factors of shiners from the embayment habitat (k = 1.00) were significantly higher ($P< 0.05$) than those from the shoal area (k = 0.94); however, condition factors of shiners from tail-water (k = 0.98) and gulch areas (k = 0.96) were not significantly different ($P>0.05$) from embayment and shoal areas.

Northern Squawfish

Age determinations were made on scales from 208 northern squawfish (40-530 mm) from Little Goose Reservoir. The oldest scale examined had 9 annuli. Time of annulus formation was approximately mid June to early July.

Mean back-calculated lengths for all year classes ranged from 59 mm at age I to 428 mm at age IX (Table 48). The model that provided the "best" fit between scale length and body length was:

Table 48. Backcalculated total lengths at annulus formation and annual increments of growth for northern squawfish collected in 1979 and 1980 from Little Goose Reservoir, Washington.

Year Class	Number 1979	Number 1980	Mean Length (mm) I	II	III	IV	V	VI	VII	VIII	IX
1979	17	-	56								
1978	3	10	60	157							
1977	22	9	59	138	209						
1976	15	8	60	139	206	234					
1975	10	17	62	133	203	257	304				
1974	20	11	57	128	199	259	298	326			
1973	16	12	58	139	207	260	301	327	352		
1972	13	12	62	148	222	271	315	353	388	408	
1971	8	5	58	142	210	261	307	348	380	406	417
Weighted Mean			59	139	207	260	304	339	377	406	428
Increment of growth			59	80	68	53	44	35	38	29	22
Number			208	188	156	132	114	77	50	25	5

$$\log BL = \log 0.48094 + 0.8628 (\log SL) \quad r^2 = 0.97$$

where:

BL = total length (mm)
SL = scale length (mm)

Northern squawfish grew an average 80 to 53 mm a year during their first 4 years of growth and 44 to 22 mm thereafter. The largest growth increment (80 mm) occurred during the second year.

Growth of northern squawfish generally was similar among year classes. No trends in growth were found in back-calculated mean lengths among year classes (Table 48). The von Bertalanffy and second degree polynomial growth models developed from the back-calculated mean lengths of northern squawfish from Little Goose Reservoir were:

von Bertalanffy -- $l_t = 544 (1-e^{-0.1780(t-0.3624)})$

Polynomial -- $l_t = -13.90 + 82.64(t) - 3.77(t^2) \quad R^2 = 0.999$

where:

l_t = total length (mm) at time t.

Young-of-year northern squawfish grew at an exponential rate from 10 August to 6 November, 1980. The instantaneous growth model that described daily growth was:

$l_t = 30.2 (e^{0.00698(t)})$

where:

l_t = total length (mm) at time t (days).

Northern squawfish in Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than growth in length (Fig. 83). Condition factors for all seasons combined did not differ significantly ($P>0.05$) between male ($k = 0.93$) and female ($k = 0.93$) squawfish. Condition factors also were similar ($P>0.05$) among seasons (fall--k = 0.90; summer--k = 0.91; and, spring--k 0.90). Condition factors of squawfish collected in the embayment (k = 0.92), gulch (k = 0.91), shoal (k = 0.92), and tailwater (k = 0.89) were similar (P>0.05).

Brown Bullhead

Age determinations were made on 66 brown bullhead spines from Little Goose Reservoir (Table 49). The brown bullheads collected ranged from III to VIII years old with considerable overlap in lengths between age classes.

White Sturgeon

Age determinations were made on 48 white sturgeon (523-1050 mm) from Little Goose Reservoir (Table 50). White sturgeon ranged from age IV to XII with considerable overlap in lengths between age classes.

White sturgeon in Little Goose Reservoir demonstrated allometric growth, increasing in weight at a faster rate than length (Fig. 83).

Bridgelip Sucker

Bridgelip suckers in Little Goose Reservoir manifested allometric growth, increasing in length at a faster rate than growth in weight (Fig. 83). Condition factors for all seasons combined did not differ significantly (P>0.05) between male (k = 1.08) and female (k = 1.08) suckers. Also, no significant (P>0.05) seasonal (spring--k = 1.00, summer--k = 0.98, fall--k = 1.01) or habitat (deepwater--k = 1.03, embayment--k = 0.98, shoal--k = 1.00, tailwater--k = 1.02) differences were found.

Largescale sucker

Largescale suckers from Little Goose Reservoir also demonstrated allometric growth, increasing in length at a faster rate than the growth

Table 49. Total length (mm) and age of brown bullheads collected from Little Goose Reservoir, Washington. Bullheads were collected during 1979 and 1980.

Age	Mean Length	Range	n
3	226	181-282	17
4	282	232-319	10
5	297	238-344	23
6	316	238-347	11
7	319	297-349	3
8	295	290-300	2

Table 50. Total length (mm) and age of white sturgeon collected from Little Goose Reservoir, Washington. Sturgeon were collected during 1979 and 1980.

Age	Mean Length	Range	n
4	698	585-815	3
5	699	528-1030	4
6	653	572-791	9
7	660	523-810	13
8	727	708-818	7
9	842	815-868	2
10	882	830-929	5
11	1032	940-1050	3
12	878	850-950	2

in weight (Fig. 83). Condition factors for all seasons combined did not vary significantly ($P>0.05$) between male ($k = 0.99$) and female ($k = 0.98$) largescale suckers. Condition factors of fish caught in the spring ($k = 0.93$), summer ($k = 0.92$), and fall ($k = 0.91$) also were not statistically different ($P>0.05$). Condition factors were significantly higher ($P<0.05$), however, for fish caught in the deepwater ($k = 0.96$) that those for fish from the shoal ($k = 0.91$) and tailwater ($k = 0.92$) areas. Condition factors of largescale suckers caught in the gulch ($k = 0.93$) and embayment ($k = 0.93$) were not significantly different from those for fish from deepwater, shoal, and tailwater areas.

Chinook Salmon

Young-of-year chinook salmon in Little Goose Reservoir grew at an exponential rate from 12 April to 17 June, 1980. The instantaneous growth model that best described their growth was:

$$l_t = 43\ (e^{0.0077(t)})$$

where:

l_t = total length at time t (days).

American Shad

Young-of-year American shad collected from Little Goose Reservoir grew exponentially from 21 August to 7 November. The instantaneous growth model that best described their freshwater growth was:

$$l_t = 37.2\ (e^{0.0101(t)})$$

where:

l_t = total length at time t (days).

DISCUSSION

Food Habits

Smallmouth Bass

Food habits of smallmouth bass in the lower Snake reservoirs are similar to those of smallmouth bass throughout the United States and Canada. Crayfish, fish terrestrial insects, and aquatic insects have been reported as major food items of smallmouth bass (Doan 1940, Watt 1959, Applegate et al. 1966, Mullan and Applegate 1968, Keating 1970, Forney 1972, Aggus 1971). Crayfish have been reported as the most important food item of smallmouth bass (Watt 1959, Applegate et al. 1966, Fedoruk 1966, Keating 1970, Forney 1972), but when absent or less abundant, fish are usually the most important food item (Doan 1940, Surber 1940, Mullan and Applegate 1968, Keating 1970). Crayfish was the major food item of smallmouth bass in the lower Snake reservoirs (Figs. 52-56, Table 25). The dominance of crayfish as a food item varied little among seasons and habitats. A preference for crayfish is probably related to their availability (Keating 1970) and vulnerability (Lewis et al. 1961, Lewis and Helms 1964, Stein and Magnuson 1976, Stein 1977).

Major food items of smallmouth bass in the lower Snake reservoirs are similar to those of smallmouth bass prior to dam construction, although diet composition and relative abundance has changed with impoundment. Keating (1970) examined food habits of smallmouth bass in the Snake River from Lewiston, Idaho to 145 km upstream. He found that crayfish, fish, terrestrial insects, and aquatic insects occurred in 58, 13, 16, and 21% respectively, of the stomachs which contained food. We found the same food items in smallmouth bass collected from Little Goose Reservoir, although the abundance of fish increased (32%) while the abundance of insects declined (terrestrial 7%, aquatic 6%). The higher incidence of fish and lower frequency of occurrence of aquatic and terrestrial insects in the diet of smallmouth bass from Little Goose Reservoir probably reflects differences in abundance and diversity of food items associated with changes from a lotic to lacustrine environment. For example, Keating (1970) found that dace, shiners, small suckers, and juvenile smallmouth bass were fishes consumed by bass while we found that sculpins, white crappies, redside shiners, northern squawfish, catfish, bluegill, yellow perch, chinook salmon, bridgelip sucker, and pumpkinseed were eaten by bass in Little Goose Reservoir. Although a few dace were collected in Little Goose Reservoir (Table 15), their low abundance is probably the reason why they were absent from the diet of smallmouth bass. Also, emerging Ephemeroptera, Plecoptera, and Odonata were the major aquatic insects in the diet of bass prior to dam construction (Keating 1970), while bass collected from Little Goose Reservoir contained primarily chironomid pupae and larvae.

White Crappie

White Crappies from other areas of their range feed mostly on entomostraca (Evers and Boesel 1935, Nurnberger 1930, Nelson et al. 1967, Siefert 1968), whereas insects and fish have been reported to be important food items of larger crappies (Hoopes 1960). All of these items also were important food items of white crappies from Little Goose Reservoir (Figs. 57-60). Cladocerans were the dominant food items of white crappie in Little Goose and other lower Snake reservoirs (Fig. 61). We found that dietary items varied seasonally. Cladocerans were most important in the diet in the summer, whereas fish increased in importance in the fall. The diet of white crappie from embayment and gulch habitats was generally similar, while crappies from the shoal habitat consumed a greater proportion of aquatic insects (Figs. 58-60).

Black Crappies

Food habits of black crappie in Little Goose Reservoir were similar to those for white crappie (Fig. 62). Cladocerans, aquatic insects and fish were the most important food items. The abundance of cladocerans in the diet increased from spring to fall, while aquatic insects decreased in abundance during this period. Black crappies from other waters also feed on entomostracans, insects and fish (Carlander 1977). Several authors have reported that entomostracans are consumed by young crappies (Ball and Kilambi 1973, Tucker 1973), whereas fish and aquatic insects increase in importance as black crappies get older (Ball and Kilambi 1970, Huish 1957, Lux and Smith 1960).

Channel Catfish

Dietary components of channel catfish from Little Goose Reservoir demonstrated their omnivorous feeding habit. A fairly high percentage (33%) of the stomachs examined were empty. The proportion of empty stomachs increased from spring (17.8%) to summer (37.3%).

Food items of channel catfish varied seasonally and by habitat. Fish were the major food item in the spring, whereas crayfish, aquatic insects and cladocerans were major items in the summer (Fig. 63). Crayfish were more important in up-river habitats (tailwater and shoal, Figs. 64 and 65) while chironomid larvae and pupae were relatively more important in embayment (Fig. 66) and gulch (Fig. 67) habitats. The abundance of aquatic insects in stomachs of channel catfish decreased with an increase in abundance of cladocerans. Our findings that fish, aquatic insects, and crayfish are important dietary items agrees with those reported by Bailey and Harrison (1945). Hoopes (1960) found that aquatic insects were the major dietary component of channel catfish from the Mississippi River, whereas in Little Goose Reservoir they were absent in channel catfish from the tailwater habitat.

Redside Shiners

Food items of redside shiners varied seasonally and between upper and lower reservoir zones (Fig. 68). Insects were consistently present, although aquatic insects predominated in occurrence. Cladocerans were the single most important food item (Fig. 69 and 70). Few differences in dietary components were found between reservoirs (Fig. 71). Dietary items of redside shiners were similar to those reported by Scott and Crossman (1973), with the exception that we did not find fish eggs in their diet. Few differences in the diet of redside shiners are found between Little Goose and Ice Harbor reservoirs.

Northern Squawfish

Greater than one-third of all northern squawfish stomachs examined were empty. The highest number of empty stomachs was observed during spring and summer (37%).

Food items of northern squawfish varied by season and location in Little Goose Reservoir (Fig. 72). Fish was the major food item of northern squawfish from the tailwater area in the spring (Table 33) while crayfish and aquatic insects were important in the shoal and lower reservoir (Figs. 73 and 74). The increase in cladocerans in their diet probably reflected an increase in availability in the lower reservoir in the summer and fall.

Largescale Suckers

Major dietary items of largescale sucker varied little by season and habitat. Diatoms were the single most important food item (Figs. 75 and 76). Detritus was second in abundance and much of this material was probably incidental to the consumption of the actual food items. Blue-green algae was third in importance and increased in importance from spring to winter.

Bridgelip Sucker

The dietary items in bridgelip suckers were similar to those of largescale suckers. Diatoms and detritus were the major food items while algae was of lesser importance (Fig. 77). Two of the genera of diatoms (*Melosira* sp. and *Fragilaria* sp.) were found in the stomachs of both species of suckers. The bridgelip suckers we examined contained fewer insect larvae than those collected from the flowing portion of the Columbia River (Dauble 1980) while other items were similar.

Diel Food Habits

White Crappie

Food items consumed by white crappie varied little throughout a 24-hour period. Cladocerans (the major food item) and unidentified fish decreased from 0600 to 2500 hours (Fig. 78). Also, we found significantly less food in the stomachs from 1800-2400 hours than the morning (0600-1200) period.

Channel Catfish

Although the percentage of empty stomachs increased from 0600-1200 (17.3%) to 2400-0600 (30.6%), mean volume of food in channel catfish stomachs was similar. Most major items demonstrated little variation in importance throughout the 24-hour period (Fig. 79). Cladocerans and aquatic insects were the major food items found in channel catfish during this period.

Resident Fish Predation on Juvenile Salmonid Smolts

Smallmouth Bass

Our results indicated that smallmouth bass were not a major predator on chinook salmon and steelhead trout in Little Goose Reservoir. All fish eaten by smallmouth bass had a mean length of 80 mm, whereas chinook salmon and steelhead trout generally average about 150 mm and 190 mm, respectively (Rudy Ringe, University of Idaho, Moscow). If our samples for stomach analysis were representative of the size structure of bass in the population, then few bass would be feeding on fish as large as chinook salmon or steelhead smolts. However, based on our participation in the Bass Tournament in Little Goose Reservoir (Objective 1), we found that we didn't sample the larger bass in the population. These larger bass may be more effective predators on juvenile anadromous fishes but are comparatively fewer in number. Our estimation that about 2% of the smallmouth bass consumed smolts was probably an underestimate but also reflects a low level of predation. Smolt consumption in the John Day Reservoir is reportedly higher than 2%, however (Jerry Gray, U.S. Fish and Wildlife Service, Cook, WA). One possible reason for the low occurrence of smolts in the diet of smallmouth bass in Little Goose, and presumably other lower Snake reservoirs is a result of the low water temperature during April and May. Water temperatures during this period in the lower Snake reservoirs ranged from 8 to 14 C. Smallmouth bass don't feed below 10 C and their metabolism is low at those temperatures. Therefore, we believe that smolt predation by smallmouth bass in the lower Snake reservoirs during April and May does not appear to be a significant source of smolt mortality.

Channel Catfish

Approximately 41% of the channel catfish collected during the spring in tailwater and shoal areas contained chinook salmon and steelhead trout smolts (Fig. 80). Salmonid smolts were the most abundant food items of channel catfish at these areas in the spring. Salmonid fishes accounted for a higher proportion of food items in channel catfish stomachs at the tailwater area than in the shoal area. Seventy-two percent of the channel catfish examined at the tailwater (n = 50) consumed some salmonid, while at the shoal (n = 25) about 35% consumed smolts. These data are probably representative of the intensity of predation on salmonid smolts because we sampled a wide range of sizes of channel catfish (365-635 mm). Also of interest was the high average number of steelhead ($\bar{x}$ = 3.1) and chinook salmon ($\bar{x}$ = 3.8) in channel catfish that consumed smolts.

The timing of the smolt migration over Lower Granite Dam coincides with an up-reservoir migration by channel catfish. Our spring samples indicate considerably higher catch per effort of channel catfish in the tailwater in the spring (Fig. 34). This movement may be in response to a potentially abundant and readily available food supply in the smolts or be coincidental. Regardless of the reason for increased abundance of catfish in the tailwater area in the spring, occurrence of smolts in stomachs of channel catfish should be of concern to resource managers. Although we have found that channel catfish consumed smolts in the tailwater and shoal areas of Little Goose Reservoir, our data do not indicate the nature of that feeding. For example, Bailey and Harrison

(1945) reported that fish were the dominant food item of channel catfish longer than 305 mm, whereas insects were the dominant food item for smaller catfish. This would suggest that catfish are actively preying on fish within the water column rather than feeding on the bottom. If bottom feeding occurred in shoal and tailwater areas, channel catfish probably would be feeding on dead or moribund smolts. The nature of channel catfish predation on smolts in Little Goose Reservoir only can be based on speculation at the present and additional study is required before we conclude that channel catfish are significant predators on salmonid smolts.

Northern Squawfish

Our limited samples (n = 21 with food) demonstrated that northern squawfish consume smolts. The frequency of occurrence of salmonids in the diet of northern squawfish from the tailwater of Lower Granite Dam averaged 19%. Numerically and volumetrically smolts represented about 30 and 67% of dietary items in squawfish in April and May from the tailwater area, respectively (Fig. 81). Our findings compare with those of Ebel (1977) but are considerably higher than those of Horjt et al. (1981) and Buchanan et al. (1980) who reported the frequency of occurrence of smolts in the stomachs of northern squawfish was < 10% and 2%, respectively.

Age and Growth

Smallmouth Bass

Size at various ages and growth increments of smallmouth bass from the lower Snake reservoirs were generally smaller than those of bass of the same age found in other waters of the United States (Table 51).

Table 51. Back-calculated mean lengths at annulus formation and growth increments (mm) for populations of smallmouth bass in the U.S. and Canada.

Location	I	II	III	IV	V	VI	VII	VIII
Little Goose Resv., WA	71	132	190	244	298	336	363	390
Increment	71	61	58	54	54	38	27	27
Salmon River, ID[1]	82	137	180	221	249	268	288	306
Increment	82	55	43	41	27	19	20	18
Lower Snake River, ID[1]	84	145	206	239	267	292	310	322
Increment	84	61	59	34	26	24	18	15
Quabbin Resv., MA[2]	89	170	259	328	373	409	424	434
Increment	89	81	89	69	45	36	15	10
Red Cedar River, WI[3]	100	190	274	329	383	407	424	444
Increment	100	90	84	55	54	24	17	20
Lake Huron, South Bay[4]	111	154	234	267	293	326	356	
Increment	111	43	80	33	28	36	31	
Patomac River, MD[5]	99	193	244	284	335	373		
Increment	99	94	51	40	51	38		

[1] Keating 1970

[2] McCaig and Mullan 1960

[3] Paragamian and Coble 1975

[4] Watt 1959

[5] Sanderson 1958

Mean back-calculated lengths of smallmouth bass from Little Goose Reservoir were similar to those reported for bass from the Snake River prior to impoundment and the Salmon River, Idaho.

Temperature and food abundance affect growth and are probably responsible for differences in mean lengths of smallmouth bass at various ages in different localities (Coble 1975). Growth of smallmouth bass generally increases with temperature, although some researchers have suggested that a shortage of food may mask the effect of temperature (Coble 1967, Keating 1970, Forney 1972).

As water temperatures drop to approximately 10 C smallmouth bass activity decreases, fish move to deeper water (Beeman 1924, Munther 1967) and rarely eat (Coble 1975), becoming torpid at approximately 4.4 C. The little food that is consumed at low temperatures usually does not provide enough energy to maintain body weight (Keast 1968). In the spring as temperatures warm to 10 C the fish become active and start feeding (Keast 1968, Munther 1967). Laboratory experiments have indicated that water temperatures of 26 to 28 C are optimal for growth (Horning and Pearson 1973).

Growth of smallmouth bass has changed as a result of impoundment. Present growth of smallmouth in the lower Snake reservoirs is slower than that prior to dam construction for the first 3 years but in older age classes, present growth is greater (Keating 1970). The slower growth currently seen in the first 3 years may reflect a differential mortality of young-of-year fish between lotic and lentic conditions or interspecific and/or intraspecific competition for food between smallmouth bass and other species as a more diverse species community probably currently exists in the reservoir system. The increased growth of smallmouth bass in the lower Snake reservoirs from age 4 compared to those of bass prior to dam construction suggests some advantage(s) currently exists for living in the reservoirs. Temperature regimens within the river changed little before and after dam construction and as a result, the number of thermal units (number of degree days over 10 C) available for growth are similar. From our data, the number of thermal units for Little Goose Reservoir in 1979 and 1980 was 1332 and 1500, respectively. Keating (1970) calculated an average 1330 thermal degree days for the lower Snake River from 1960-1967. Coble (1967) indicated that waters near or below 1000 degree days typically exhibit slow growth. Low temperatures are probably one reason why growth of smallmouth bass from Little Goose Reservoir is less than that in other areas within their range (Table 51).

In addition, differences in the quantity and quality of food available may affect growth differences after impoundment. The higher incidence of fish in their diet suggests that quantity and quality of food may have improved. If available, fish would be expected to produce more digestable energy than crayfish which are largely composed of non-digestable organic salts and chitin. This argument would support Keating's (1970) hypothesis that slower growth rates of bass from the warmer Snake River compared to those of bass from the colder Clearwater and Salmon rivers were a result of a limited food supply for bass over 100 mm in length from the Snake River. Bass in the Clearwater River fed predominantly on fish, whereas fish from the Snake River fed predominantly on crayfish.

Length-weight equations and condition factors of smallmouth bass from Little Goose Reservoir are similar to those reported for other areas of the country (Carlander 1977). Condition factors of bass were highest in the fall and similar in the spring and summer. Higher K-factors in the fall probably reflect an increase in body fat reserves and elaboration of sex products (Subobjective 4).

Largemouth Bass

A small sample (11) of largemouth bass were collected from Little Goose Reservoir. These fish ranged in age from I to VII. During these years, growth increments ranged from 85 to 60 mm per year (Table 36). Although our sampling indicates few largemouth are found in Little Goose Reservoir, growth increments exceeded those for smallmouth bass (Table 34). Growth of largemouth bass in Little Goose Reservoir was similar to that for bass in the north Idaho chain lakes (Goodnight 1980) but generally slower than in other waters in the U.S. (Carlander 1977). Low water temperatures and comparatively short growing seasons are believed responsible for the slow growth. A number of studies have reported that largemouth bass generally prefer water temperatures at 29 C; these temperatures rarely occur in the shallow backwater areas of Little Goose Reservoir where largemouth are found.

White Crappie

White crappie grew well in Little Goose Reservoir (Table 37). Growth increments averaged 85-61 mm per year during the first three years of growth and 35-11 mm thereafter. We did not find any significant changes in growth in previous age classes and among lower Snake reservoirs (Table 38). Growth increments of white crappie in the lower Snake reservoirs generally are longer or comparable to those in other waters in similar latitudes. For example, mean back-calculated lengths of white crappie at annulus formation for a number of lakes in California were smaller than those in Little Goose Reservoir (Goodson 1966). Growth increments of white crappies summarized by Carlander (1977), were similar to those in lower Snake reservoirs for most central (Ohio, Iowa, etc.) and many south central waters (Kansas, Missouri, Tennessee, etc.). Comparable growth rates of white crappie in lower Snake reservoirs were probably a result of the high densities of zooplankton in the backwater areas. We caught few white crappie in the main channel, probably a result of decreased zooplankton densities compared to backwater areas.

We found that mean condition factors of white crappie did not differ between males and females but were significantly higher in the fall. Mean condition factors of white crappie in spring (k = 1.30) and fall (k = 1.42) were similar or higher than those reported by Carlander (1977) for most waters in the U.S.

Black Crappie

Growth of black crappie was slightly slower than that for white crappie in lower Snake reservoirs (Tables 39 and 40). We did not find any significant changes in growth among year classes and reservoirs. Why growth is slower for black crappie than white crappie in lower Snake reservoirs is probably related to the habitat requirements of this species. Carlander (1977) indicates that black crappie are found in clearer, deeper and cooler waters than white crappie; our captures of crappie in the lower Snake reservoirs attest to this difference. Higher numbers of white crappie were caught in backwater areas as compared to black crappie that generally were caught in the main channel. Growth differences between white and black crappies may be related to temperature differences between backwater and main channel areas and/or dietary differences. As indicated earlier, white crappies consumed higher numbers of fish than black crappies which fed mainly on zooplankton and aquatic insects. Higher consumption of fish by white crappie is probably one reason white crappie grew faster than black crappie.

Growth comparisons between black crappie from lower Snake reservoirs and other waters generally were similar to those for white crappies. Of the growth increments summarized by Carlander (1977), those from lower Snake reservoirs were comparable to many central and south central waters.

Although growth increments were slightly longer in white crappie, black crappie manifested higher condition factors and increased weight per unit length at a higher rate (Fig. 82). As with white crappie, condition factors of black crappie were highest in the fall ($k = 1.53$), and either similar or higher than for most waters in the U.S. (Carlander 1977).

Bluegill

Growth increments of bluegill were considerably lower than those for species previous mentioned. Growth increments averaged 35 to 51 mm during the first 3 years but decreased to 18-30 mm thereafter (Table 41). These increments, although shorter, are comparable to those in northerly waters but generally less than those for central and south central waters (Carlander 1977).

Condition factors of bluegill in Little Goose Reservoir were similar between males and females and among seasons. Condition factors of bluegill generally were higher than those for many waters in the U.S. (Carlander 1977) and bordered on the "good" category for Illinois waters (Bennett 1948).

Pumpkinseed

Growth of pumpkinseed was slightly slower than that for bluegill (Table 41 and 42). For example, growth increments of pumpkinseed averaged 33-44 mm during the first 3 years of growth and declined to 17-20 mm thereafter, compared to 35-51 mm and 18-30 mm for bluegill, respectively. Although these growth increments are small, they are comparable to slower growing populations throughout the U.S. (Carlander 1977).

Condition factors of pumpkinseed from Little Goose Reservoir varied seasonally and between embayment (k = 2.31) and gulch habitats (k = 2.22). Fish caught in the fall manifested the highest condition factors (k = 2.36), whereas pumpkinseed caught in the spring had the lowest (k = 2.24). Condition factors of pumpkinseed from Little Goose Reservoir were similar or higher than those reported by Carlander (1977) in other waters.

Yellow Perch

Yellow perch growth in Little Goose Reservoir was similar among year classes (Table 43). Mean annual increments were from 36-56 mm per year during the first 2 years, 36 mm to their 6th year and declined to about 18 mm per year thereafter. Seasonal differences were found in body condition, as condition factors were significantly higher in the fall (k = 1.24). Condition factors also were different among habitats.

Channel Catfish

Growth of channel catfish in Little Goose Reservoir was comparatively rapid as average increments of 56-80 mm were found during the first 6 years (Table 44). After 7 years, growth increments were variable but declined to less than 30 mm per year. Growth increments, although variable, have increased since 1969. Growth increments in older fish at the present time are similar to those for one catfish of the 1964 year class. We do not know why growth has increased but believe that increased growth could be related to the availability of food. The presence of smolts at Lower Granite Dam may be one reason. If smolts were more abundant and available to catfish, a high protein source would be available for about 2 months. Changes in the availability and abundance of other food sources also could be related to the increases in growth.

Also, growth was different among reservoirs (Table 45). Channel catfish growth was not significantly different ($P>0.05$) between Lower Monumental and Little Goose reservoirs but catfish were significantly ($P<0.05$) smaller in Ice Harbor Reservoir. We do not know why growth is slower in Ice Harbor but believe it may be related to the aging of the reservoirs. That growth rates decline with reservoir aging has been reported for several fishes (Finnell and Jenkins 1954).

Growth increments and size at annulus formation were similar to that for several waters of the midwestern U.S. (Carlander 1969). Thus, channel catfish growth in the lower Snake reservoirs is good in spite of relatively low environmental temperatures for this species. For example Kilambi et al. (1970) found that optimum growth conditions for channel catfish was at 32 C. Also, Lovell and Sirikul (1974) suggested that 12.5 C was a minimal temperature for feeding of channel catfish. These data suggest that channel catfish in the lower Snake reservoirs may have evolved mechanisms to make them more independent of low environmental temperatures. The presence of smolts in their stomachs when temperatures were approximately 10 C corroborates this hypothesis.

Condition factors of channel catfish were similar between sexes and among seasons and habitats. Mean conditions factors (k = 1.10) increased with an increase in length (b>3.0) and were higher than those reported by Carlander (1969) for seven of eight waters.

Redside Shiner

Growth increments and conditions factors were similar among lower Snake reservoirs. No seasonal differences in condition factors were found and condition factors generally were similar throughout the various habitats. Growth increments ranged from 34-59 mm per year during the first 3 years of growth and 17 mm thereafter (Table 47). The oldest shiners from the lower Snake reservoirs were age V; these fish were larger (x = 182) than the maximum size (170 mm) in Paul Lake, British Columbia (Larkin and Smith 1954).

Northern Squawfish

Growth of northern squawfish generally was comparable to that of other species in the lower Snake reservoirs. Growth increments averaged 53 to 80 mm during the first 4 years and decreased to 22-44 mm thereafter (Table 48). Growth in the lower Snake reservoirs was similar to that in several north Idaho lakes (Jeppson and Platts 1959) but faster than those for squawfish from Montana (Carlander 1969).

Condition factors were similar among seasons, habitat types, and between sexes. Condition factors increased with increased body length (b = 3.09).

White Sturgeon

Growth of white sturgeon was variable among age classes. Individuals captured from Little Goose Reservoir ranged in age from IV to XII;

considerable overlap was found among year classes (Table 50). The majority of fish examined were age VII and ranged in lengths from 523-810 mm. Our estimates of the mean total length of white sturgeon from Little Goose Reservoir were considerably higher than those reported by Coon (1978) for white sturgeon from the middle Snake River. The range in lengths at various annuli were also larger which may suggest an increase in growth following impoundment.

Suckers

Bridgelip and largescale suckers were examined for allometric growth but not linear growth. Based on the allometric equation (Fig. 83), condition factors of suckers did not increase with length. Also, no seasonal or habitat differences in condition factors were found. Dauble (1980) reported condition factors and allometric growth of bridgelip suckers from the Hanford Reach of the Columbia River but his results were not directly comparable.

Chinook Salmon

Young-of-year chinook salmon grew rapidly in Little Goose Reservoir from 12 April to 17 June, 1980. The instantaneous growth model indicated that growth was approximately 0.4 mm/day during that period. Back-calculating the time of emergence based on the exponential growth model and 29 mm at emergence (Reiser 1981) indicated that the time of emergence was late February to early March.

American Shad

Young-of-year American shad in Little Goose Reservoir, on the average, grew more rapidly than chinook slamon. Growth of American shad was approximately 0.6mm/day from mid August to early November.

SUMMARY

1) To evaluate food habits, age structure, and growth of selected warmwater fishes in lower Snake River reservoirs, fish were collected from April 1979 to November 1980.

2) Stomachs for food habit analysis were obtained from fish collected by trapnets, electrofishing, and gill nets. Food items were sorted, identified, and enumerated and volumetric displacement (V), numbers (N), and frequency of occurrence (F) recorded. The relative importance of food items was determined by the Index of Relative Importance (IRI = (N+V) F).

3) Spines or scales were taken from fish and interpreted for age and growth information. Data obtained were used to examine the age structure, size at annulus formation, and growth increments. Length and weights, measured at the time of collection, were used to calculate allometric growth and condition factors.

4) Crayfish, aquatic insects, zooplankton, and fish were the more important food items in the stomachs of warmwater fishes. Smallmouth bass consumed mainly crayfish, fish, and insects. White and black crappies ate mostly cladoceran zooplankton, fish, and aquatic insects. Channel catfish stomachs contained mainly aquatic insects, crayfish, wheat, and cladocerans. Fish, cladocerans, and crayfish were the predominant food items of northern squawfish. Suckers consumed mainly diatoms, detritus, and algae. Redisde shiners stomachs mainly contained cladocerans, aquatic insects, and terrestrial insects.

5) Diel feeding habits of channel catfish and white crappie were determined by collecting fish at 6-hour intervals and examining the quantity of stomach contents. Mean volume of food items consumed throughout a 24-hour period were similar for channel catfish but peaked from 0600-1200 and 1200-1800 hours for white crappie.

6) Stomachs from smallmouth bass (n = 184), channel catfish (n = 83), and northern squawfish (n = 44) from Little Goose Reservoir during April and May, 1980 were examined for the presence of smolts. The frequency of occurrence of smolts in these stomachs varied among predators and between tailwater and shoal areas. Less than 2% of smallmouth bass stomachs contained smolts. Frequency of occurrence for chinook salmon and steelhead trout smolts in the stomachs of channel catfish was different at the tailwater (54 vs 38%) but not at the shoal (40 vs 40%). Based on a limited sample of squawfish stomachs, the frequency of occurrence of chinook salmon (19%) was higher than that for steelhead trout (9.5%).

7) Age composition and growth increments were variable among resident species examined in lower Snake reservoirs. Maximum growth increments generally occurred during the first three years and decreased thereafter. Growth increments and size at annulus formation indicated growth of most species examined was comparable or slower than that for the same species in other areas of the United States.

Growth of white crappies, however, was an exception as growth increments of crappies from the lower Snake reservoirs generally were larger than those from other waters in similar latitudes. Also, our estimates of mean length of white sturgeon from Little Goose Reservoir were considerably higher than those reported from the mid-Snake River.

8) Allometric growth and conditions factors varied among species but generally were similar to those reported for other parts of the U.S. Condition factors of crappies and channel catfish from lower Snake reservoirs generally were higher than those for these species reported in the literature.

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Subobjective 4

To evaluate reproductive cycles and spawning habitat preferences of selected warmwater fishes in lower Snake River reservoirs.

To effectively manage a fishery in a multiple use reservoir system, timing and habits of spawning of resident fishes must be known. Prior to this study, no information was available on the timing and location of spawning activity of warmwater fishes in lower Snake River reservoirs. Several species commonly sought by anglers in the reservoirs were known to be shallow water spawners. Power peaking operations could adversely affect spawning success and early life history of these resident sport fishes.

METHODS

Reproductive Cycles

Individuals of several resident fishes were dissected to evaluate the timing and duration of spawning activity in lower Snake River reservoirs. Fish from the field collections (Subobjective 2) were placed on ice, weighed (g), measured (total length mm), and dissected within 12 hours of collection. Gonads were excised and weighed (0.10 g). To minimize variation associated with different fish sizes, gonad weights were expressed as a percent of body weight, or the gonosomatic index (GSI) of Kaya and Hasler (1972). Monthly sizes of gonads were expressed as a mean GSI. State of maturity of excised gonads was recorded as: Stage 1 - sexually immature; Stage 2 - developing; Stage 3 - ripe; Stage 4 - spent; Stage 5 - no development (modified from Bennett 1976). Also, diameters of 10 randomly selected ova were recorded (0.01 mm) for each ovary containing visible eggs. We compared total lengths of sexually mature and immature fish to assess the minimum size of sexual maturity.

Observations of Spawning Activity

To locate spawning areas and obtain additional information on timing of reproduction of selected resident species in Little Goose Reservoir, suspected spawning areas were examined underwater by snorkeling and SCUBA diving. Biologist divers swam systematically parallel to shore. Signs of spawning (presence of embryos, nests, adults, etc.) were noted to a depth of about 3 m. Deeper areas, however, were occasionally also examined for spawning using SCUBA. Also, observers waded the shoreline and visually examined the shoreline. Wading only was used in suspected spawning areas when water levels were low and transparency was high. Sites selected for survey were based on the presence of general habitat characteristics reportedly required for the spawning of selected species (e.g., substrate requirements, velocity, submerged cover, etc.). Visually located spawning sites were recorded as to location in the reservoir and depth (cm) of spawning activity relative to extant water levels. Also, when spawning nests were observed, we recorded these additional data: level of spawning activity (inactive: nest silted; active: clean, nest without silt but no additional signs of spawning activity present; active: with embryos fry, and/or adult present; and active: with dead embryos and/or fry); water temperature (0.1C); substrate type and size (silt, sand, gravel, organics); nest diameter; and dissolved oxygen (measured with a YSI model 57 dissolved oxygen meter (mg/l) and calibrated probe.)

To assess the effects of fluctuating water levels on fishes which spawn in shallow water, the elevations (nearest 2.5 cm msl) of spawning sites were determined by comparison with hourly water elevation records. The time, date, and vertical distribution of spawning activity were compared to pool elevations in Little Goose Reservoir maintained by the U.S. Army Corps of Engineers at the forebay and tailwater of Little Goose and Lower Granite dams, respectively. The median, upper, and lower quartiles of vertical spawning activity were compared with the range of daily water level fluctuations during the spawning season to quantify the effects of water level fluctuations on spawning activity.

To assess the relative importance of habitats for spawning in Little Goose Reservoir, the number of spawning sites located in each habitat type, within each of the upper and lower reservoir zones, were expressed as a number per unit survey effort to account for disproportionate amounts of survey effort. Differences in the number of spawning sites observed among habitat types were determined with a Friedman's test (the nonparametric analog of the two-way analysis of variance (Conover 1971)). Comparison of the number of spawning sites per effort was made between upper and lower reservoir zones with a Mann-Whitney test (Daniel 1978).

Larval Fish Abundance and Distribution

Sampling

Larval fishes were sampled at bi-weekly intervals from April through November 1980, at embayment, gulch, and shoal areas in upper and lower reservoir zones of Little Goose Reservoir, and the tailwater of Lower Granite Dam (Fig. 2). Two conical plankton nets (2.134 m in length, 0.5 m diameter opening, 1.0 mm stretched mesh), extended about 1 m on opposite sides of the boat, were towed at a speed of 1.3 m/sec. A calibrated flow meter positioned in the mouth of each net was used to determine the volume of water filtered per net during each tow. Stepwise oblique tows were conducted in 1 m increments from the surface to a maximum depth of 3 m. Standard tows were of 3 minute duration at each depth. High plankton densities in the summer at the lower embayment, lower shoal and lower gulch stations necessitated reducing tow durations to less than 3 minutes.

Three paired series of stepwise oblique tows were conducted at each sampling station per sampling period. Night collections were utilized as a result of increased efficiency of tow netting (Houde 1969; Isaacs 1964; Netsch et al. 1971). All samples were filtered through a 1.0 mm mesh screen and immediately preserved in 10 percent buffered neutral formalin (Lowe-McConnell 1978; Setzler-Hamilton et al. 1981). Water temperature (0.1C) was measured at a depth of 1 m at the time and location of sampling. Additional limnological information including water velocity, amount of littoral habitat, and aquatic macrophyte distribution (Subobjective 2) also were collected for later analysis.

Specimen Processing

In the laboratory, larvae were separated from the plankton samples, utilizing a 3-diopter fluorescent binocular magnifier, and transferred to 50 percent ethanol (Richard Wallace, Department of Biology, University of Idaho, personal communication). Larvae were examined using variable power (10x-30x) stereomicroscopy. All larvae were identified to the lowest possible taxon using a dichotomous key developed from the literature of known fishes occurring in the lower Snake reservoirs. To facilitate identification, preanal and postanal lengths (0.1 mm) on each larval fish were measured using a 100-unit ocular micrometer.

Analysis

For comparative purposes, larval fish abundance was expressed as the number of larvae per 1000 m^3 filtered water (Krause 1979; Krause and Van Den Avyle 1979; Netsch et al. 1971; Setzler-Hamilton et al. 1981; Tuberville 1979). Analysis of variance was used to compare catch per effort (CPE) between stations and months. One unit of effort per sampling period consisted of the average of six tows (3 paired series) conducted at each sampling station. A $(\ln(X+1);(X=CPE))$ transformation (Krause 1979) of the catch was necessary to normalize the distribution and achieve homogeneity of variances to appropriately utilize analysis of variance procedures. We restricted use of analysis of variance to monthly periods when non-zero CPEs occurred at all sampling stations.

Relative abundance (%) estimates were calculated as a frequency of occurrence of larval fishes sampled in Little Goose Reservoir. These estimates were made for the families of larval fishes and genera of larval game fishes occurring in the reservoir and on a station and time comparison. Comparison of mean CPE was made by analysis of variance. Duncan's multiple range test was performed when analysis of variance indicated significant differences ($P<0.05$) in CPE between months and location (Ott 1977).

Associations among the abundance of larval fishes in Little Goose Reservoir were made by Pearson product-moment correlation analysis using sample frequencies. Sample frequencies consisted of the mean density (number/1000 m^3) of each genus (and members of the family Cyprinidae) collected monthly, from May through October, at each of seven sampling stations. Six sample frequencies at seven sampling stations produced 42 observations for each of 9 categories of larval fishes included in the analysis.

Relationships between larval fish abundance and various limnological characteristics were assessed by calculating Pearson product-moment correlations between sample frequencies for each genus and selected limnological characteristics. Sample frequencies were calculated as those used in the analysis of larval fish associations. Limnological characteristics included in the correlation analysis were: water temperature; water transparency; water velocity; littoral reach; and aquatic macrophyte distribution. Water transparency values included in this analysis were obtained during beach seine sampling. Values for limnological characteristics were expressed as follows:

water temperature - monthly mean temperature (taken at a depth of 1 m);

water transparency - monthly mean secchi disc (m);

water velocity - ranks based on velocity measurements;

littoral reach - distance from the shoreline which the littoral zone (2 m depth) extended in a perpendicular direction; and

aquatic macrophyte distribution - percent area coverage.

Young-of-Year Fish Abundance and Distribution

Sampling Effort

Young-of-year (YOY) fishes were sampled using a 30.5x2.4 m seine, constructed of 6.35 mm knotless nylon mesh, with a 2.4x2.4x2.4 m bag. Sampling was conducted seasonally during 1980 at three stations on each of Lower Granite, Lower Monumental and Ice Harbor reservoirs (Fig. 1). Intensive sampling of YOY fishes in Little Goose Reservoir was conducted biweekly from March through November 1980, at seven stations representative of major habitat types (Fig. 2). One unit of effort per sampling period consisted of the sum of three standardized hauls at each sampling station. A standard haul consisted of setting the seine parallel to the shoreline at a distance of 15 m using extension ropes, then drawing the seine directly into shore. At the location and time of sampling, water temperature and transparency were taken. Water temperature (0.1C) was measured at a depth of 1m while water transparency (nearest 0.1m) was determined by secchi disc. Additional limnological information was collected at each sampling station, including water velocity, amount of littoral habitat, and aquatic macrophyte distribution (described under Subobjective 2).

Specimen Processing

Young-of-year fishes identifiable to species at the time of collection were enumerated, measured (total length mm) and released. Specimens not readily identifiable were measured (weight-g, length-mm) and then immediately preserved in 10 percent formalin. Specimens in formalin (9-15 months) were rinsed in water and placed in ethanol (50%) prior to processing (Lowe-McConnell 1978). To assess change in length resulting from preservation, specimens also were measured after preservation. Pre-preservation lengths (adjusted as a result of regression analysis) were used for all analyses. All captured YOY specimens were separated into 5 mm size classes (e.g., 1-5, 6-10, 11-15, etc.). Number of individuals of each species per seine haul were recorded for median values of each size class (e.g., individuals 16-20 mm recorded as "18 mm").

Analysis

The number of YOY fishes collected from Little Goose Reservoir was expressed as mean (X) catch per effort (CPE). A transformation of the catch (ln(X+1)) was used to normalize the distribution for comparison of mean CPE.

Relative abundance of each species was calculated as the frequency of occurrence (%) for each sampling station at each lower Snake reservoir. Overall relative abundance (i.e. all sampling stations and periods combined) of each species was calculated for Little Goose Reservoir.

Locational comparisons of YOY fish abundance in Little Goose Reservoir were made on a sampling station basis and for upper vs. lower reservoir zones. Mean CPE of all YOY fishes collected from each reservoir zone (upper vs. lower) were compared using linear contrast analysis ($P<0.15$) (Ott 1977). Differences in monthly mean CPE of upper vs. lower zones sampled (excluding the tailwater area) were determined using the Wilcoxon two-sample test (Daniel 1978). Comparison of mean CPE (among sampling stations) was conducted using two-way analysis of variance and Duncan's multiple range test (Ott 1977).

Temporal comparisons of YOY fish abundance in Little Goose Reservoir were conducted on a monthly basis. Comparisons of monthly mean CPE of all YOY fishes collected were performed using two-way analysis of variance and Duncan's multiple range test.

Associations among the abundance of YOY fishes in Little Goose Reservoir were assessed by calculating Pearson product-moment correlations among sample frequencies. Sample frequencies consisted of the total number of YOY individuals (sum of six seine hauls) of each species collected monthly, from April through November, at each of seven sampling stations. Species were not included in the correlation analysis if less than 50 individuals were collected throughout the sampling period. Eight sample frequencies at seven sampling stations produced 56 observations for each of 12 species included in the analysis.

Relationships between YOY fish abundance and various limnological characteristics were assessed by calculating Pearson product-moment correlations between sample frequencies for each species and selected limnological parameters. Sample frequencies were calculated as those used in the analysis of the species association. Limnological characteristics included in the correlation analysis were: water temperature, water transparency, water velocity, littoral reach and aquatic macrophyte distribution. Values for limnological characteristics were expressed as follows:

water temperature - monthly mean temperature (taken at a depth of 1 m);

water transparency - monthly mean secchi disc (m);

water velocity - ranks based on velocity measurements;

littoral reach - distance from the shoreline which the littoral zone (2 m depth) extended in a perpendicular direction; and

aquatic macrophyte distribution - percent area coverage.

RESULTS

Reproductive Cycles

We examined a total of 2523 gonads from 12 species of resident fish from the lower Snake River reservoirs during 1977 and 1980. Individuals of species that we examined initiated their reproductive development in the fall and spawned from early spring through late summer.

Northern Squawfish

Reproductive development of northern squawfish was initiated in late fall and early winter (Fig. 84). Mean size of gonads were small in the fall and attained maximum sizes in June for males and females. Based on the presence of ripe gametes, spawning was initiated in June and probably continued into early August. Spent females were first collected during July, whereas all females collected during August were spent. Ripe ova averaged 1.8 mm (diameter). Water temperatures during the time when gonads were in a ripe reproductive condition ranged from 14.0 to 20.4 C.

Minimum sizes of northern squawfish collected in the lower Snake reservoirs exhibiting reproductive development were 254 and 240 mm (total length) for females and males, respectively.

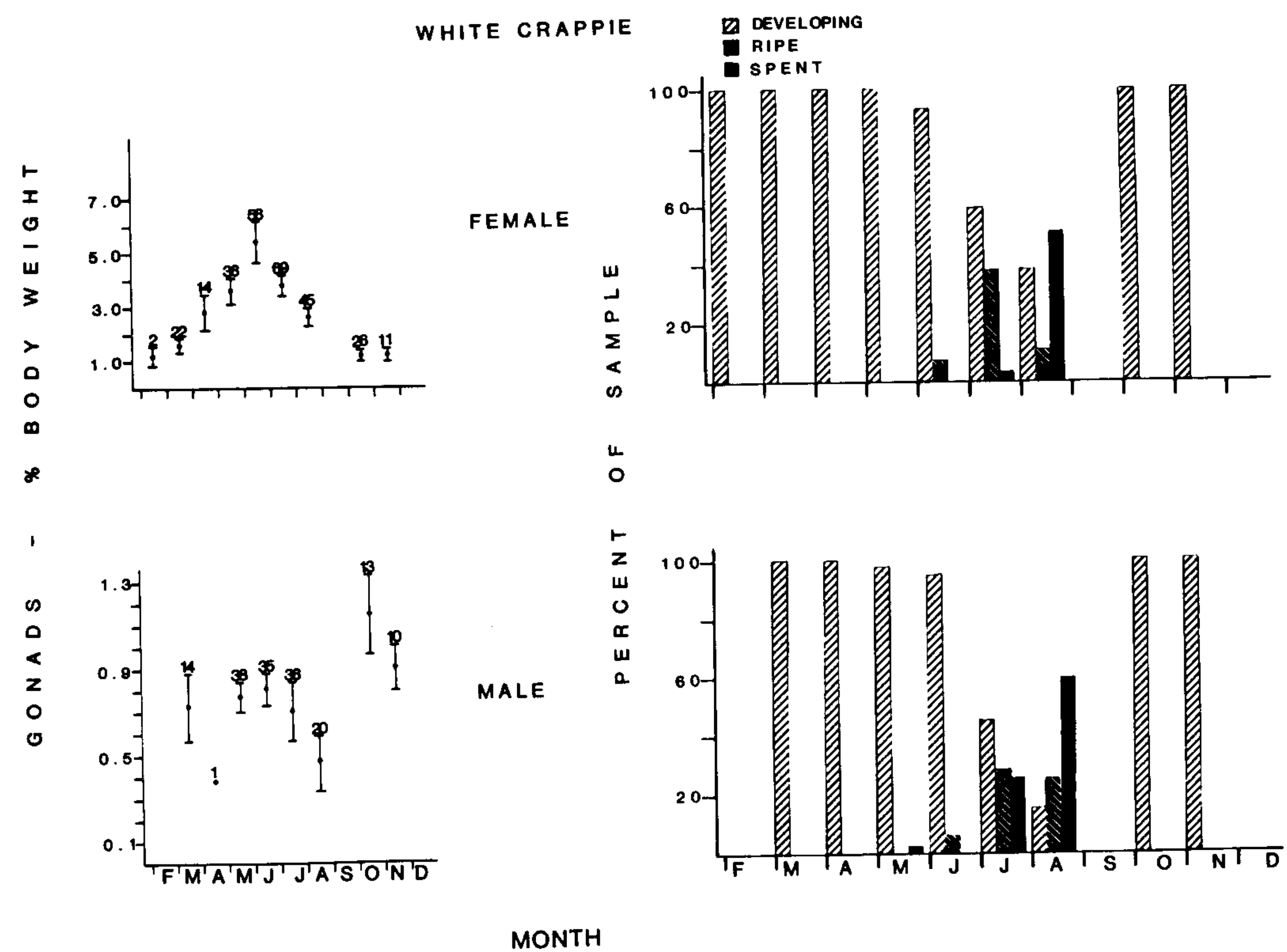

Figure 84. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) northern squawfish. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

Redside Shiner

Redside shiner initiated reproductive development during late fall and early winter (Fig. 85). Mean sizes of gonads increased through spring and attained maximum sizes in June for males and females. Based on the presence of ripe gametes, spawning was initiated in July and probably continued into early August. Spent individuals were first collected during July. All males examined during July were spent, although a small percentage of males examined during August were in a ripe reproductive condition. Ova averaged 1.6 mm (diameter) when ripe. Water temperatures during the time when gonads were in a ripe reproductive condition ranged from 18.1 to 20.4 C.

Minimum sizes of redside shiner collected in the lower Snake River reservoirs exhibiting reproductive development were 130 and 127 mm (total length) for females and males, respectively.

Suckers

Bridgelip suckers

Changes in gonad sizes suggest that bridgelip suckers are one of the earlier spawning resident species in the lower Snake River reservoirs (Fig. 86). Mean size of testes were large in the fall and ripe females first appeared in the April collections. The spawning period for bridgelip suckers was probably April and May. Ripe ova for bridgelip suckers averaged 2.5 mm. Water temperatures in April and May averaged from 10.2 to 12.2 C. The minimum size of bridgelip suckers exhibiting reproductive development was 310 and 282 mm (total length) for female and males, respectively.

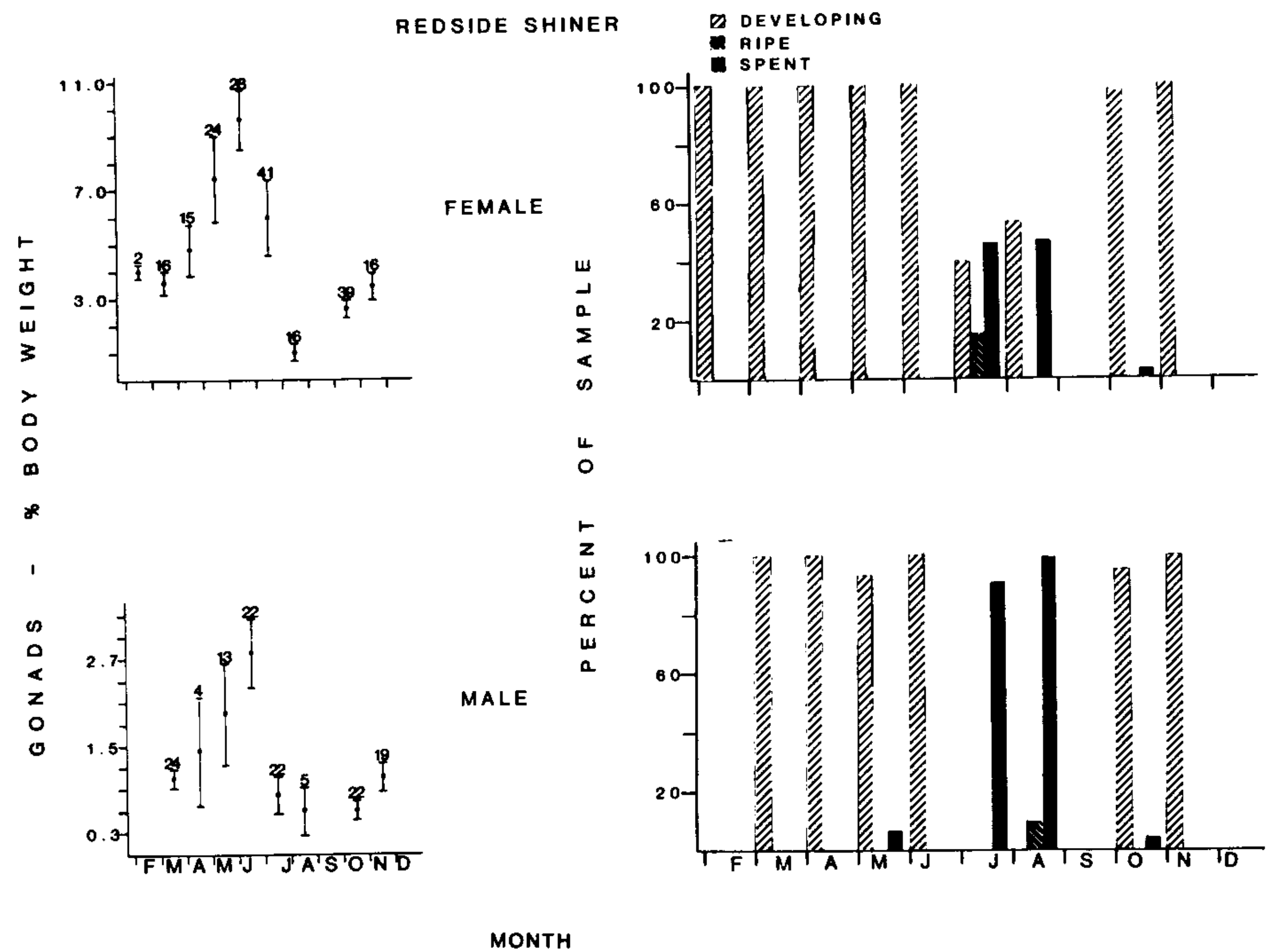

Figure 85. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) redside shiner. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

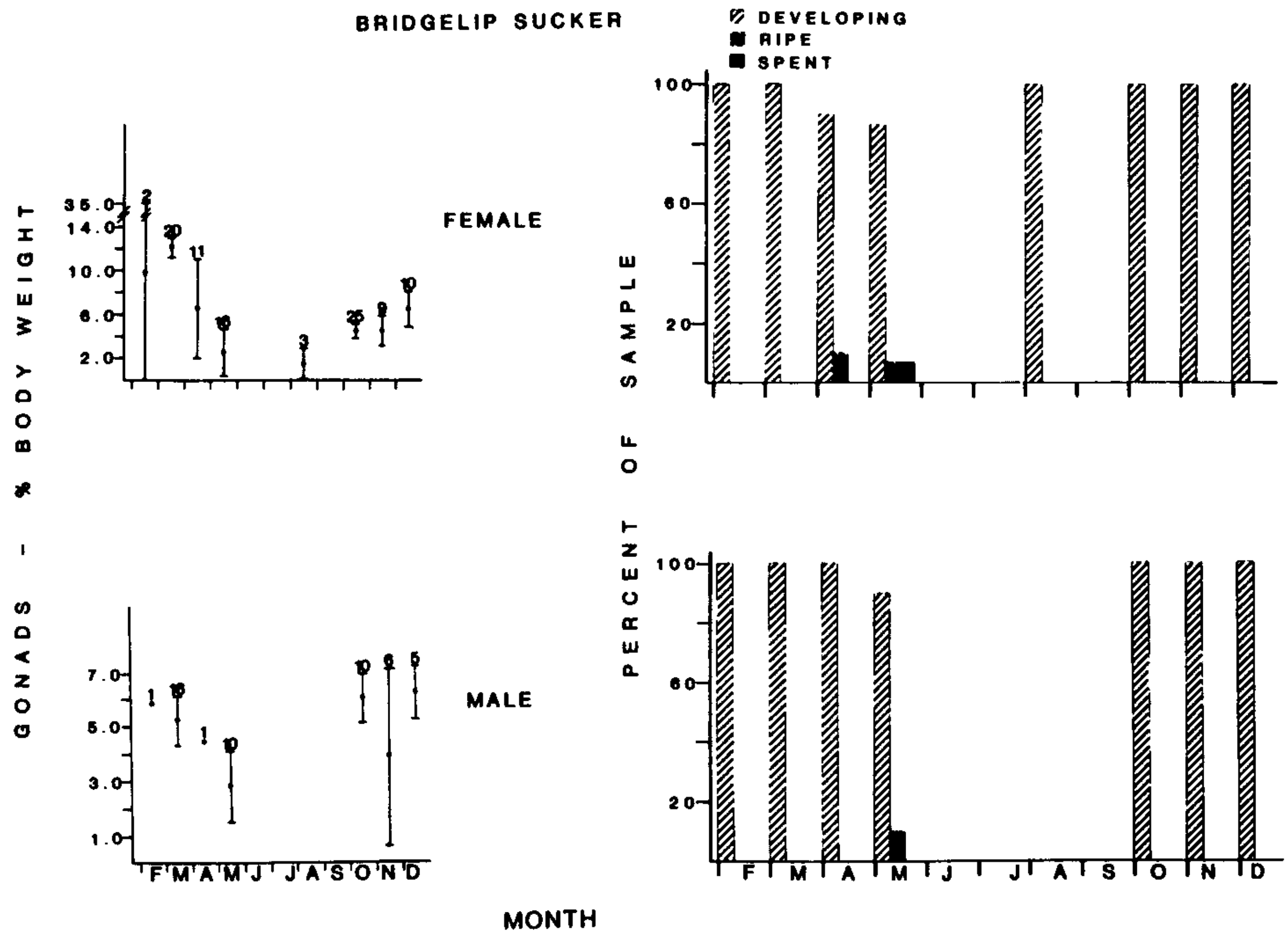

Figure 86. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) bridgelip sucker. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

Largescale suckers

Changes in gonad sizes for largescale suckers generally were similar to those from bridgelip suckers (Fig. 87). Mean size of testes were large in the fall and GSIs were similar to those in the spring. The presence of milt and ripe ova suggest spawning of largescale suckers occurred in May and June in the lower Snake River reservoirs. Water temperatures during May and June were 12.2 to 15.8 C.

Minimum sizes of suckers manifesting reproductive development were similar between species. The minimum size of largescale suckers exhibiting reproductive development was 320 mm.

Brown Bullhead

Based on the presence of ripe ova in our samples, gonads of brown bullhead increased in size from fall to spring; largest size of ovaries and testes occurred in June through August (Fig. 88).

Ripe ova diameters averaged 2.6 mm. Water temperatures ranged from 20.4 to 21.7 C at the time gonads were ripe.

The smallest brown bullheads exhibiting reproductive development were 182 and 240 mm (total length) for females and males, respectively.

Channel Catfish

Variations in gonad sizes and stages of reproductive activity were found in channel catfish (Fig. 89). Based on the presence of ripe gonads, channel catfish spawned in the lower Snake River reservoirs during July and August. Female and male channel catfish exhibited decreased mean GSIs from July to August. Spent fishes of both sexes were collected during July, whereas 90 percent of the females and 60 percent of the males collected during August were spent. Ripe ova

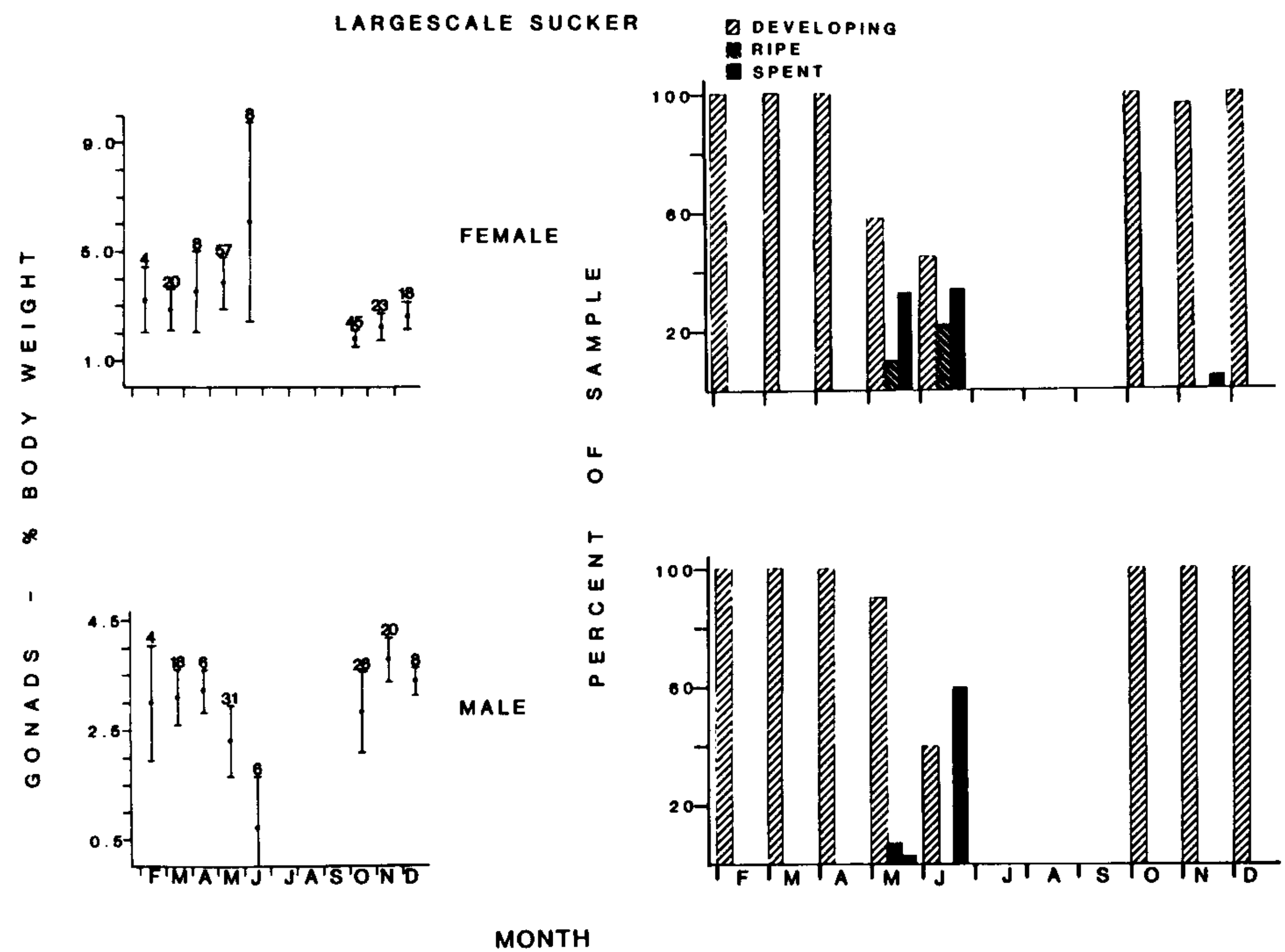

Figure 87. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) largescale sucker. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

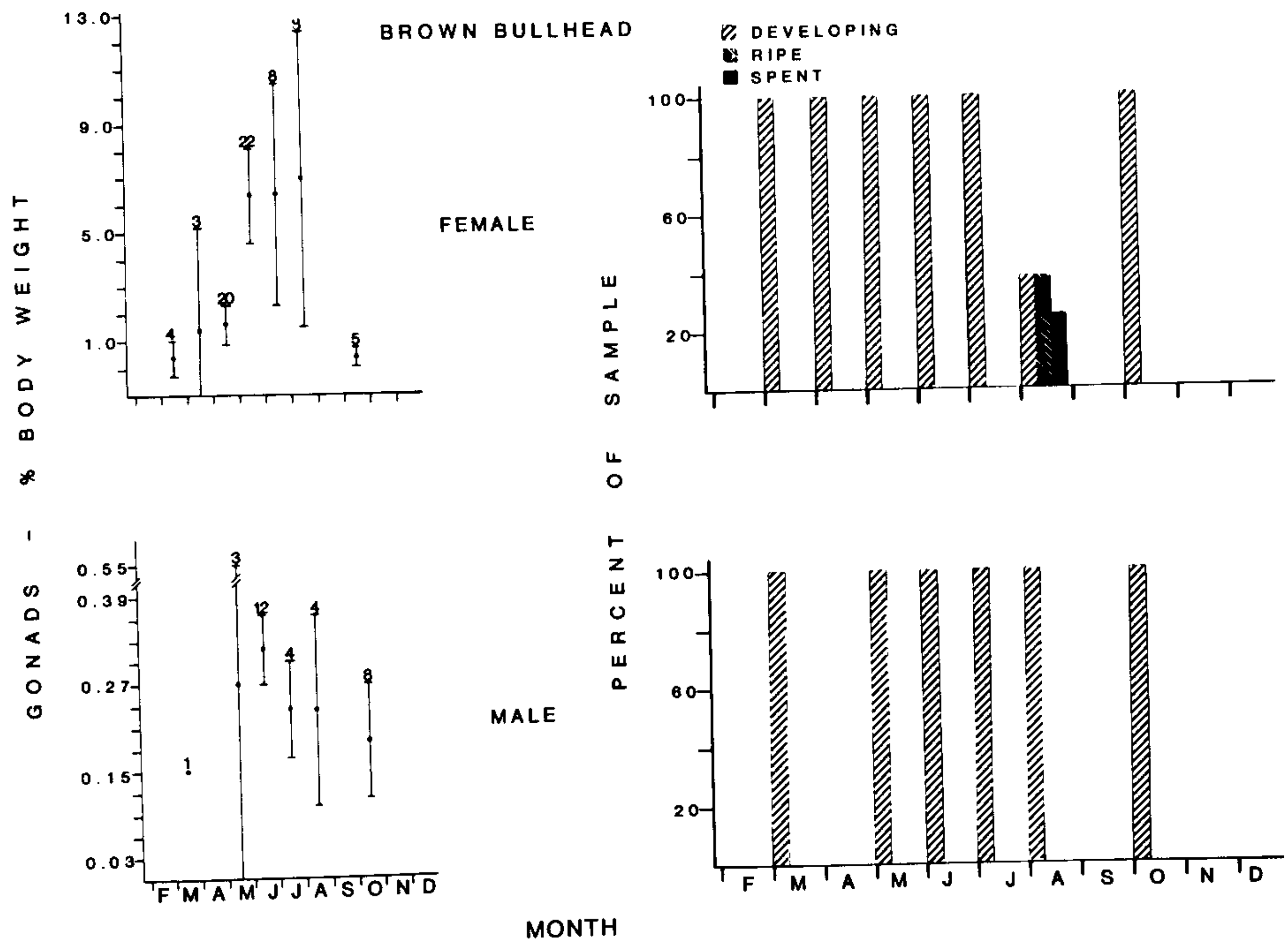

Figure 88. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) brown bullhead. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

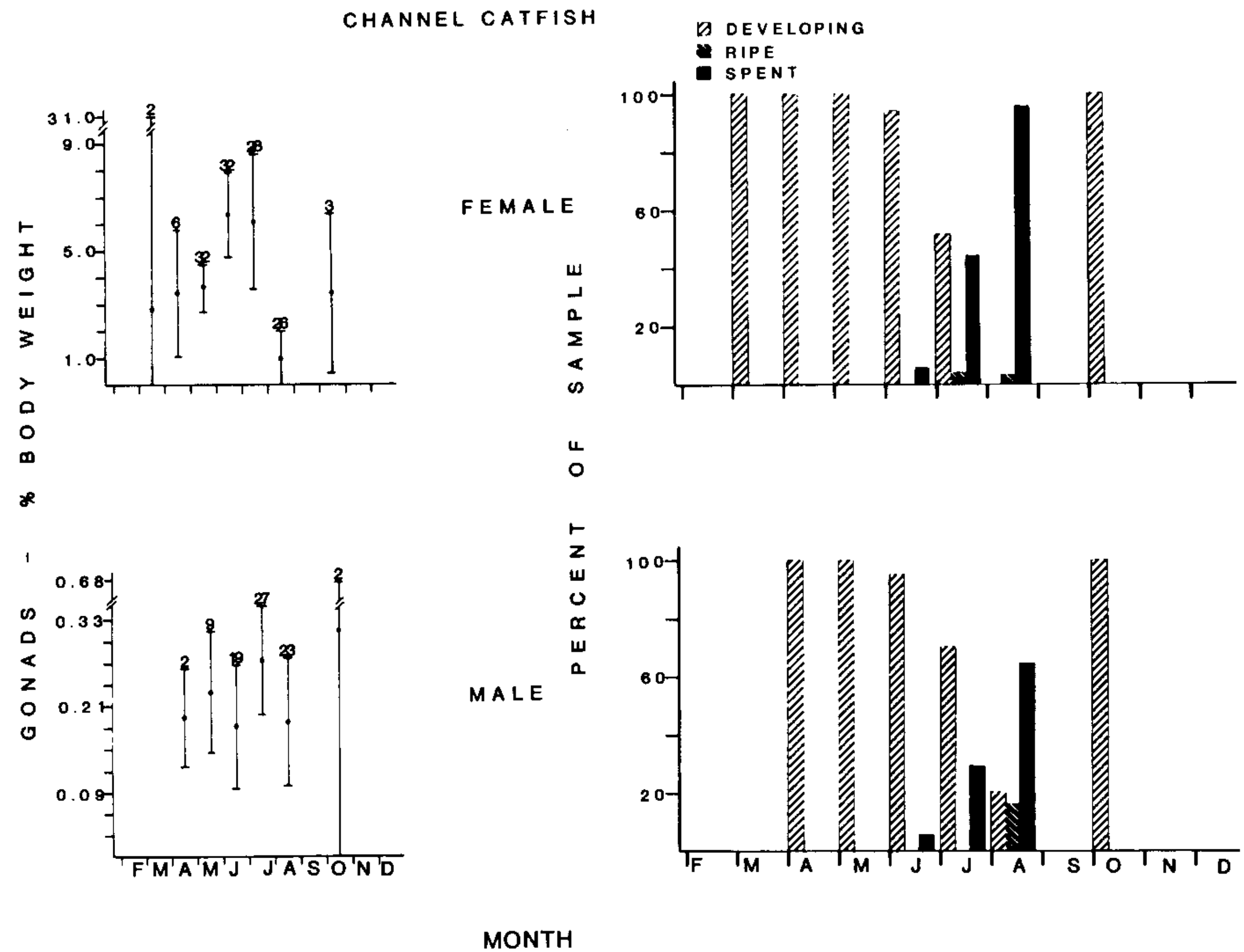

Figure 89. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) channel catfish. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

diameters averaged 3.1 mm in diameter. Water temperatures during July and August ranged from 18.1 to 21.7 C. Our data indicates the minimum size of fish exhibiting reproductive development was 311 and 347 mm (total length) for females and males, respectively.

Pumpkinseed

Reproductive development of pumpkinseed was initiated in late fall and early winter (Fig. 90). Mean sizes of gonads were small during fall and spring and attained maximum sizes in June and July for females and July for males. Based on the presence of ripe gametes, spawning was initiated in late June and continued into early August. Females in a ripe reproductive condition were collected from late June through early August, whereas all males collected during August were spent. Ova averaged 0.85 mm (diameter) when ripe. Water temperatures during the time gonads were in a ripe reproductive condition ranged from 18.1 to 19.6 C.

Minimum sizes of pumpkinseed in the lower Snake River reservoirs exhibiting reproductive development were 97 and 101 mm (total length) for females and males, respectively.

Bluegill

Bluegill initiated reproductive development during fall (Fig. 91). Mean sizes of gonads were generally small from fall through May and attained maximum size in June for females and July for males. Based on the presence of ripe gametes, spawning occurred through July into August. Males and females exhibiting a ripe reproductive condition were collected during July and August. Ripe ova averaged 0.9 mm (diameter). Water temperatures during the time when gonads were in a ripe reproductive condition ranged from 19.6 to 21.7 C.

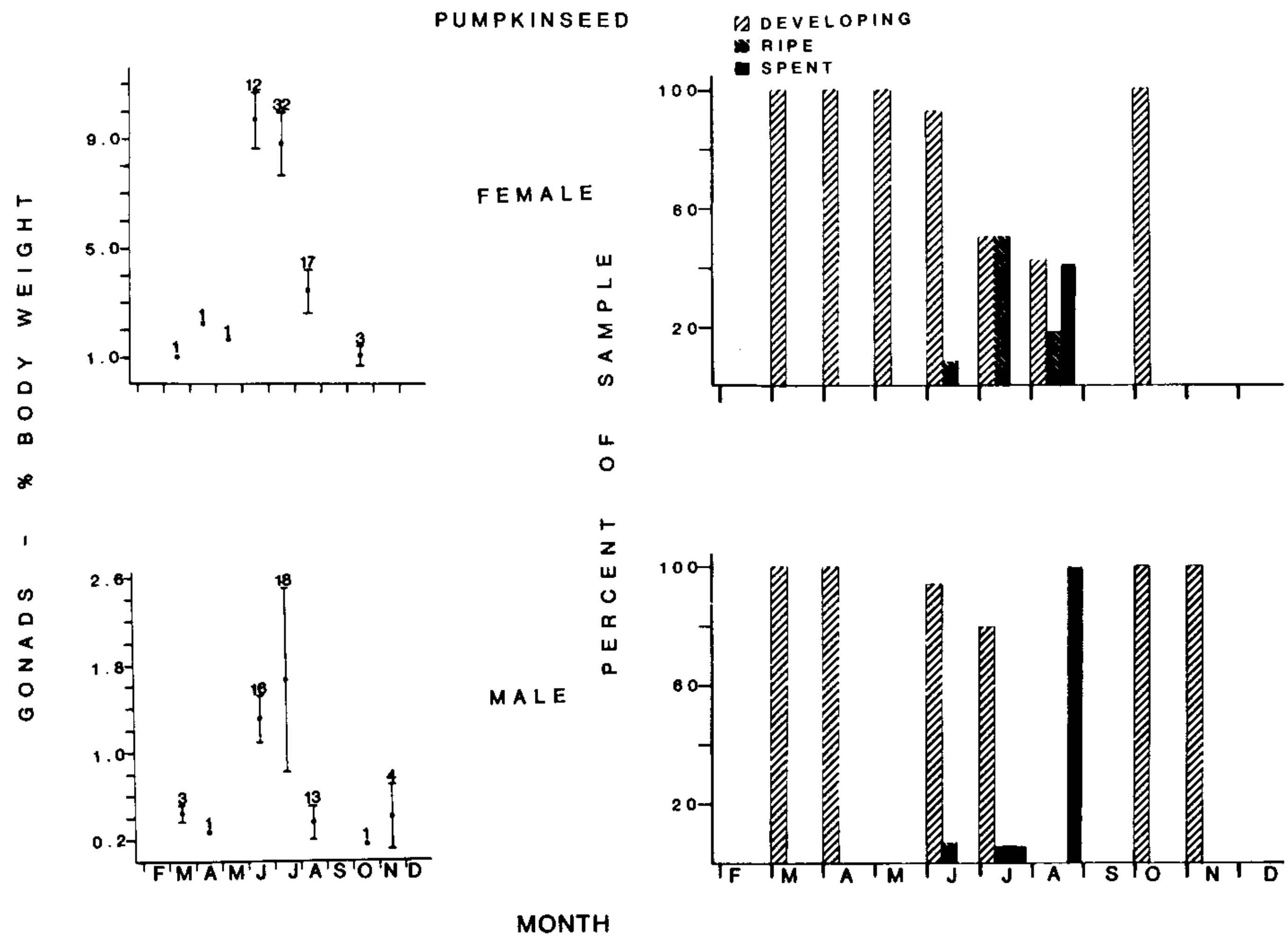

Figure 90. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) pumpkinseed. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

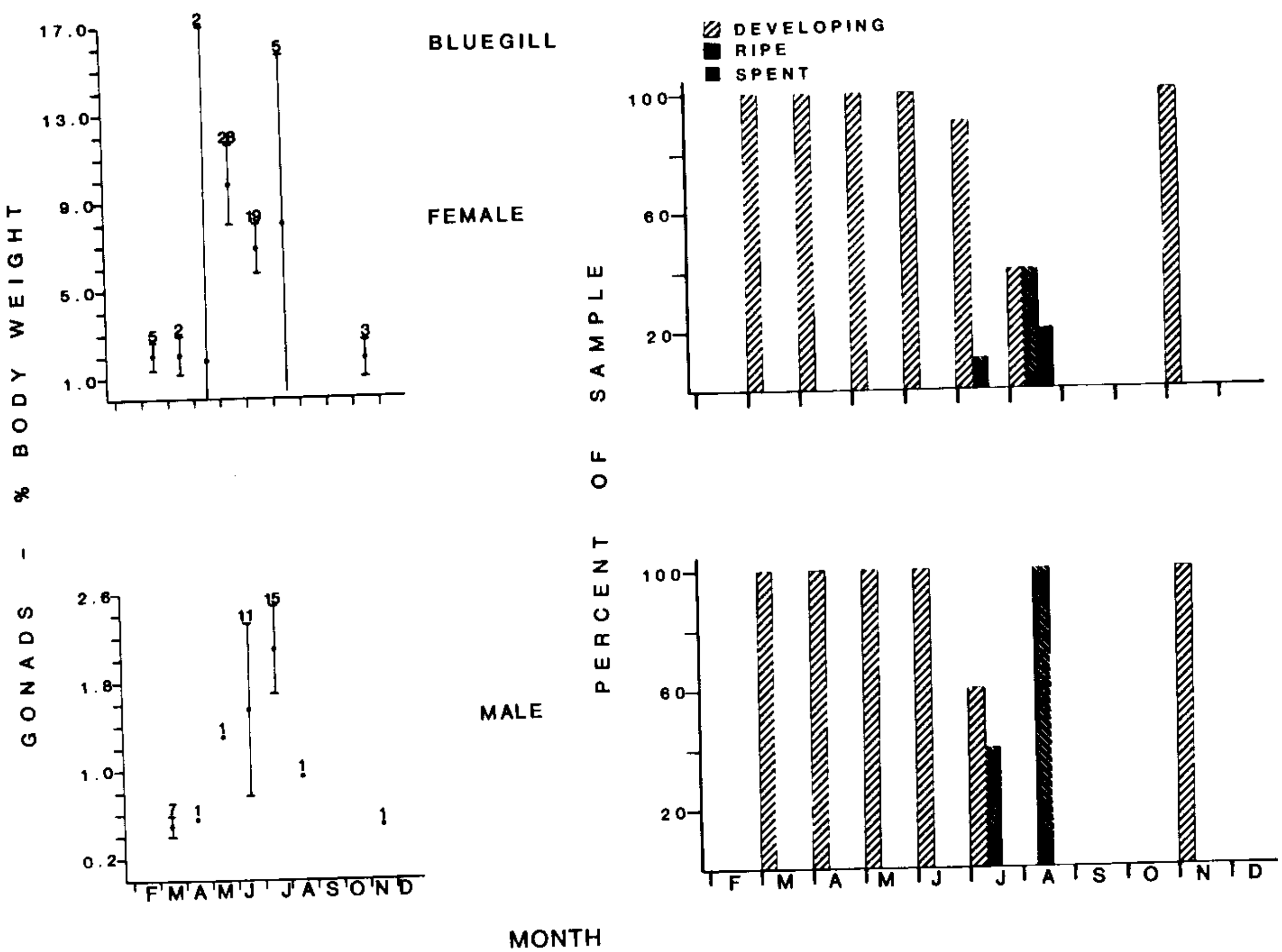

Figure 91. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) bluegill. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

Minimum sizes of bluegill collected in the lower Snake River reservoirs exhibiting reproductive development were 112 and 104 mm (total length) for females and males, respectively.

Smallmouth Bass

Smallmouth bass generally were in spawning condition from June until the latter part of July (Fig. 92). Gonads initiated their development in October and attained maximum size from April through July. Ripe females first appeared in late May, and spent individuals were collected during June. Gonads of females and males exhibited a marked decrease in size from July to August. Water temperatures during the time when ripe gametes were found in June and July ranged from 14.0 to 19.6 C. Ripe ova diameters averaged 2.0 mm. We determined the minimum size of reproductive development for smallmouth bass was 191 mm and 184 mm (total length) for females and males, respectively.

White Crappie

Changes in gonad sizes of white crappie were similar to those of black crappie (Fig. 93). Largest mean size of ovaries was found in June and decreased in July and August. State of maturity data, however, suggested spawning could occur from June into August. Ripe ova diameters averaged 0.73 mm. Water temperatures during the suspected spawning period were 15.8 to 20.4 C.

The minimum sizes of male and female white crappie exhibiting reproductive development were 170 and 153 mm, respectively.

Black Crappie

Maximum mean size of gonads occurred in June (Fig. 94). The decrease in size of gonads between June and July and the presence of ripe gonads

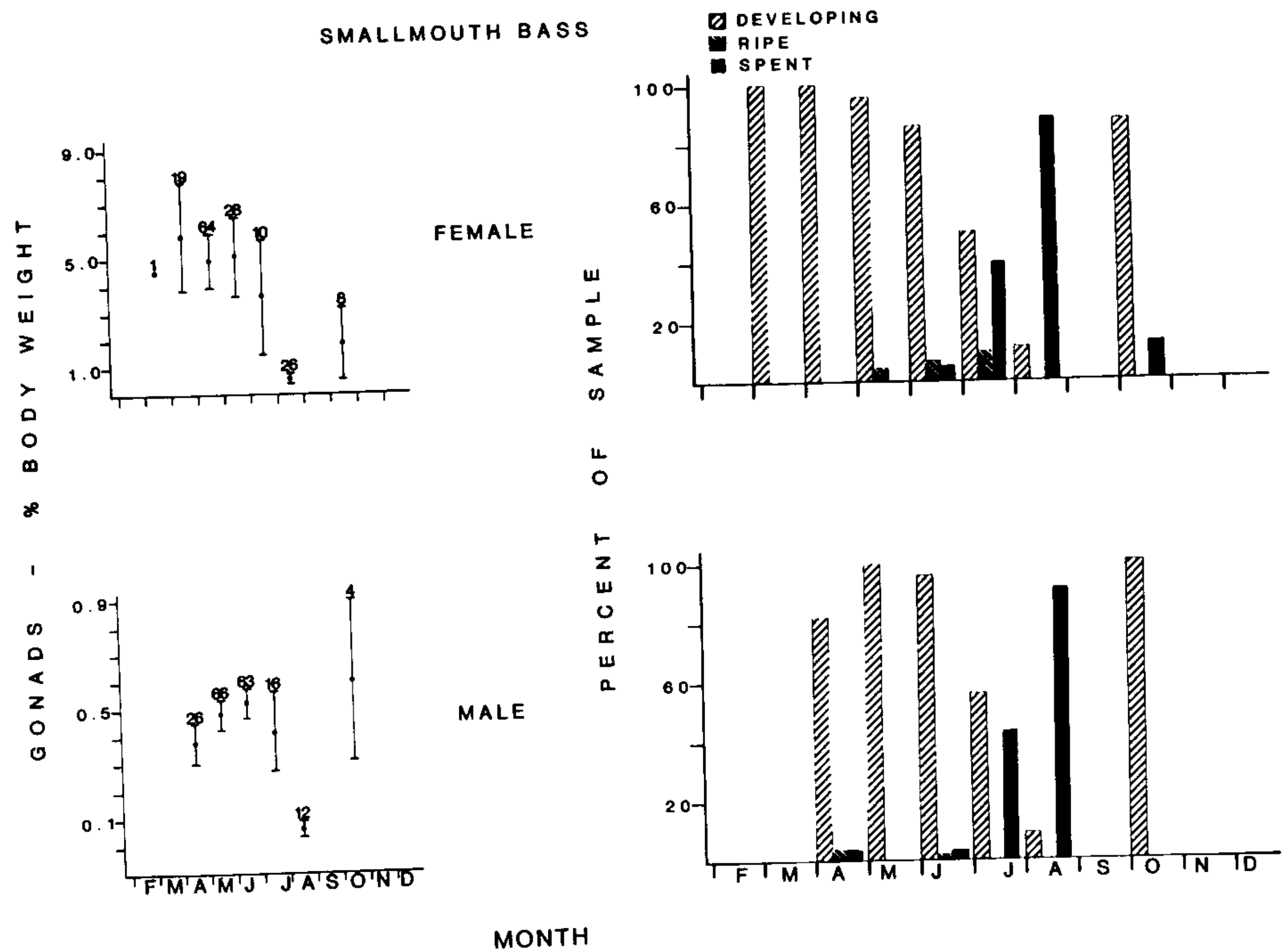

Figure 92. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) smallmouth bass. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

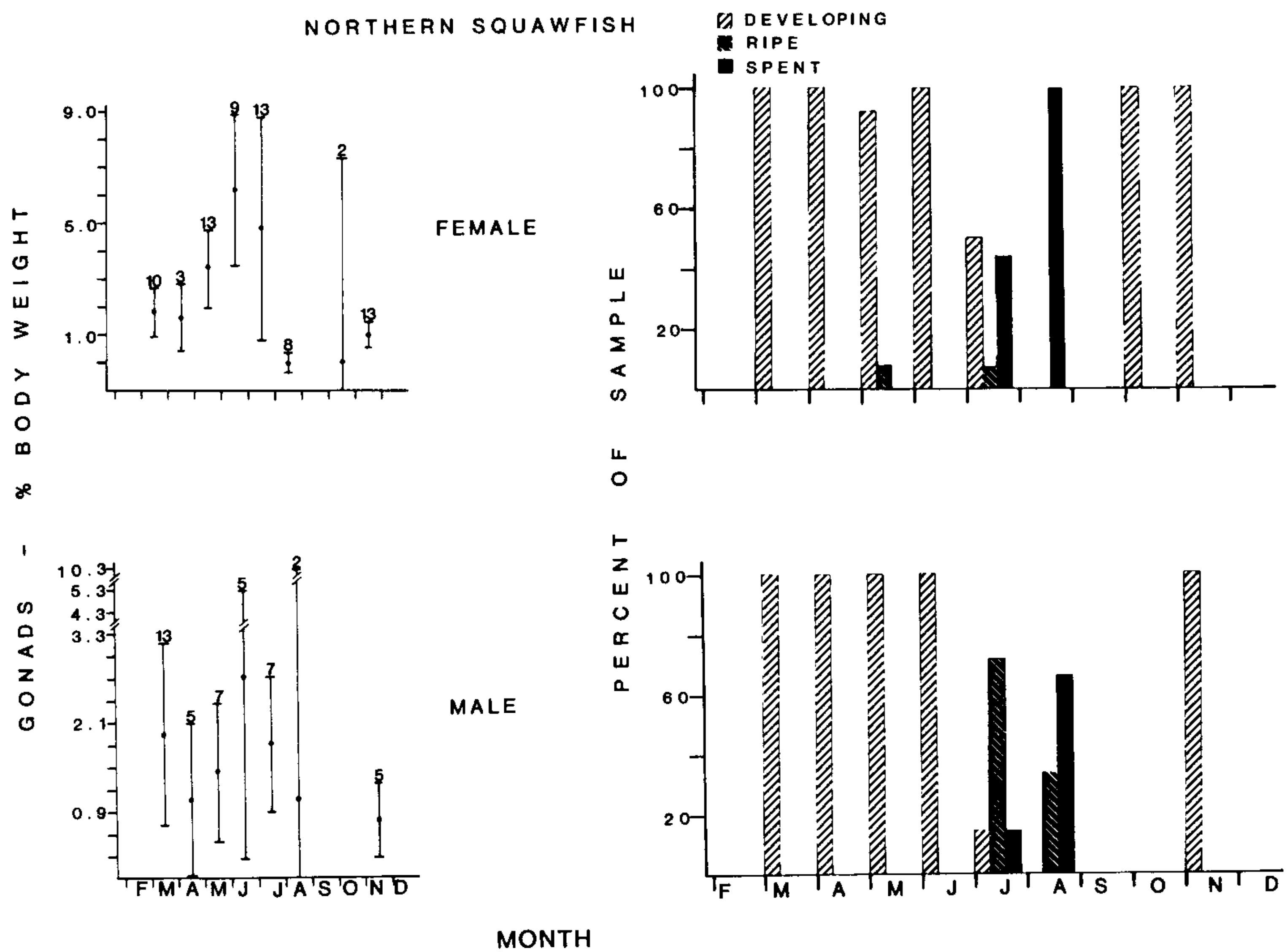

Figure 93. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) white crappie. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

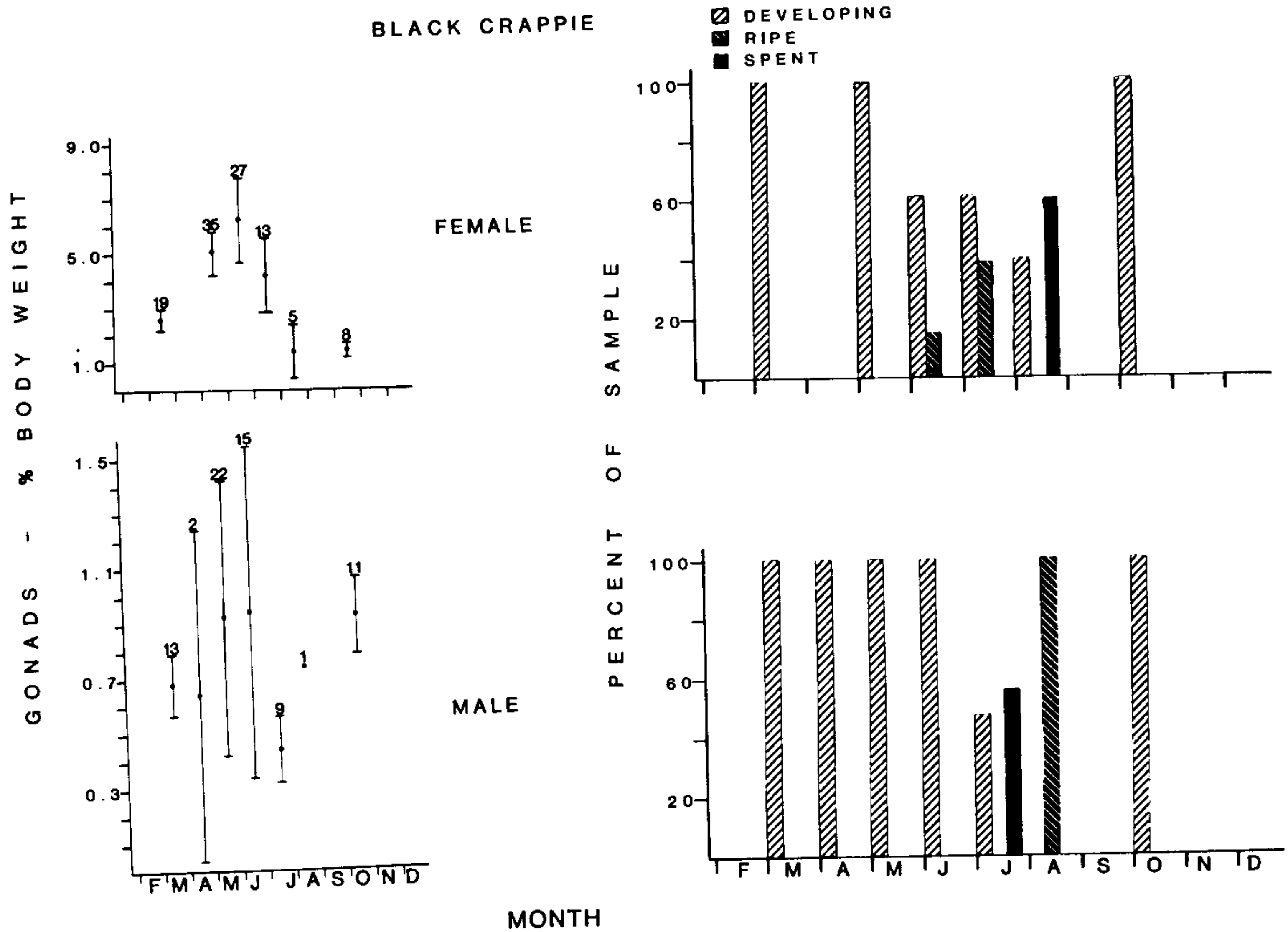

Figure 94. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) black crappie. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

in the samples indicated that most spawning probably occurred in June and July. Males initiated testicular development earlier in the fall and winter than ovary development. Ripe ova diameters averaged 0.78 mm. Water temperatures in June and July were 15.8 to 19.6 C.

The minimum sizes of male and female black crappie exhibiting reproductive development were 180 and 170 mm, respectively.

Yellow Perch

Gonad samples indicated that yellow perch are one of the earliest spawning resident species in the lower Snake River reservoirs (Fig. 95). Largest ovaries and testes were found in March and April. State of sexual maturity suggested most spawning occurred in April and May. Few spent fish were observed in April, whereas in May and June most yellow perch were spent. Ripe ova diameters were 1.2 mm. Water temperatures in April and May were 12.2 to 13.6 C.

The minimum sizes of male and female perch manifesting reproductive development were 137 and 153 mm, respectively.

Spawning Areas

Spawning Nests

A total of 256 spawning nests were located in Little Goose Reservoir during 1979 and 1980. One hundred sixteen smallmouth bass, 4 crappie (*Pomoxis* sp.) and 129 sunfish (*Lepomis* sp.), and 1 catfish (*Ictalurus* sp.) spawning nests were located. Six additional spawning nests were located; however, these were without embryos, fry and/or attended by adults and, therefore, could not be identified as to the species utilizing them for spawning.

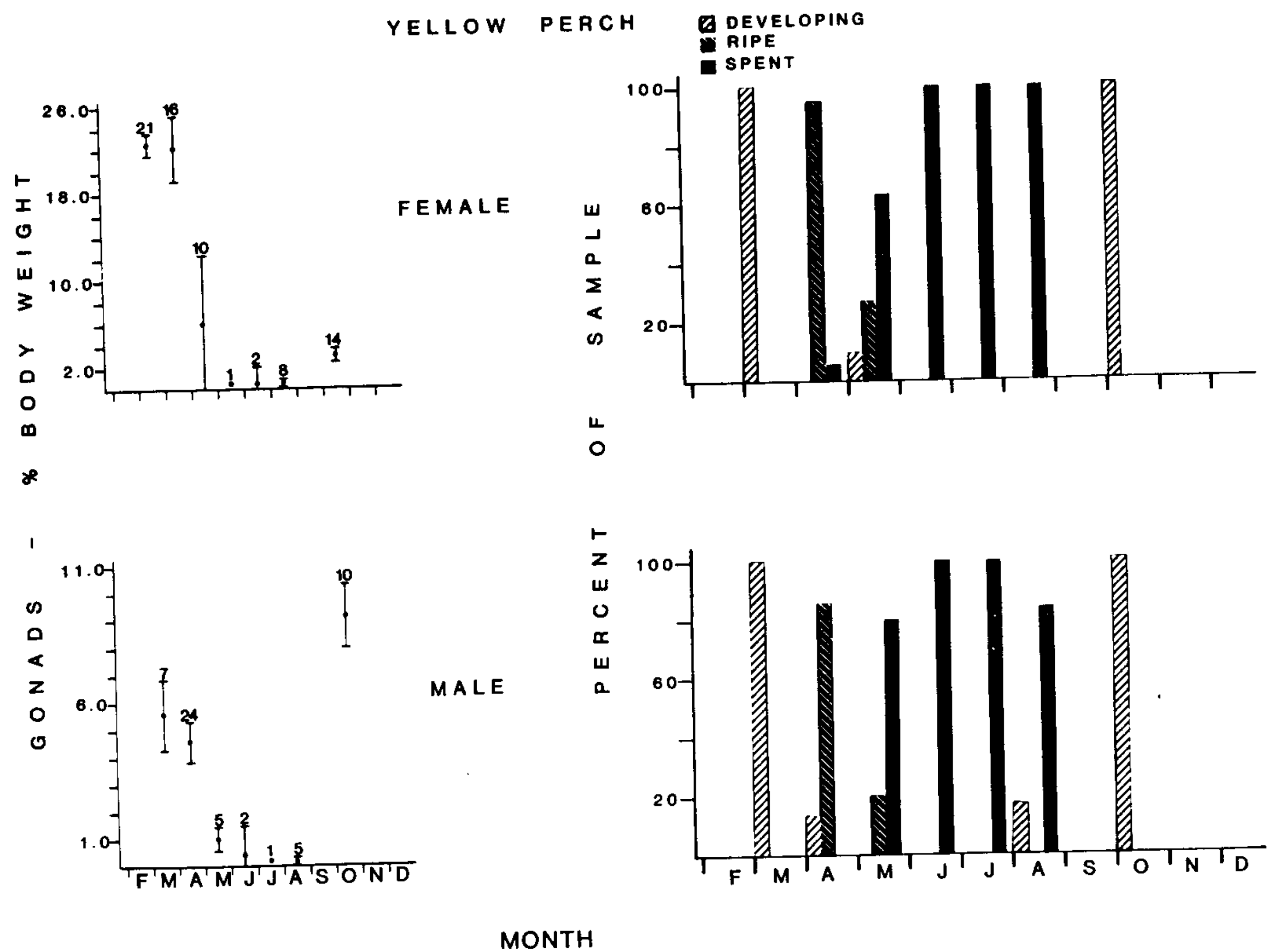

Figure 95. Monthly mean gonosomatic (GSI) index (and 95% confidence intervals) and percentage of gonads in developing, ripe, or spent reproductive condition of female (top) and male (bottom) yellow perch. Fish were collected during 1979 and 1980 from lower Snake River reservoirs, Washington. Number of individuals included in the analysis is indicated.

Spawning Nest Appearance and Differentiation

Smallmouth bass and sunfish spawning nests generally appeared as roughly circular, cleared areas. Smallmouth bass spawning nests were significantly larger ($t=15.83$, $P<0.05$) than sunfish spawning nests. As a result of this analysis, nests unattended and >34 cm in diameter were considered to be those of smallmouth bass, while those <31 cm in diameter were sunfish nests; nests within the interval 31-34 cm diameter could not be identified.

Temporal Distribution

Smallmouth bass spawning nests were located over a greater period of time than were sunfish spawning nests. Based on the presence of active spawning nests, the spawning season for smallmouth bass was initiated on 18 June 1979 and 15 June 1980. Smallmouth bass spawning nests which contained embryos and/or fry were periodically located until 31 July 1979 and 27 July 1980. In comparison, active sunfish spawning nests were not observed until 4 July 1979 and 13 July 1980. Sunfish spawning nests which contained embryos and/or fry were located until 2 August 1979 and 28 July 1980.

Water Temperatures

The range of water temperatures at active smallmouth bass spawning nests was similar between 1979 and 1980. Minimum incubation temperatures of 15 C in the early spawning period occurred on 20 June 1979 and 15 June 1980. Maximum temperatures recorded at spawning nests containing embryos and/or fry were 22.2 C on 8 July 1979 and 23.3 on 27 July 1980.

During the sunfish spawning season, water temperatures varied by less than 4.0 C at nests containing embryos and/or fry. Incubation was observed at minimum water temperatures of 20.0 C on 4 July 1979 and 20.1 C on 19 July 1980. Maximum incubation temperatures of 24.0 and 23.3 C were recorded on 26 July 1979 and 27 July 1980, respectively.

Spawning Substrate

Substrate utilized by smallmouth bass for nest construction was fairly consistent throughout Little Goose Reservoir. All of the observed smallmouth bass spawning nests were constructed on low gradient shorelines with gravel substrate. Substrate size varied from sand to 100 mm (diameter) gravel, although most (85%) spawning nests were found on substrate from 6 to 50 mm.

Sunfish utilized a broader range of substrate types for spawning nest construction than smallmouth bass. Approximately 55% of all sunfish spawning nests were found on gravel, 42% on mixed substrate (silt, sand, gravel, and organics), and 3% on silt or sand only. Those nests constructed on mixed substrate were usually shallow depressions in silted areas, with partially exposed sand, gravel, and/or organics.

Locational Distribution

A total of 137 and 121 hours of survey effort were expended to locate spawning areas in Little Goose Reservoir during 1979 and 1980, respectively. Although greater survey effort was expended during 1979, nearly three times as many spawning nests were located during 1980 than 1979 (191 vs. 65).

Based on the number of nests per unit survey effort located, smallmouth bass spawning nest distribution was similar among habitat types and within each reservoir zone between 1979 and 1980 (Table 52). In the

Table 52. Distribution of smallmouth bass spawning nests in Little Goose Reservoir, Washington, during 1979 and 1980.

Reservoir Zone	Habitat type	Effort (hours)		No. of nests		No. of nests/hour	
		1979	1980	1979	1980	1979	1980
Upper Reservoir	Embayment	----	7.50	----	1	----	0.13
	Gulch	4.50	9.75	0	2	0.0	0.21
	Shoal	11.92	21.00	8	19	0.67	0.91
Total		16.42	38.25	8	22	0.67	1.25
Lower Reservoir	Embayment	28.92	41.67	0	13	0.0	0.31
	Gulch	55.50	26.50	18	38	0.32	1.43
	Shoal	36.92	15.00	9	8	0.24	0.53
Total		121.34	83.17	27	59	0.56	2.27
Grand Total		137.76	121.42	35	81	1.23	3.52

lower reservoir zone, spawning nests were more frequently observed in gulch areas, followed by shoal and embayment habitats. In contrast, within the upper reservoir zone, smallmouth bass spawning nests were more commonly observed in shoal areas. The relatively high percentage of the total number of nests per unit survey effort found in shoal areas of the upper reservoir zone may reflect the relative paucity of gulch and embayment areas within the upper zone (Fig. 2). The number of smallmouth bass spawning nests located per unit survey effort was similar among habitat types and between reservoir zones. However, on an entire reservoir basis, the percentage of the total number of nests located per unit survey effort was slightly higher in gulch areas (47%) than shoal areas (41%) during 1980. Forty percent of all smallmouth bass spawning nests located in gulch areas contained embryos and/or fry, while approximately 26% of the nests located in shoal areas contained embryos and/or fry. Only about 12% of the total number of smallmouth bass spawning nests located per unit survey effort was found in embayment areas. Of those, approximately 29% contained embryos and/or fry.

A higher number of sunfish spawning nests per unit survey effort was found at all habitat types in 1980 than 1979 (Table 53). The distribution of sunfish spawning nests in the lower reservoir zone was similar between 1979 and 1980. Sunfish spawning nests were more frequently observed in gulch areas of the lower reservoir zone, followed by embayment and shoal areas. No sunfish spawning nests were located in the upper reservoir zone during 1979.

Sunfish spawning nests located per unit survey effort were significantly higher in abundance in the lower than upper reservoir zone during 1980 ($T=1$, $P<0.10$). Of those sunfish spawning nests located per

Table 53. Distribution of sunfish spawning nests in Little Goose Reservoir, Washington, during 1979 and 1980.

Reservoir Zone	Habitat type	Effort (hours) 1979	Effort (hours) 1980	No. of nests 1979	No. of nests 1980	No. of nests/effort hour 1979	No. of nests/effort hour 1980
Upper reservoir	Embayment	----	7.50	----	2	----	0.27
	Gulch	4.50	9.75	0	1	0.0	0.10
	Shoal	11.92	21.00	0	17	0.0	0.81
Total		16.42	38.25	-	20	0.0	1.18
Lower reservoir	Embayment	28.92	41.67	6	41	0.21	0.98
	Gulch	55.50	26.50	19	36	0.34	1.36
	Shoal	36.92	15.00	4	7	0.11	0.47
Total		121.34	83.17	29	84	0.66	2.81
Grand Total		137.76	121.42	29	104	0.66	3.99

unit survey effort in the upper reservoir zone, nearly 69% were found in shoal areas, 23% in embayment areas and 8% in gulch areas (Table 53). On an entire reservoir basis, abundance of sunfish spawning nests was approximately equal among habitat types. As with smallmouth bass, the highest number of active sunfish spawning nests were located in gulch areas (38%), while 28 and 25% of observed nests were active in embayment and shoal areas, respectively.

Some gulch areas were observed to be simultaneously utilized for spawning by both smallmouth bass and sunfish. Pumpkinseed sunfish preyed heavily on embryos and fry in smallmouth bass spawning nests when both species were observed spawning in close proximity. During 1979, complete losses of embryos were observed at several smallmouth bass spawning nests as a result of pumpkinseed predation.

Vertical Distribution

The vertical distribution of spawning activity for smallmouth bass was generally similar in 1979 and 1980. Observed smallmouth bass spawning nests ranged in elevation from 189.19 to 193.43 m msl (620.7 to 634.6 ft msl) during 1979, and from 191.14 to 194.22 m msl (627.1 to 637.2 ft msl) during 1980. Approximately 54% during 1979 and 25 percent in 1980 of all observed smallmouth bass spawning nests were located below minimum pool elevation (192.94 m or 633.0 ft msl) (Fig. 96).

The range of daily water level fluctuations remained above the median elevation (192.85 m or 632.7 ft msl) of smallmouth bass spawning nests located throughout the 1979 spawning period (Fig. 97). In contrast, water levels dropped to, or below, the median elevation (193.27 m or 634.1 ft msl) of located smallmouth bass spawning nests repeatedly during the 1980 spawning period. Twenty-seven% (22 nests) of the

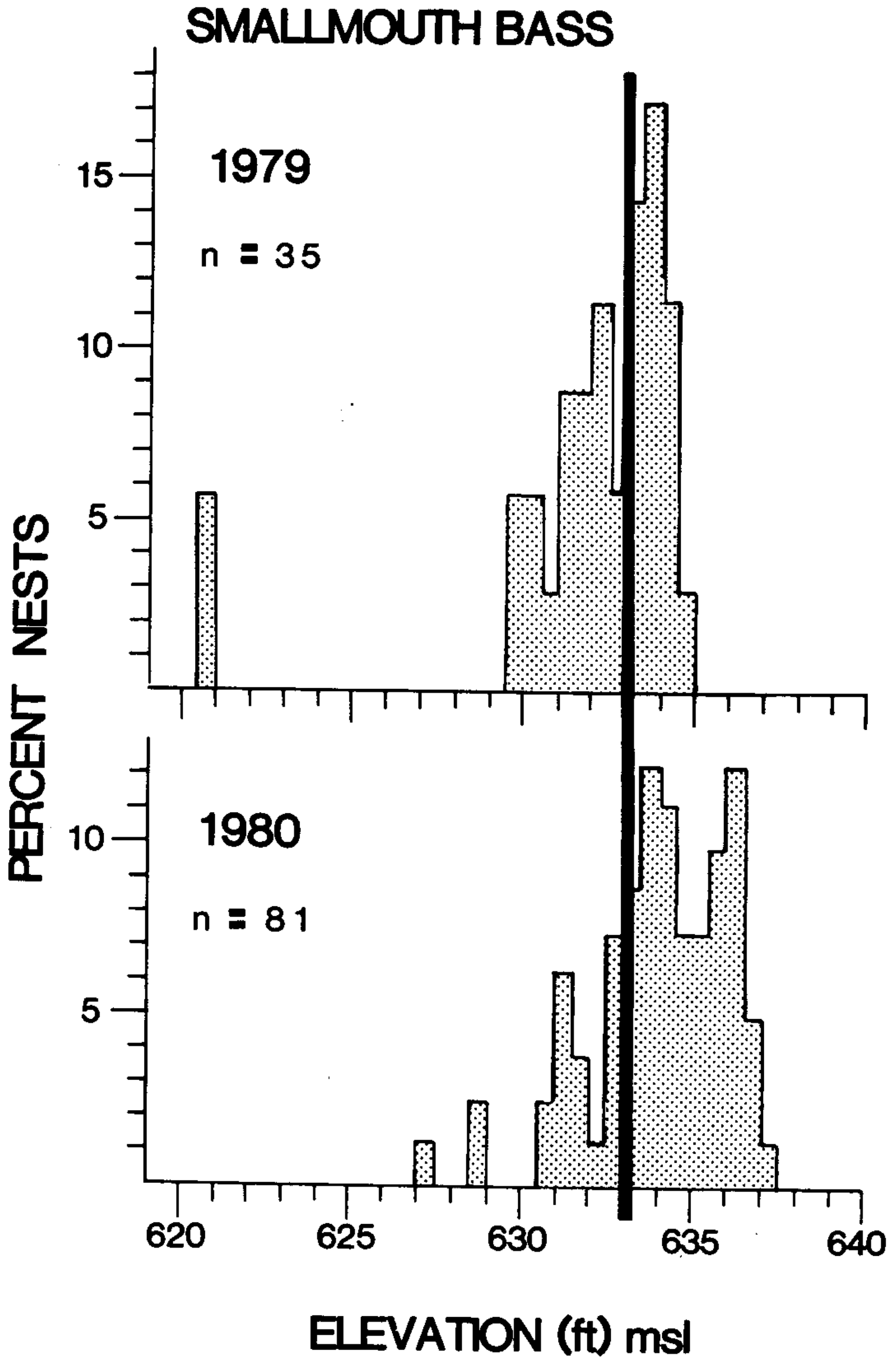

Figure 96. Vertical distribution of smallmouth bass spawning nests located in Little Goose Reservoir, Washington, 1979 and 1980. Solid vertical line represents minimum pool elevation (633.0 ft and 192.94 m msl).

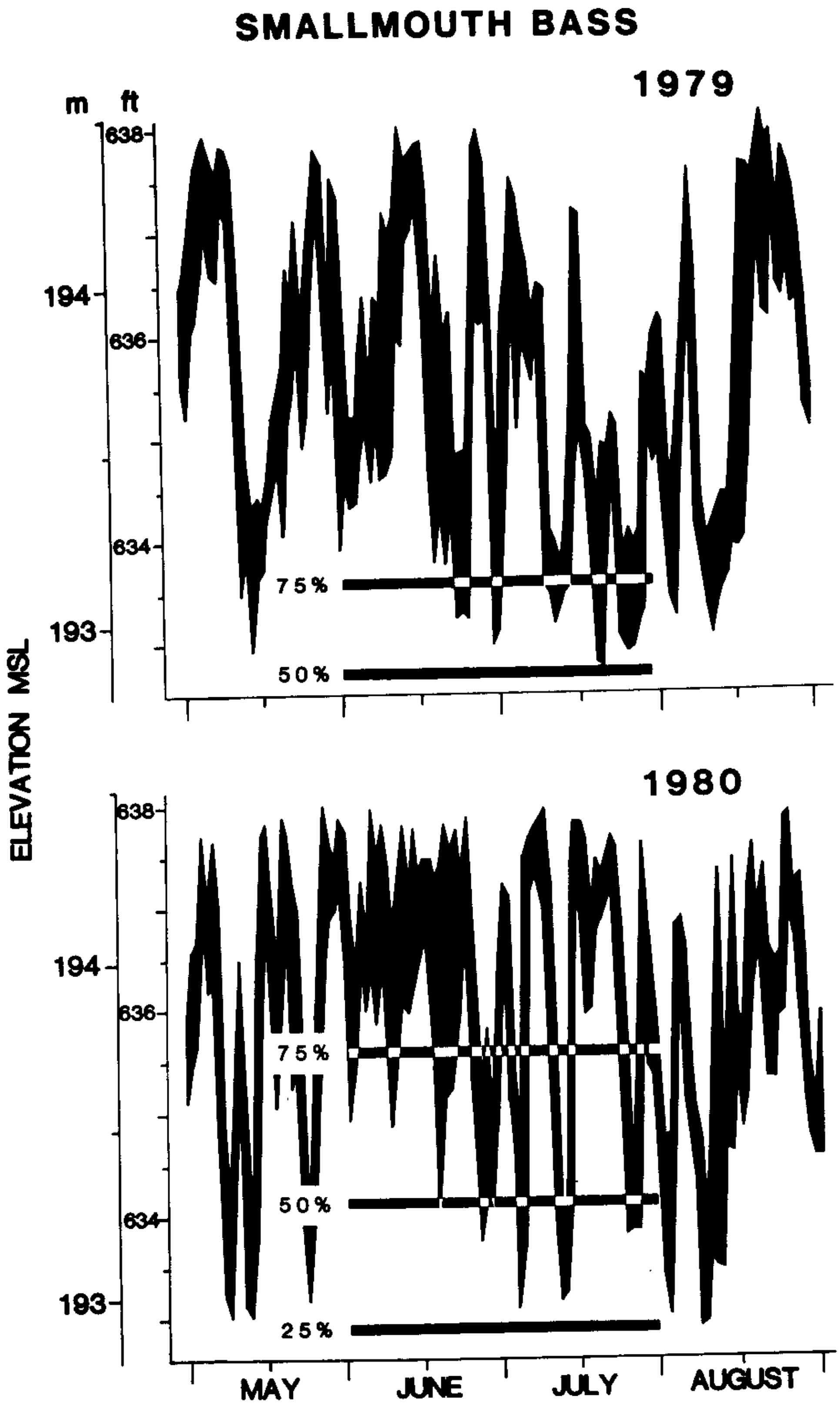

Figure 97. Range of daily water elevations from 1 May through 31 August 1979 and 1980 for Little Goose Reservoir, Washington. Horizontal lines represent the median, upper, and lower quartiles of the elevations of smallmouth bass nests observed during the spawning season.

total number of smallmouth bass spawning nests located during 1980 were exposed (above water level) at the time of observation, ten of which contained embryos and/or fry.

The range in elevation of sunfish spawning nests was approximately 0.9 m (3.0 ft) during 1979 (192.66 to 193.55 m or 632.1 to 635.0 ft msl), and 2.13 m (7.0 ft) during 1980 (191.84 to 194.00 m or 629.4 to 636.5 ft msl). Twenty-eight and twenty-seven% of all observed sunfish spawning nests were located below minimum pool elevation (192.94 m or 633.0 ft msl) during 1979 and 1980, respectively (Fig. 98).

Daily water levels dropped below the median elevation of sunfish spawning nests during July 1979 and 1980 (Fig. 99). One nest or 3% of the total number of sunfish spawning nests located during 1979 were exposed to air at the time of observation. During 1980, 7 of 100 nests located were exposed at the time of observation. Two of these nests contained embryos and/or fry.

General Observations

One catfish (Ictalurus sp.) spawning site was located on 24 July 1980. The spawning site was comprised of a burrow in rubble located along the shoreline in a lower gulch area. An adult catfish was observed above the spawning nest, protecting the embryo mass. The spawning nest was located at an elevation of 192.91 m (632.9 ft) msl. Water depth over the spawning nest was 73 cm (2.4 ft), and water temperature at the time of observation was 22.0 C at the nesting depth.

Yellow perch embryo masses were observed on 28 April, 1979 at the lower embayment sampling station (Fig. 2). Surface water temperature at the time of observation was 14.0 C. Additional yellow perch embryo masses were observed on 26 and 27 April 1980 at the upper shoal and

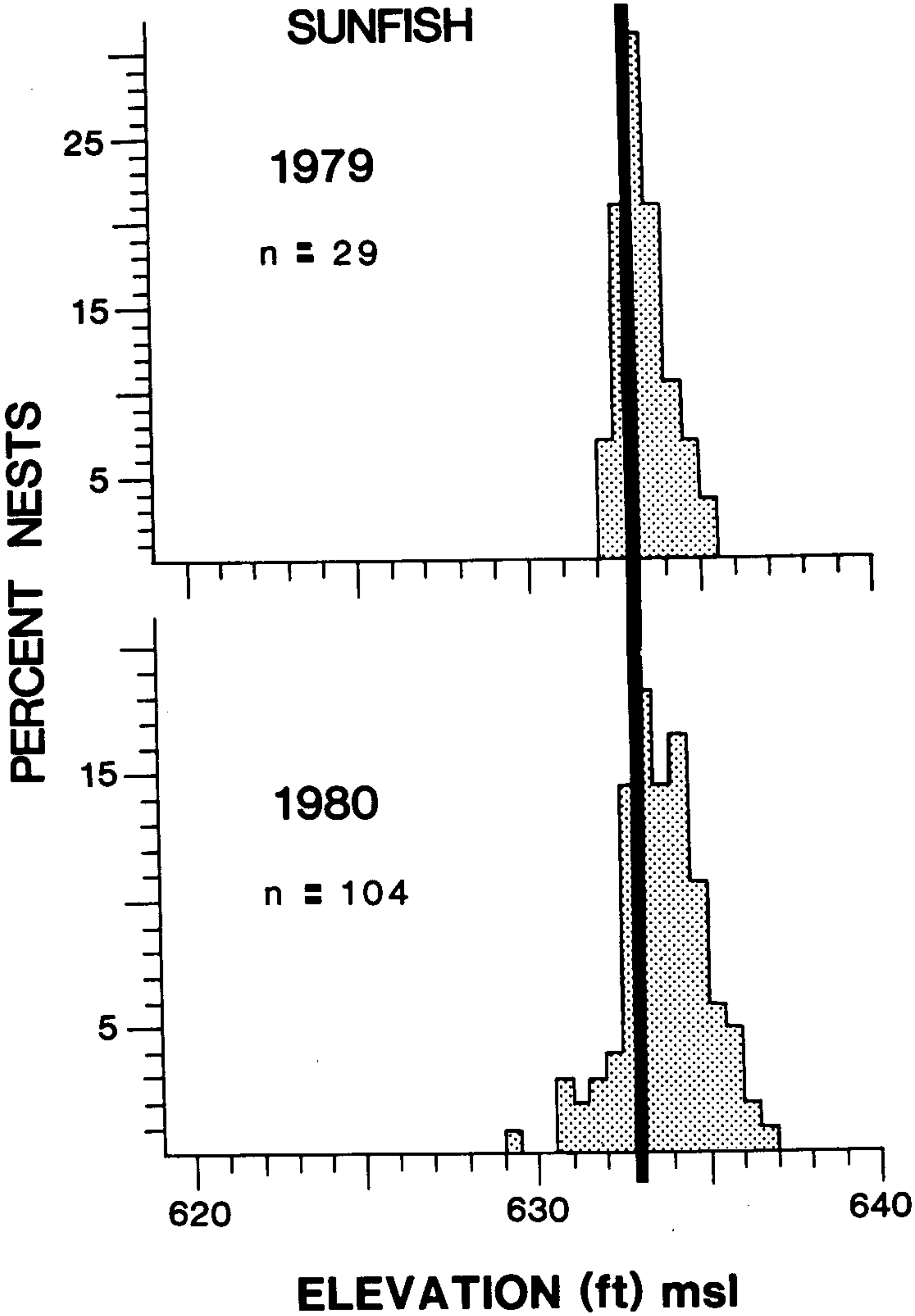

Figure 98. Vertical distribution of sunfish (Lepomis sp.) spawning nests located in Little Goose Reservoir, Washington, 1979 and 1980. Solid vertical line represents minimum pool elevation (633.0 ft or 192.94 m msl).

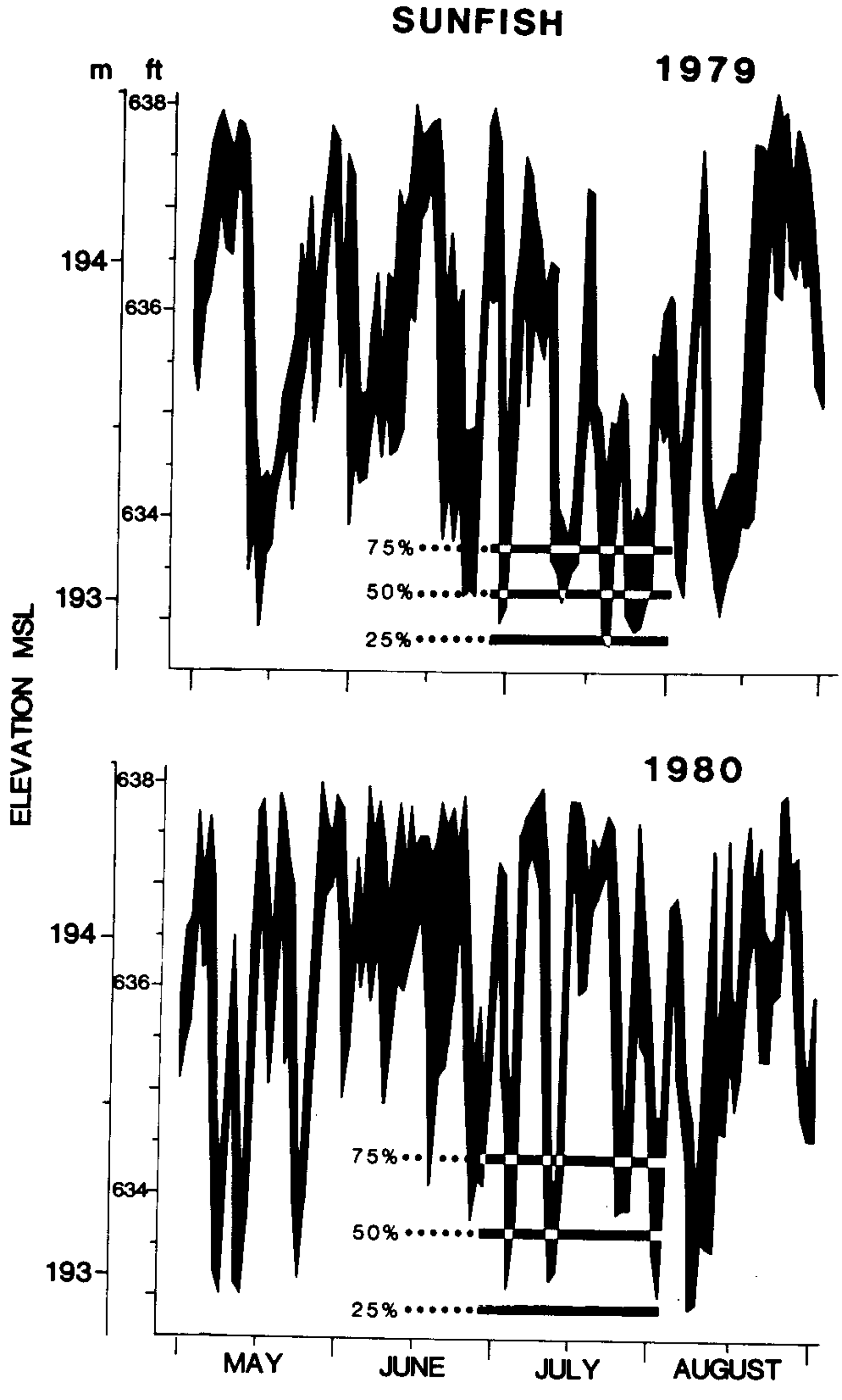

Figure 99. Range of daily water elevations from 1 May through 31 August 1979 and 1980 for Little Goose Reservoir, Washington. Horizontal lines represent the median, upper, and lower quartiles of the elevations of sunfish (Lepomis sp.) nests during the spawning season.

lower embayment sampling stations, respectively. Surface water temperatures on those dates were 11.1 C at the upper shoal sampling station, and 15.0 C at the lower embayment station. Observed yellow perch embryo masses were elongated, transparent, and gelatinous in appearance. The semi-buoyant embryo masses were found adhering to submerged vegetation and to various nets used in sub-adult and adult fish collections.

Pre-spawning groups of carp were observed congregating at lower embayment and upper shoal areas during the third week of June 1980. By 25 June, 1980 groups typically comprised of 1 or 2 females with 2 to 5 males were observed spawning in the littoral region of the lower embayment area in water approximately 20 to 60 cm deep. Carp also were observed spawning on 29 June, 1980 at upper shoal areas of Little Goose Reservoir. This group, comprised of 1 female and 9 males, was observed spawning near the surface over submerged aquatic macrophytes. Surface water temperatures of 16.5 and 17.0 C were recorded at the time of spawning. Water depths at spawning sites ranged from 1.2 to 1.8 m (4 to 6 ft). Numerous eggs and embryos were observed adhering to submerged aquatic macrophytes.

Larval Fish Abundance and Distribution

Species Composition

A total of 3873 larval fishes were collected by tow netting in Little Goose Reservoir during 1980 (Table 54). These fish comprised seven families and eight genera. Larval cyprinids could not be identified beyond the family level prior to attainment of median fin development.

Table 54. Mean densities (No./1000m^3) and standard error of larval fishes collected by tow netting Little Goose Reservoir, Washington, during 1980.

Family	Species	Mean Density	Standard Error
Clupeidae	American shad	0.5	0.2
Cyprinidae	peamouth	0.3	0.2
	northern squawfish	1.1	0.4
	redside shiner	1.8	0.6
	unidentified cyprinids	56.3	13.9
Catostomidae	suckers (*Catostomus* sp.)	3.4	0.5
Ictaluridae	yellow bullhead	0.3	0.1
	brown bullhead	0.1	0.1
	channel catfish	2.8	1.1
	unidentified ictalurids	0.1	0.1
Centrarchidae	sunfishes (*Lepomis* sp.)	17.7	4.4
	smallmouth bass	0.2	0.1
	crappies (*Pomoxis* sp.)	11.1	2.6
Percidae	yellow perch	0.3	0.1
Cottidae	sculpins (*Cottus* sp.)	4.2	0.7

Relative Abundance

Resident non-game and larval game fishes comprised 75 and 25%, respectively, of all larval fishes collected in Little Goose Reservoir (Fig. 100). Larval cyprinids were considerably more abundant than other families of larval fishes, comprising approximately 64% of all larvae collected. Other non-game larval fishes, including members of the Cottidae (sculpins), Catostomidae (suckers), and Clupeidae (shad) families accounted for an additional 11% of larvae collected.

Larvae game fishes were represented in the collections by 3 families and 5 genera (Fig. 100). Two members of the Centrarchidae family, Lepomis sp. (sunfish) and Pomoxis sp. (crappies), comprised 87% of all larval game fishes collected.

Temporal Abundance

Larval fishes were first collected during May at all sampling stations excluding the tailwater and upper shoal where larvae first appeared during June (Fig. 101). Larval fish continued to be present in the samples until October, when they were collected at the upper gulch, upper and lower embayment stations. June, July, and August were the only months during which non-zero mean CPE occurred at all sampling stations. As a result of zero mean values for several months, we restricted our analysis to June, July, and August.

Abundance of larval fishes was highest during July when mean CPE averaged 430 larvae/1000 m^3. Significant differences ($P<0.05$) in monthly mean CPE were: July vs. August (192 larvae/1000 m^3); and July vs. June (17 larvae/1000 m^3), and August vs. June.

Non-game larval fishes were present in the samples from May until September (Fig. 102). Cyprinids were significantly ($P<0.05$) more abundant

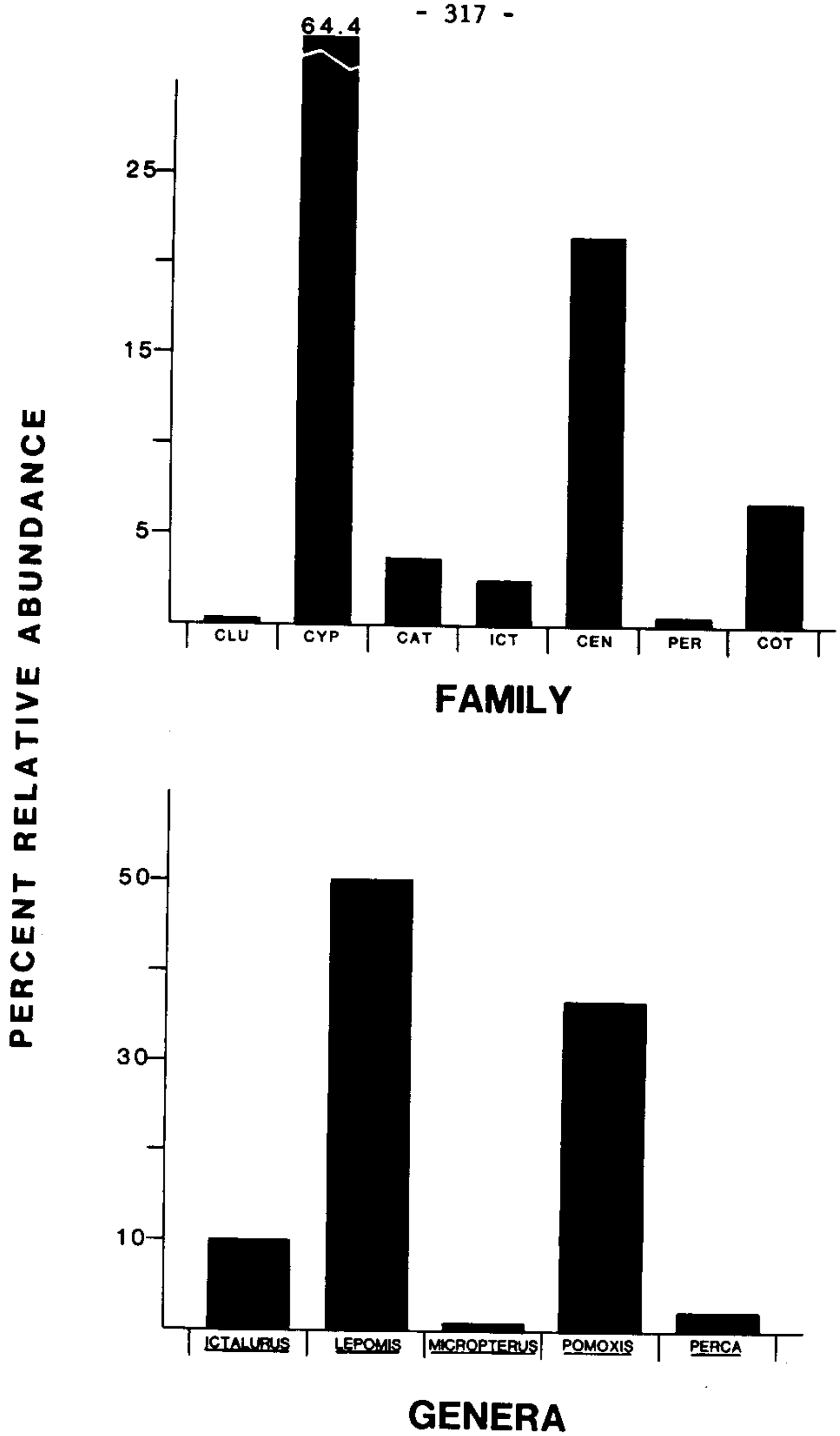

Figure 100. Relative abundance (percent of all fish collected) of larval fish families (top) and genera of game fishes (bottom) collected by tow netting in Little Goose Reservoir, Washington, from April through November, 1980. Family abbreviations are: CLU - Clupeidae; CYP - Cyprinidae; CAT - Catostomidae; ICT - Ictaluridae; CEN - Centrarchidae; PER - Percidae; COT - Cottidae.

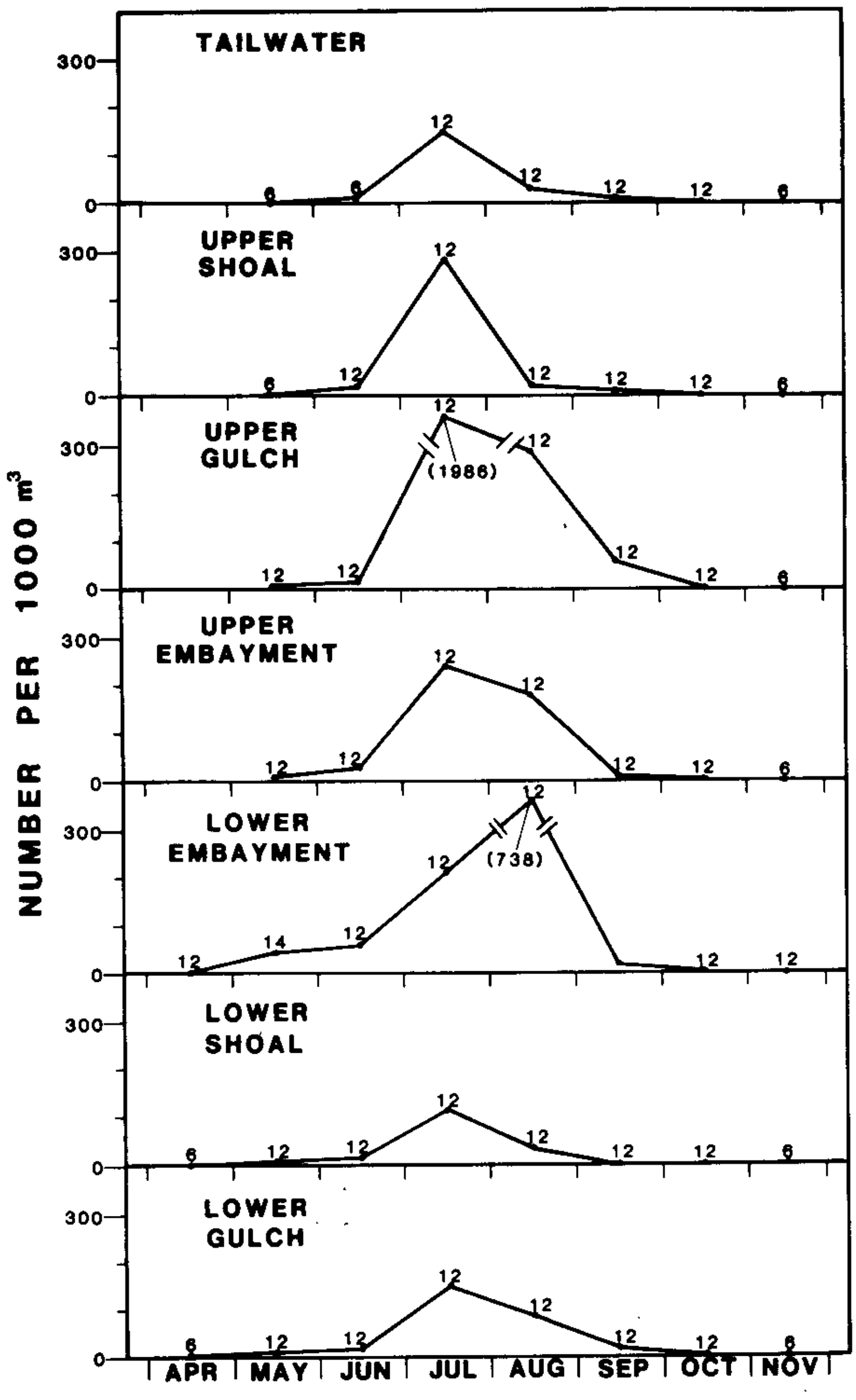

Figure 101. Mean densities (number per 1000 m^3) of larval fishes collected by tow netting at representative sampling stations on Little Goose Reservoir, Washington, from April through November, 1980. Number of tows for each monthly period is indicated.

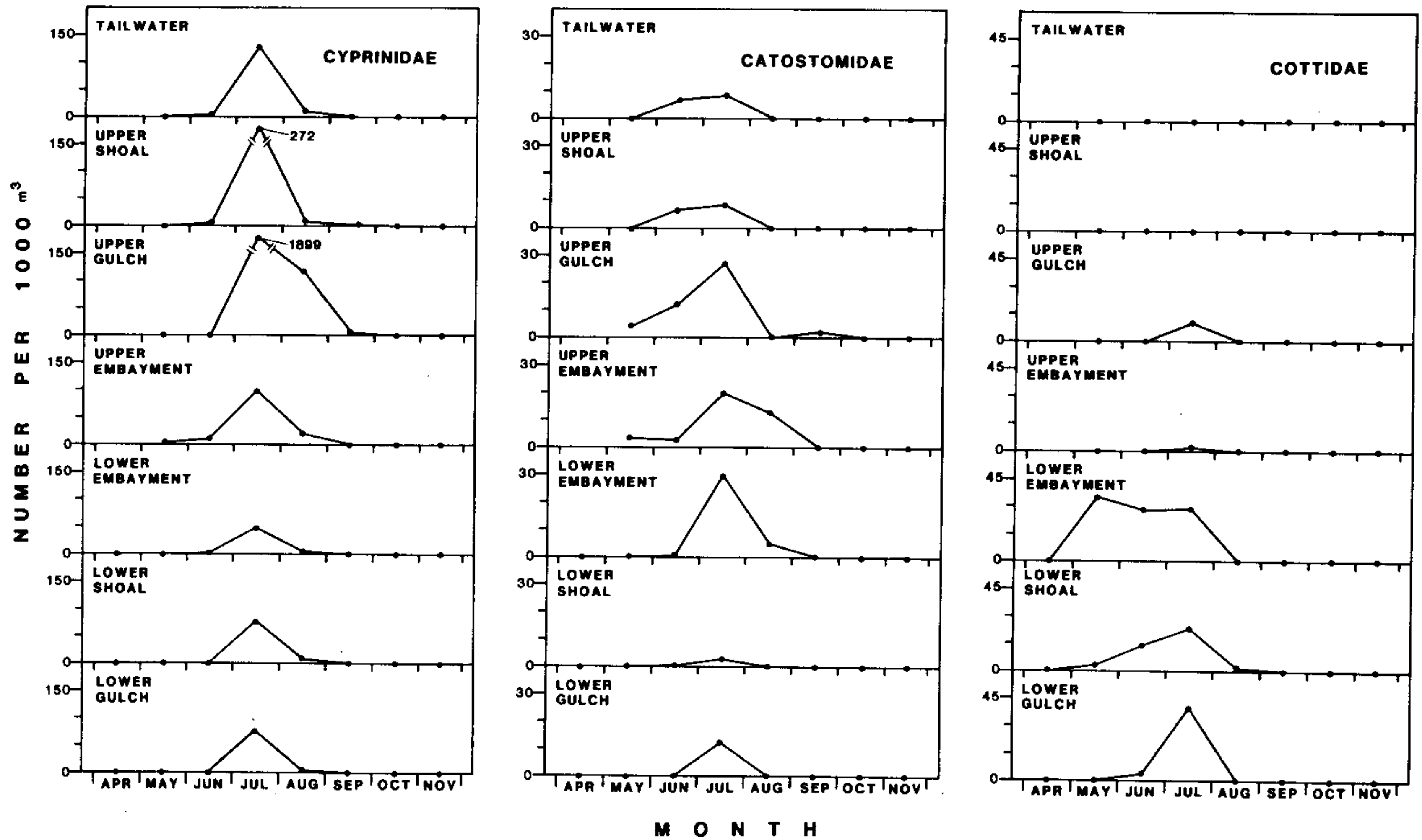

Figure 102. Mean densities (number per 1000 m^3) of larval non-game fish families collected by tow netting at representative sampling stations on Little Goose Reservoir, Washington, from April through November, 1980.

during July (371 larvae/1000 m^3) than August (23 larvae/1000 m^3). Densities of larval cyprinid fishes averaged 3/1000 m^3 during June and less than 1 larvae/1000 m^3 during May and September. Larval catostomid densities were highest during July (15 larvae/1000 m^3) followed in abundance by June (4 larvae/1000 m^3), August (2 larvae/1000 m^3), and May (1 larvae/1000 m^3). Densities of Cottidae, another family of non-game fish, were highest during the months of July (15 larvae/1000 m^3), June (7 larvae/1000 m^3), and May (5 larvae/1000 m^3).

Most resident larval game fishes were collected during July and August (Fig. 103). Percid larvae were the only game fish collected during May, when densities averaged 2 larvae/1000 m^3. Ictalurids were collected primarily during August (22 larvae/1000 m^3). Although larval centrarchids were collected from June until October, highest densities occurred during July and August. Mean densities of larval centrarchids were significantly ($P<0.05$) higher during August (143 larvae/1000 m^3) than July (34 larvae/1000 m^3). Representatives of the family Centrarchidae were: *Lepomis* sp., *Pomoxis* sp., and *Micropterus* sp. (Fig. 104). Mean densities of *Lepomis* sp. were significantly ($P<0.05$) higher during August than July, whereas, differences between monthly mean densities of *Pomoxis* sp. during July and August were not significant ($P>0.05$).

Monthly relative abundance estimates of larval fishes from Little Goose Reservoir indicated pronounced temporal variations in abundance for all families (Fig. 105). Cyprinids and catostomids were collected from May through September. Cyprinid abundance increased continuously from May through July but decreased thereafter, whereas catostomids decreased in abundance following June. Other resident non-game fishes exhibited different trends in monthly relative abundance. Cottids were

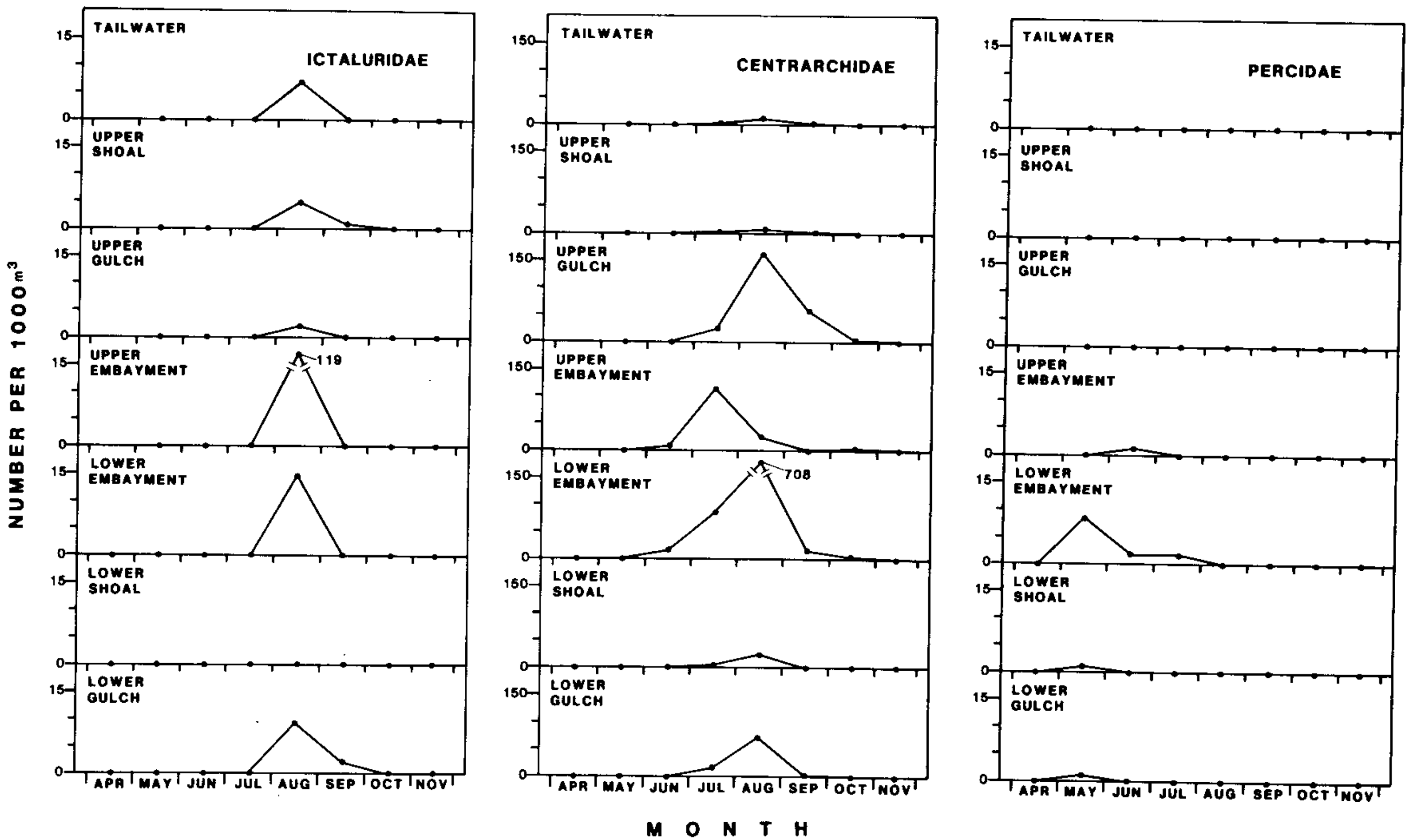

Figure 103. Mean densities (number per 1000 m^3) of larval game fish families collected by tow netting at representative sampling stations on Little Goose Reservoir, Washington, from April through November, 1980.

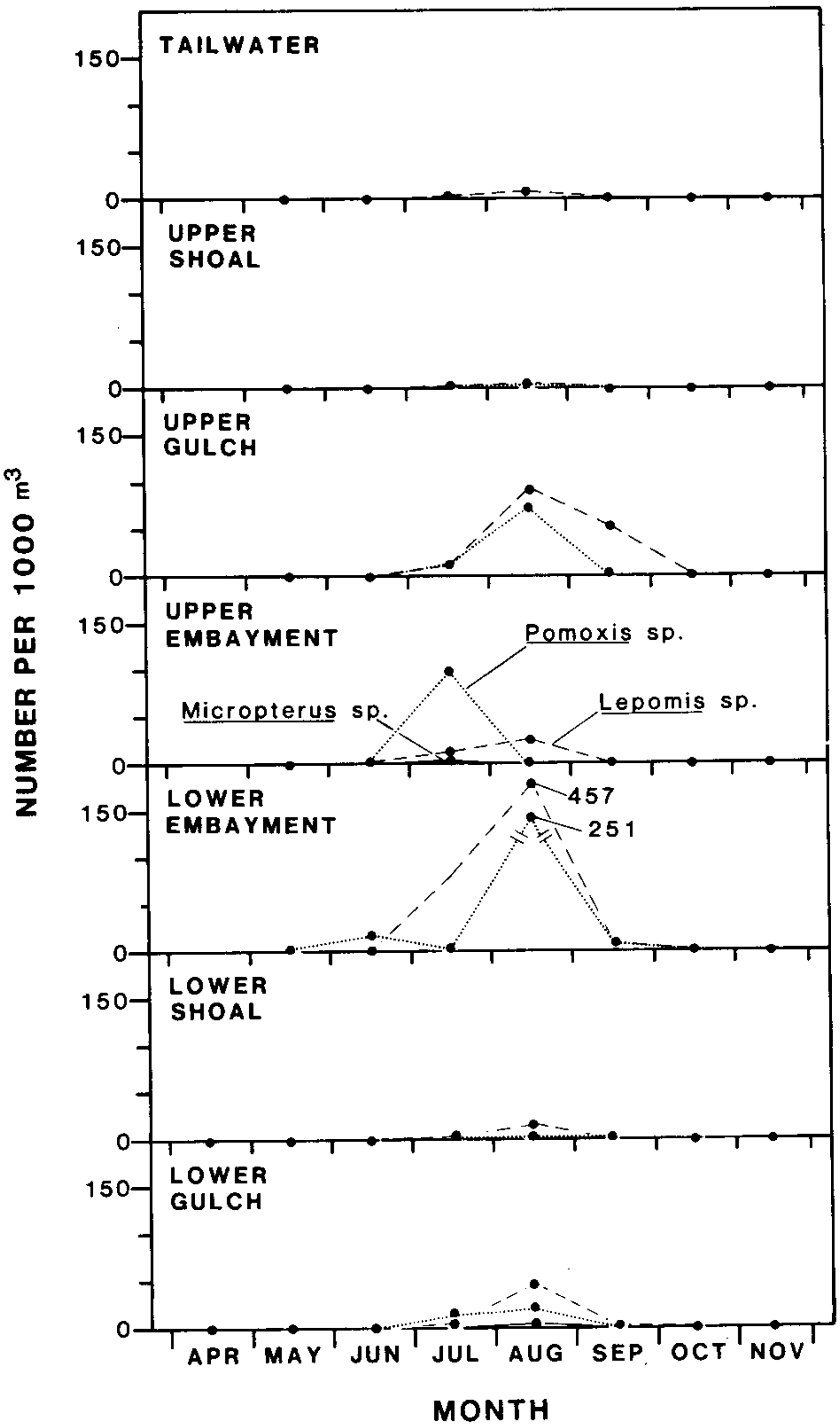

Figure 104. Mean densities (number per 1000 m^3) of centrarchid fish larvae (Lepomis sp., Micropterus sp., and Pomoxis sp.) collected by tow netting at representative sampling stations on Little Goose Reservoir, Washington, from April through November, 1980.

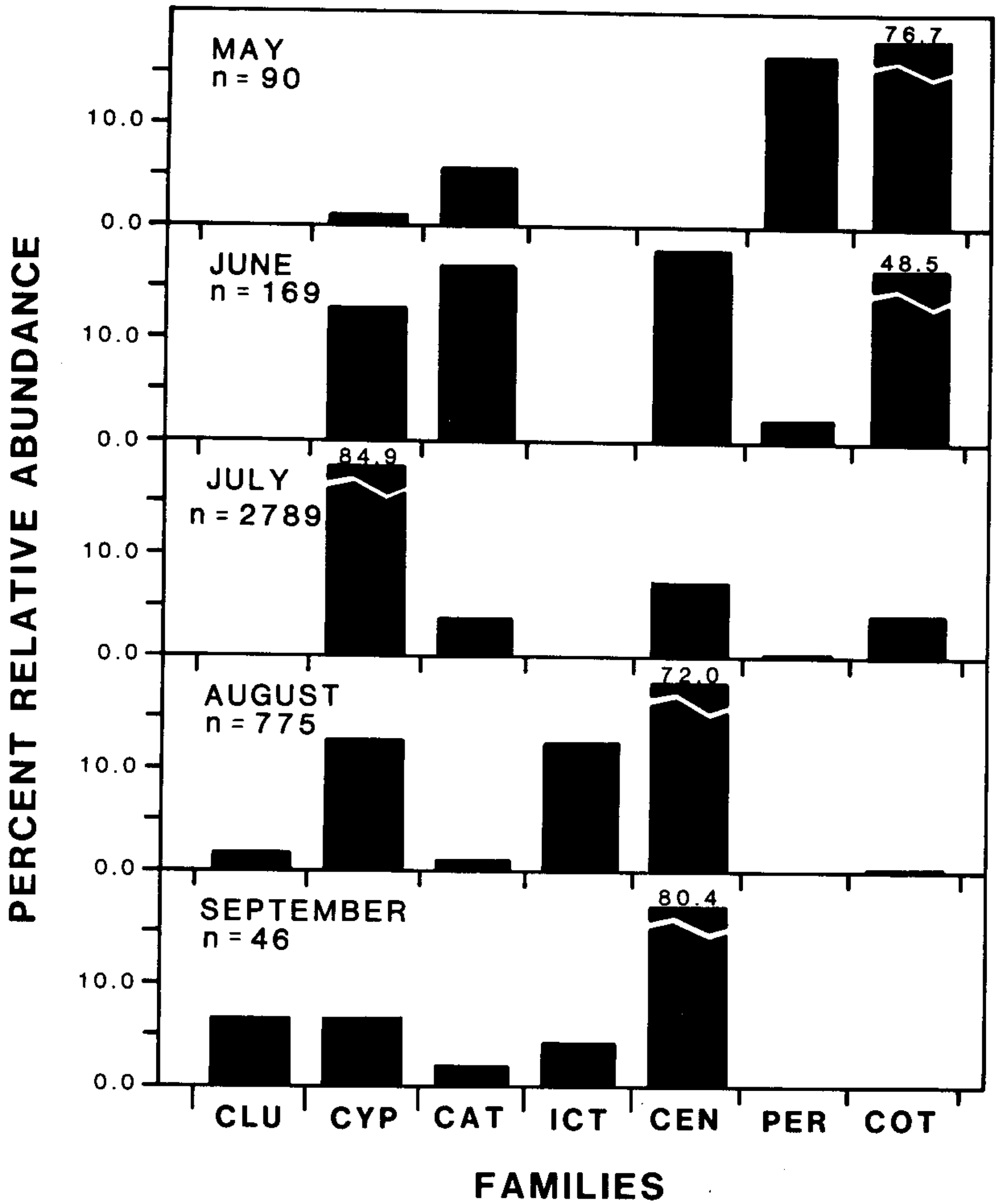

Figure 105. Relative abundance (%) of larval fish families collected by tow netting in Little Goose Reservoir, Washington, from April through November, 1980. No larvae were collected during April and November. Number of individuals collected is indicated (n).

most abundant during May and decreased continuously until August, whereas clupeids were not collected prior to August.

Resident game fishes exhibited distinct trends in monthly relative abundance. Percids were the only game fish collected during May, after which time relatively few individuals were collected. In contrast, ictalurid and centrarchid fishes were most abundant during August and September. Ictalurid and centrarchid fishes combined comprised 84 and 85% of all larval fishes collected during August and September, respectively. Also, each genus of larval game fish exhibited different trends in monthly relative abundance (Fig. 106). Lepomis sp. and Pomoxis sp. were first collected during June. Monthly relative abundance of Lepomis sp. increased continuously from June through September, whereas the relative abundance of Pomoxis sp. decreased continuously during the same period. Although few individuals were collected, Micropterus sp. were present in the collections only during July and August.

Locational Abundance

Mean density of larval fishes collected from May through October in Little Goose Reservoir was highest at the upper gulch sampling station (393 larvae/1000 m^2) (Fig. 101). The second highest mean density of larval fishes (173/1000 m^3) was found at the lower embayment station, followed in order of decreasing abundance by the upper embayment, upper shoal, lower gulch, tailwater, and lower shoal stations (77, 58, 41, 34, and 17 larvae/1000 m^3, respectively). During June, July, and August significant differences ($P<0.05$) in mean CPE of larval fishes were: lower embayment vs. tailwater, lower gulch, lower shoal and upper shoal; upper gulch vs. lower shoal and upper shoal.

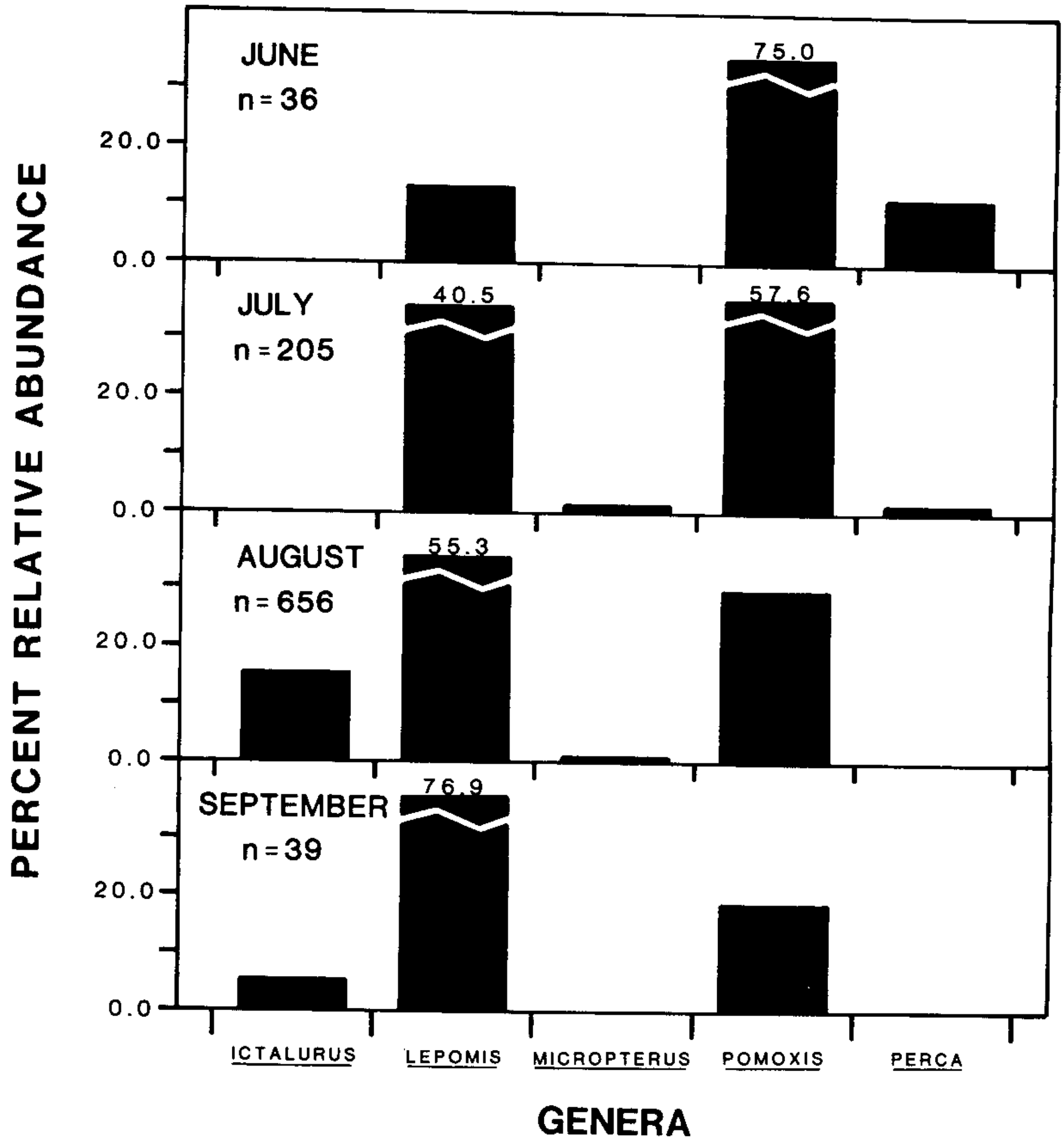

Figure 106. Relative abundance (%) of larval game fish genera collected by tow netting in Little Goose Reservoir, Washington, from April through November, 1980. No larvae were collected during April and November. Number collected is indicated (n).

Non-game larval fishes, including cyprinids and catostomids, were collected at all sampling stations (Fig. 102). Cyprinids were collected primarily during July and August, at which time mean densities were highest at the upper gulch (1009 larvae/1000 m^3) and upper shoal (140 larvae/1000 m^3) sampling stations. Mean CPE of larval cyprinids was significantly ($P<0.05$) higher at the upper gulch than all other sampling stations; however, catostomid densities were much lower than those of cyprinids. The highest densities of larval catostomids occurred during July at the lower embayment, upper gulch and upper embayment (29, 26, and 19 larvae/1000 m^3, respectively). Mean CPE of larval catostomids was not significantly different among sampling stations. The other family of nongame fish, Cottidae, was present primarily at lower reservoir sampling stations. Highest densities of larval cottids averaged 35/1000 m^3 during May at the lower embayment station and 40/1000 m^3 during July at the lower gulch station.

Resident game fishes exhibited considerable differences in densities among sampling stations (Fig. 103). Percid density was highest at the lower embayment sampling station, averaging 8 larvae/1000 m^3 during May. The upper embayment was the only upper reservoir sampling station at which percids were collected. Ictalurid fishes were collected at all sampling stations during August, excluding the lower shoal station. Highest densities of ictalurids occurred at the upper (119/1000 m^3) and lower (15/1000 m^3) embayment sampling stations. Centrarchid fishes were collected at all sampling stations. Highest mean densities of centrarchid larvae occurred at embayment and gulch sampling stations on Little Goose Reservoir. Significant differences ($P<0.05$) in mean CPE of centrarchid larvae among sampling stations during July and August were: lower embayment vs. lower gulch, lower shoal, tailwater and upper shoal; upper embayment vs. tailwater and upper shoal; upper gulch vs. tailwater and upper shoal; lower gulch vs. tailwater and upper shoal. Two genera of the family centrarchidae, Lepomis and Pomoxis, were collected at all sampling stations (Fig. 104). Mean densities (CPE) of Lepomis during August were significantly ($P<0.05$) higher at the lower embayment (269 larvae/1000 m^3) than at all other sampling stations; Lepomis densities at the upper gulch (49 larvae/1000 m^3) were significantly higher ($P<0.05$) than those at the tailwater and upper shoal sampling stations. In comparison, during the same time period, highest mean densities of Pomoxis also occurred at the lower embayment and upper gulch sampling stations, although relatively high densities (100/1000 m^3) of Pomoxis larvae were found during July at the upper embayment station. Micropterus were collected only during July at the upper embayment (2 larvae/1000 m^3) and August at the lower gulch (5 larvae/1000 m^3) sampling stations.

Relative abundance of larval fishes manifested distinct trends in abundance among sampling stations for most families (Fig. 107). Cyprinids were most abundant at upper reservoir sampling stations, comprising approximately 83, 92 and 90% of all larvae collected at the tailwater, upper shoal, and upper gulch sampling stations, respectively. In contrast, cottids were most abundant at lower reservoir sampling stations. Approximately 97% of all cottids were collected at the lower embayment, lower shoal and lower gulch sampling stations. Clupeids were collected exclusively at the upper embayment and gulch stations, whereas catostomids exhibited no definite trends in abundance among sampling stations.

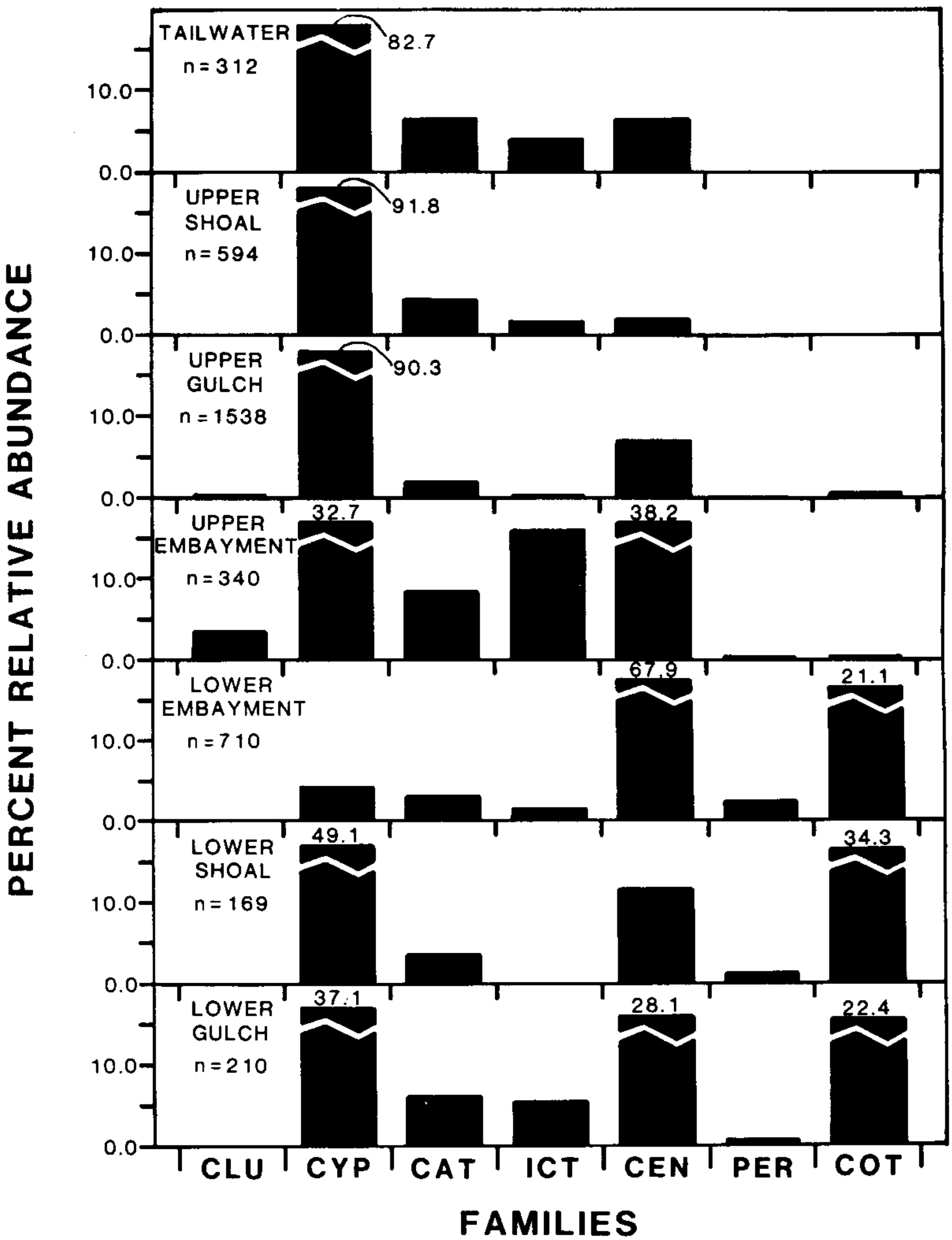

Figure 107. Relative abundance (percent of individuals collected at each station) of larval fish families collected by tow netting in Little Goose Reservoir, Washington, from April through November, 1980. Number of individuals collected is indicated (n).

Larval game fishes, including ictalurids, centrarchids, and percids were most abundant at the upper and lower embayment sampling stations. Although resident game fishes comprised only 25% of all larval fishes collected throughout Little Goose Reservoir, approximately 71 and 55% of all larval fishes collected at the lower and upper embayment sampling stations were game fishes, respectively. Of the genera of larval game fishes, Lepomis and Pomoxis were most widely distributed throughout Little Goose Reservoir (Fig. 106). Lepomis and Pomoxis comprised 87% of the genera of game fish collected. Ictalurus accounted for approximately 37 and 45% of all larval game fishes collected at the tailwater and upper shoal sampling stations, respectively.

Species Associations

We found five significant ($P<0.05$) taxon associations using Pearson product-moment correlation analysis.

The strength of the correlation resulted from categories of larval fishes occupying the same habitat types during the same monthly period of sampling. All significant associations between larval categories were positive. Cottus was weakly associated with Catostomus ($r=0.35$) and more strongly associated with Perca ($r=0.57$). Catostomus was also associated with Cyprinidae ($r=0.56$). Correlation coefficients were high for Alosa and Ictalurus ($r=0.91$). Micropterus was the only category of larval fishes included in the analysis which did not exhibit any significant associations.

Limnological Correlations

Sample frequencies of larval fishes in Little Goose Reservoir correlated with limnological characteristics produced 9 significant correlations (Table 55). Alosa (r=0.27), Ictalurus (r=0.27), Lepomis (r=0.34), Micropterus (r=0.24), and Pomoxis (r=0.31) were positively correlated with water temperature. Perca (r=0.35) and Cottus (r=0.34), collected primarily at the lower embayment station during early summer months, were negatively correlated with water transparency. Cottus also was negatively correlated with water velocity (r=0.31). Cyprinids (r=0.29) were positively correlated with aquatic macrophytes. Catostomus was the only category of larval fishes which was not significantly correlated with any of the limnological characteristics used in the analysis. No taxonomic level of larval fishes were correlated with the amount of littoral habitat.

Young-of-Year Fish Abundance and Distribution

Species Composition

A total of 11,658 YOY fishes representing 23 species were collected by seining lower Snake reservoirs from March through November 1980. Of these, 9,860 individuals representing 7 families and 22 species were collected from Little Goose Reservoir (Table 56).

Relative Abundance

Resident game and non-game species comprised 41 and 55%, respectively, of all YOY fishes collected in Little Goose Reservoir (Fig. 108). Two anadromous species, the American shad and chinook salmon, accounted for nearly 4% of all fish collected. Young-of-year northern squawfish and redside shiners were considerably more abundant than other species collected, comprising 26 and 22% of all fish, respectively. White crappie was the most abundant game species (12%), followed closely in abundance by smallmouth bass (10%), bluegill (9%) and black crappie (9%).

Table 55. Pearson product-moment correlations between limnological characteristics and sample frequencies of larval fishes collected by tow netting in Little Goose Reservoir, Washington, 1980. Significance levels of correlations are $P \leq 0.05$ unless indicated (* = $P \leq 0.15$).

	Limnological Characteristics				
Taxon	Water Temperature	Water Transparency	Water Velocity	Littoral Reach	Aquatic Macrophytes
Alosa sp.	0.27*				
Cyprinidae					0.29*
Catostomus sp.					
Ictalurus sp.	0.27*				
Lepomis sp.	0.34				
Micropterus sp.	0.24*				
Pomoxis sp.	0.31				
Perca sp.		-0.35			
Cottus sp.		-0.34	-0.31		

Table 56. Number of various young-of-year fishes collected by beach seine from Lower Snake Reservoirs from March through November, 1980.

Family	SPECIES	Lower Granite	Little Goose	Lower Monumental	Ice Harbor	Totals
Clupeidae	American shad	--	140	--	69	209
Salmonidae	chinook salmon	93	227	--	53	373
	mountain whitefish	--	4	--	2	6
	rainbow trout	--	25	--	--	25
Cyprinidae	chiselmouth	1	169	--	4	174
	carp	--	4	--	--	4
	peamouth	--	351	4	3	358
	northern squawfish	84	2522	3	10	2619
	redside shiner	8	2172	--	120	2300
Catostomidae	bridgelip sucker	--	56	--	11	67
	largescale sucker	18	148	--	1	167
Ictaluridae	yellow bullhead	--	2	--	--	2
	brown bullhead	1	14	--	--	15
	channel catfish	--	9	--	--	9
	tadpole madtom	--	8	--	--	8
Centrarchidae	pumpkinseed	--	38	--	13	51
	bluegill	95	931	--	133	1159
	smallmouth bass	78	939	93	19	1129
	largemouth bass	--	10	--	4	14
	white crappie	5	1172	14	579	1770
	black crappie	55	902	28	101	1086
Percidae	yellow perch	--	17	94	1	112
Cottidae	sculpin (Cottus sp.)	--	--	--	1	1
	TOTALS	438	9860	236	1124	11658

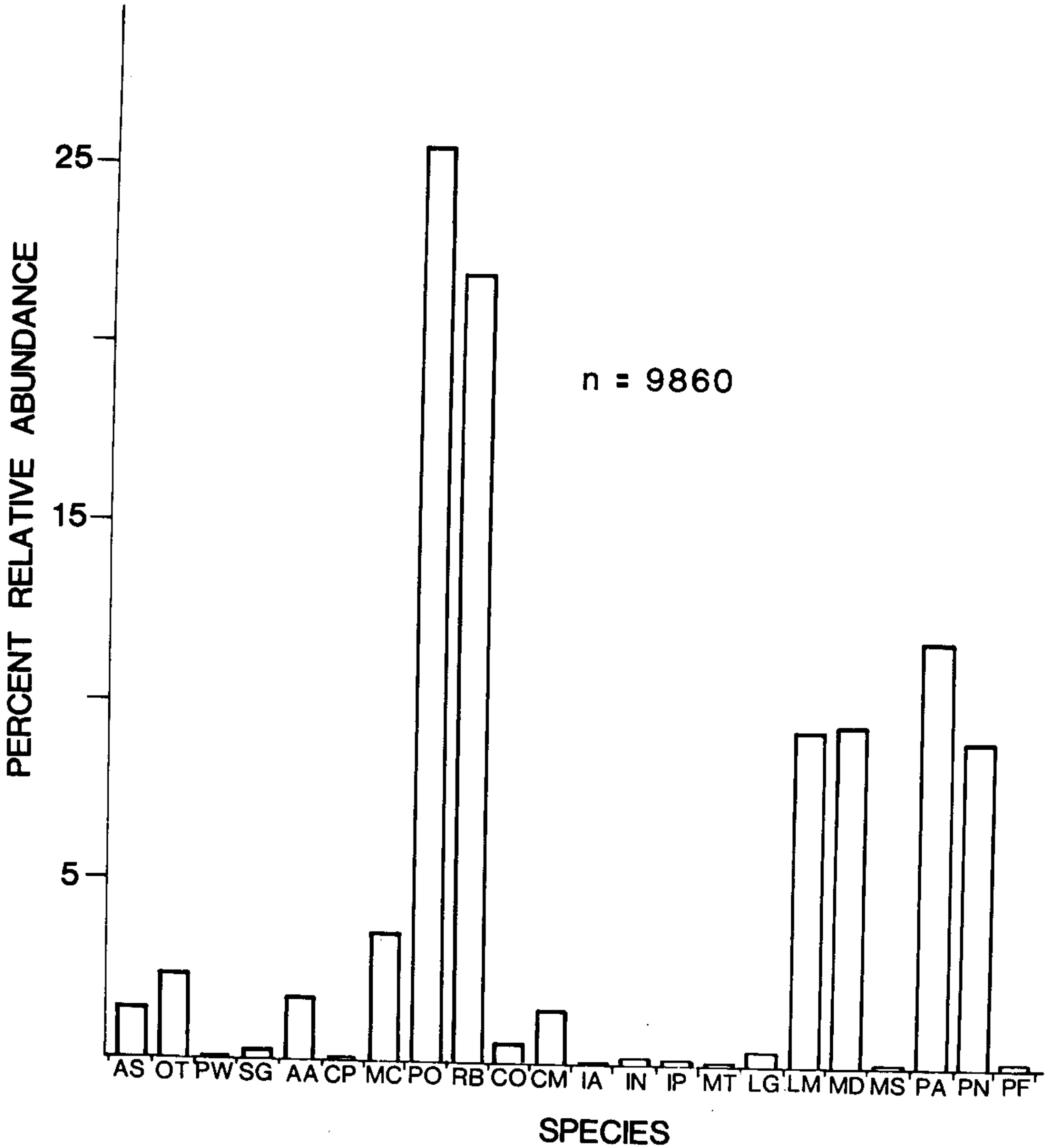

Figure 108. Relative abundance (%) of young-of-year fishes collected by seining seven representative sampling stations on Little Goose Reservoir, Washington, from March through November, 1980. Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch.

Relative abundance estimates of YOY fishes calculated by sampling stations on Lower Granite (Fig. 109), Lower Monumental (Fig. 110), and Ice Harbor (Fig. 111) reservoirs indicate similar trends in species abundance to those in Little Goose Reservoir (Fig. 112). These were: northern squawfish were widely distributed among stations; redside shiners were most abundant at upper shoal and tailwater stations; white and black crappies were primarily collected at embayment and gulch stations; and smallmouth bass were present at all stations. In Lower Granite and Ice Harbor Reservoirs, bluegill were more abundant at shoal sampling stations than in Little Goose Reservoir. The relatively high abundance of chinook salmon in Lower Granite Reservoir results from a large number of individuals collected only during spring sampling.

Abundance of several YOY fishes exhibited distinct trends among sampling stations representative of major habitat types in Little Goose Reservoir (Fig. 112). Northern squawfish were relatively abundant at all sampling stations, whereas many other non-game species, including redside shiner, peamouth and chiselmouth were more abundant at upper reservoir sampling stations. The northern squawfish and redside shiner complex comprised approximately 93, 74 and 72% of all YOY fishes collected at the tailwater, upper shoal and upper gulch sampling stations, respectively. Largescale and bridgelip suckers exhibited no definite trends in abundance among sampling stations.

Young-of-year game species, including white crappie, smallmouth bass, bluegill, black crappie, pumpkinseed and yellow perch were more abundant at embayment and gulch sampling stations in Little Goose Reservoir (Fig. 112). White and black crappies were collected primarily at the lower embayment station, collectively comprising greater than 67% of all

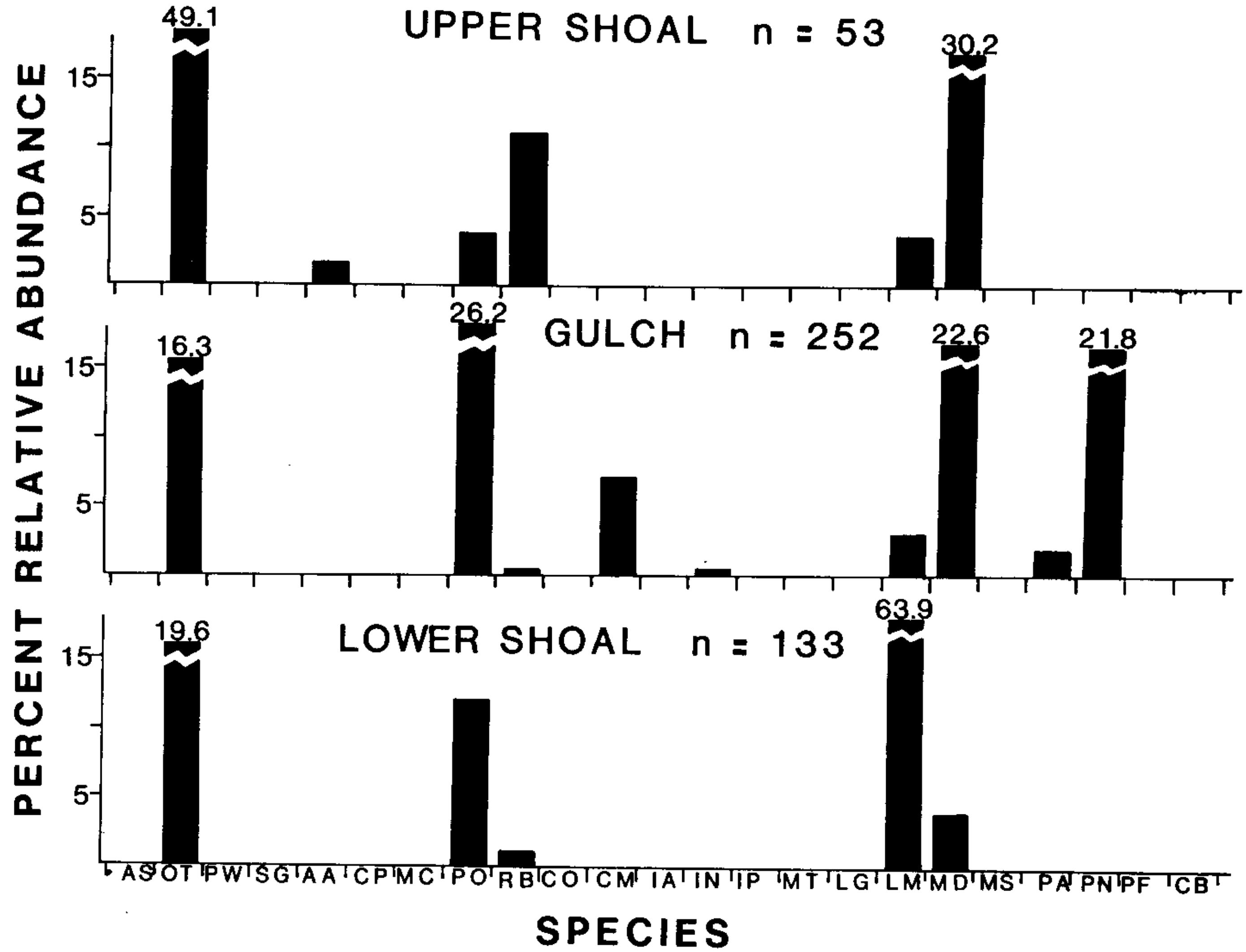

Figure 109. Relative abundance (%) of all young-of-year fishes collected by seining Lower Granite Reservoir, Washington, during spring, summer, and fall seasons, 1980. Number of individuals collected at each sampling station is indicated (n). Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch; CB - sculpin.

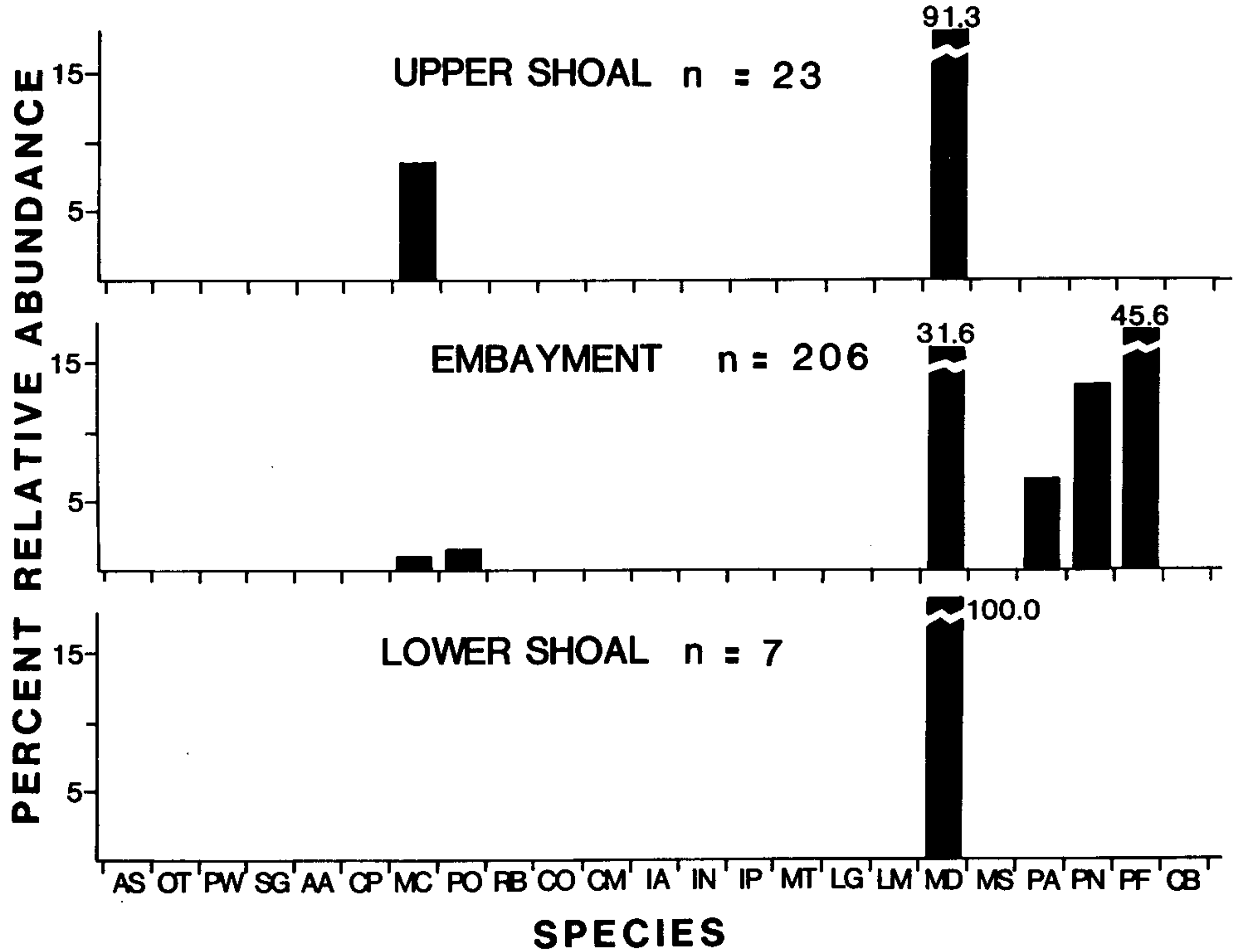

Figure 110. Relative abundance (%) of all young-of-year fishes collected by seining Lower Monumental Reservoir, Washington, during summer and fall seasons, 1980. Number of individuals collected at each sampling station is indicated (n). Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch; CB - sculpin.

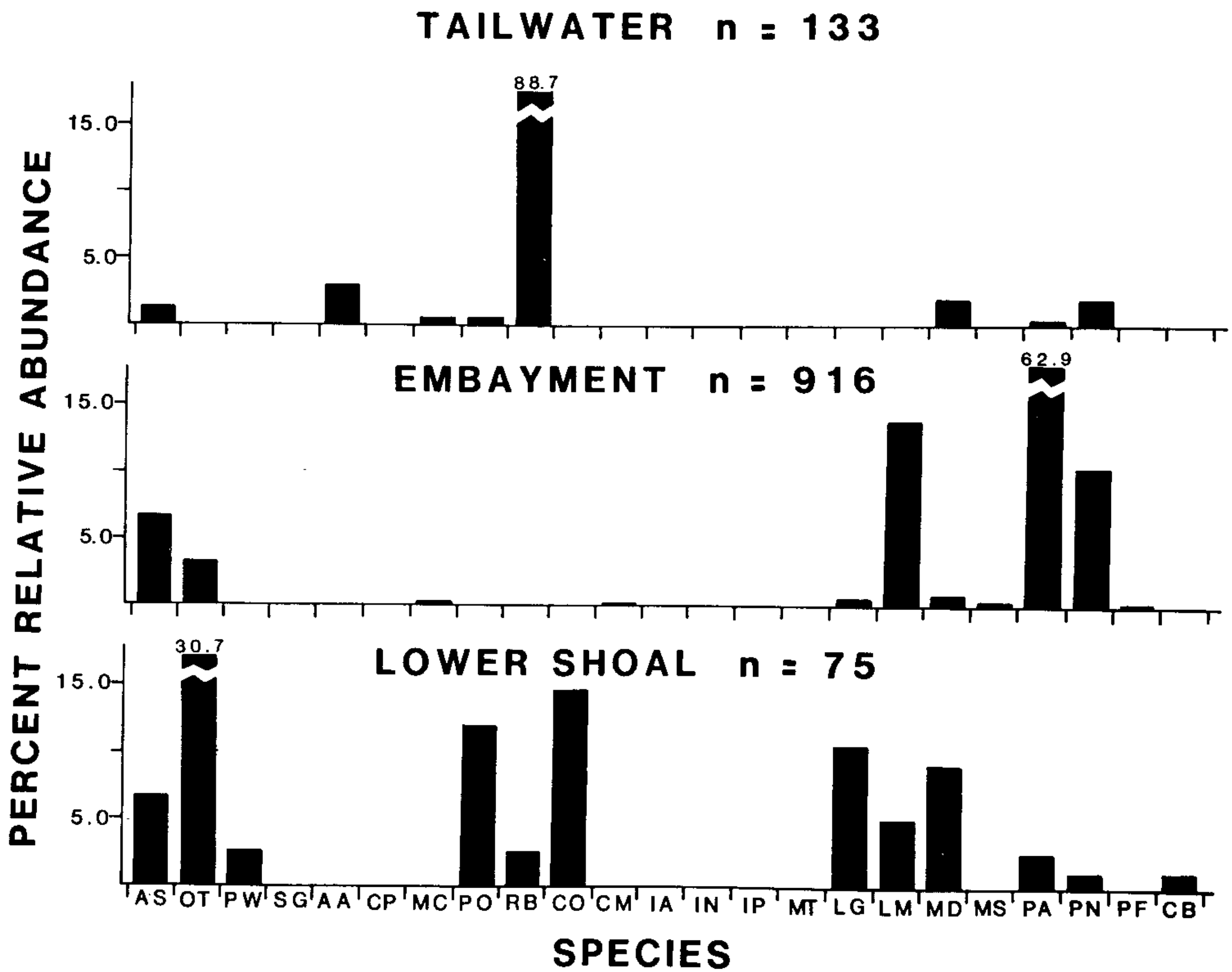

Figure 111. Relative abundance (%) of all young-of-year fishes collected by seining Ice Harbor Reservoir, Washington, during spring, summer, and fall seasons, 1980. Number of individuals collected at each sampling station is indicated (n). Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch; CB - sculpin.

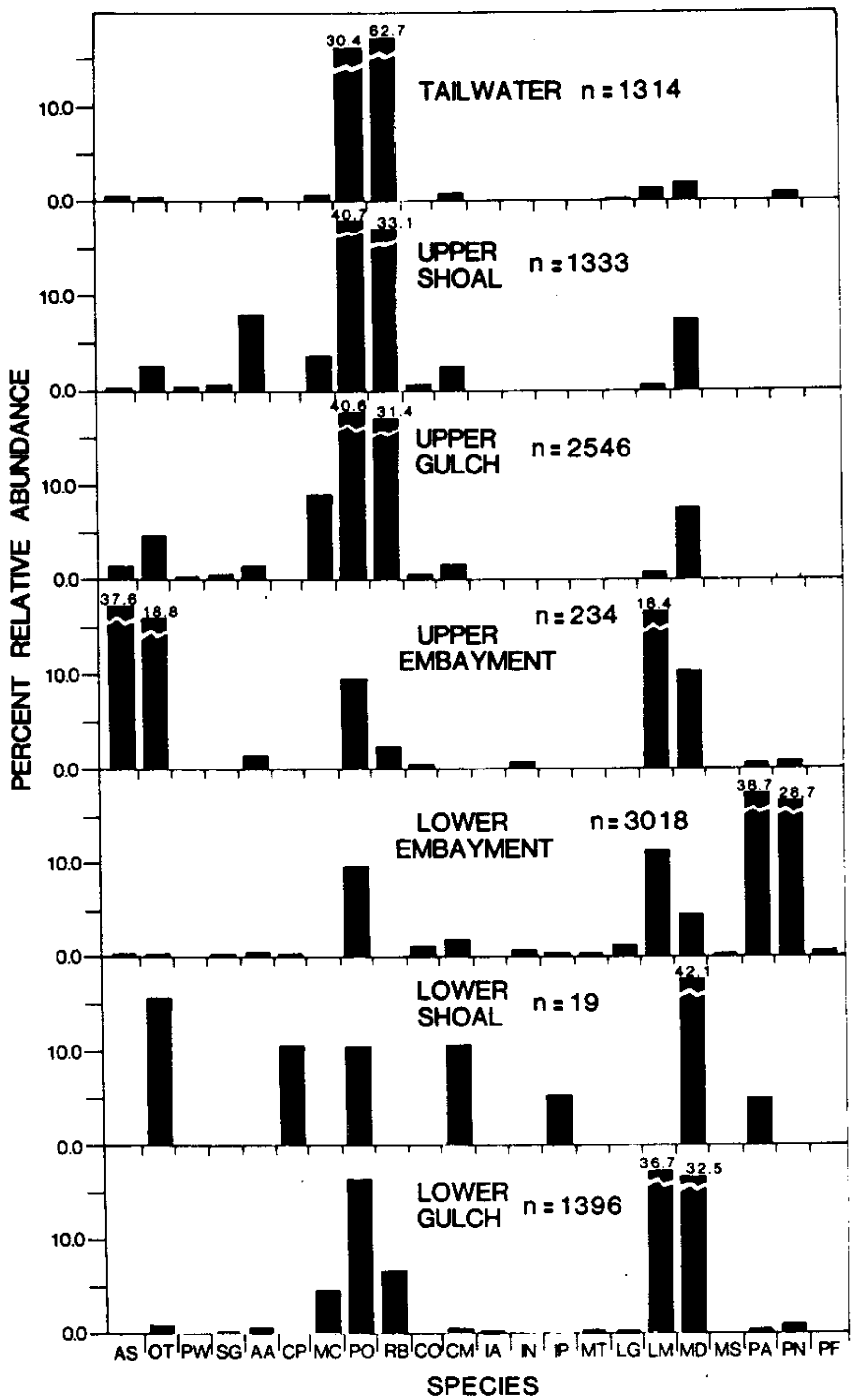

Figure 112. Relative abundance (%) of all young-of-year fishes collected by seining Little Goose Reservoir, Washington, from March through November, 1980. Number of individuals collected at each sampling is indicated (n). Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch.

YOY fish collected by seining at the lower embayment. Smallmouth bass were present at all stations, although the upper and lower gulch stations accounted for nearly 70% of all YOY smallmouth bass collected. Greater than 91% of all bluegill and pumpkinseed collected were from lower embayment and lower gulch sampling stations. Yellow perch were collected exclusively at the lower embayment station. Although resident game species comprised 41% of all YOY fishes collected throughout Little Goose Reservoir, approximately 86% of all fishes collected at the lower embayment station were game fishes.

Young-of-year anadromous species, American shad and chinook salmon, were more commonly collected at upper than lower reservoir sampling stations at Little Goose Reservoir (Fig. 112). Approximately 79% of all anadromous fishes were collected from the upper embayment and upper gulch sampling stations.

Locational Abundance

Abundance of YOY fishes in Little Goose Reservoir was significantly higher ($F=6.34; P\leq 0.02$) in the upper than the lower reservoir. The highest mean CPE, however, occurred at the lower embayment station, where nearly 60 YOY fishes were captured, on the average, throughout the sampling period (Fig. 113). All sampling stations experienced significantly higher ($P<0.05$) mean CPE of YOY fishes than the lower shoal sampling station, where an average CPE of less than 1 YOY fish was collected throughout the sampling duration. Higher mean CPE of YOY fishes occurred nearly every month at the upper than lower gulch and shoal sampling stations (Figs. 114 and 115). In contrast, YOY fish at the lower embayment sampling station consistently manifested higher mean CPE than at the upper embayment station (Fig. 114).

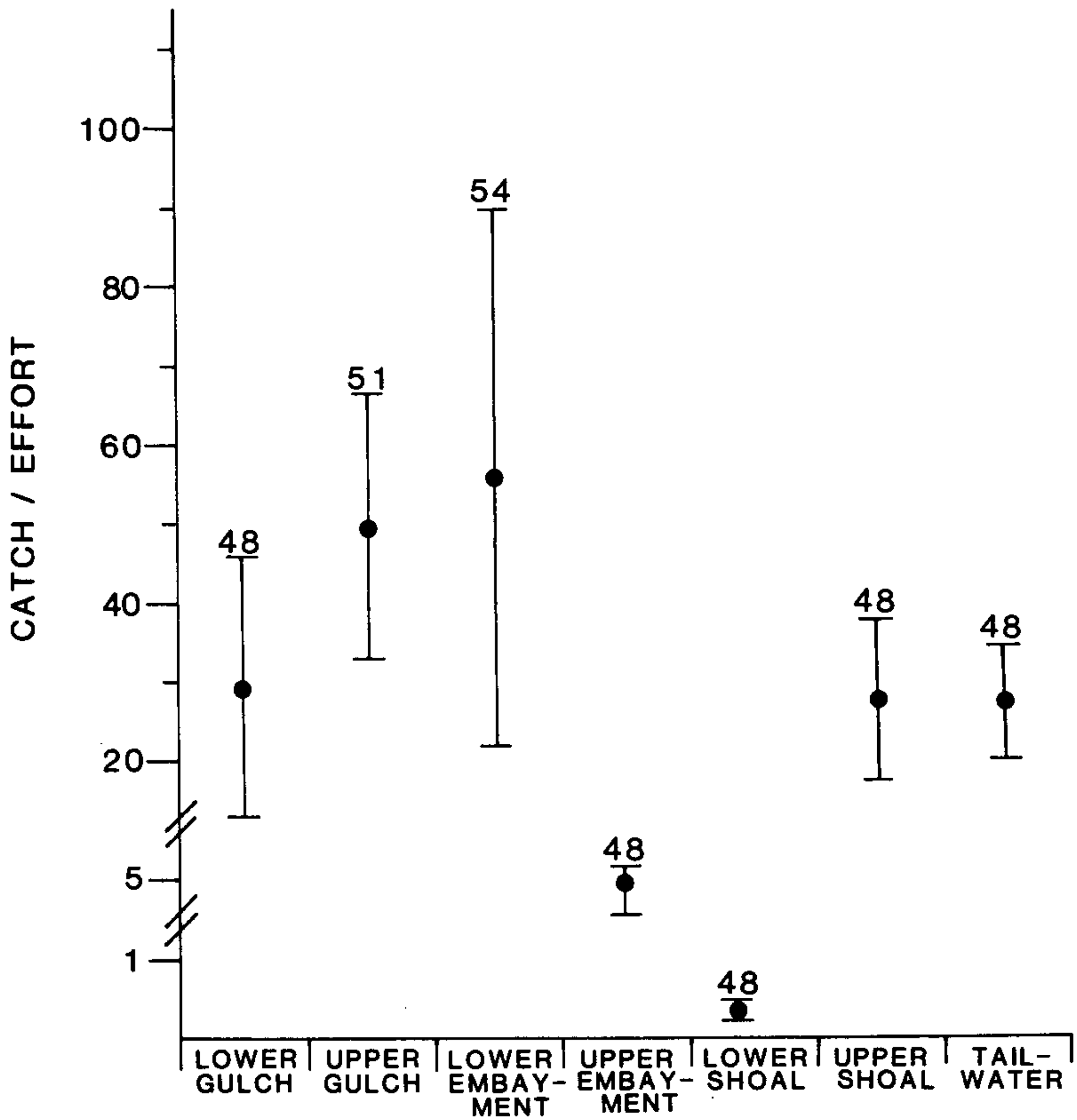

Figure 113. Mean catch/effort (± one standard error) of young-of-year fishes collected by seining at sampling stations from Little Goose Reservoir, Washington during 1980. Number of standard seine hauls is indicated. Significant differences ($P \leq 0.05$) were: Lower Gulch vs. Lower Shoal; Upper Gulch vs. Lower Gulch, Upper Embayment, Lower Shoal, and Upper Shoal; Lower Embayment vs. Lower Gulch, Upper Embayment, and Lower Shoal; Upper Shoal vs. Lower Gulch, Upper Embayment, and Lower Shoal; Tailwater vs. Lower Gulch, Upper Embayment, and Lower Shoal.

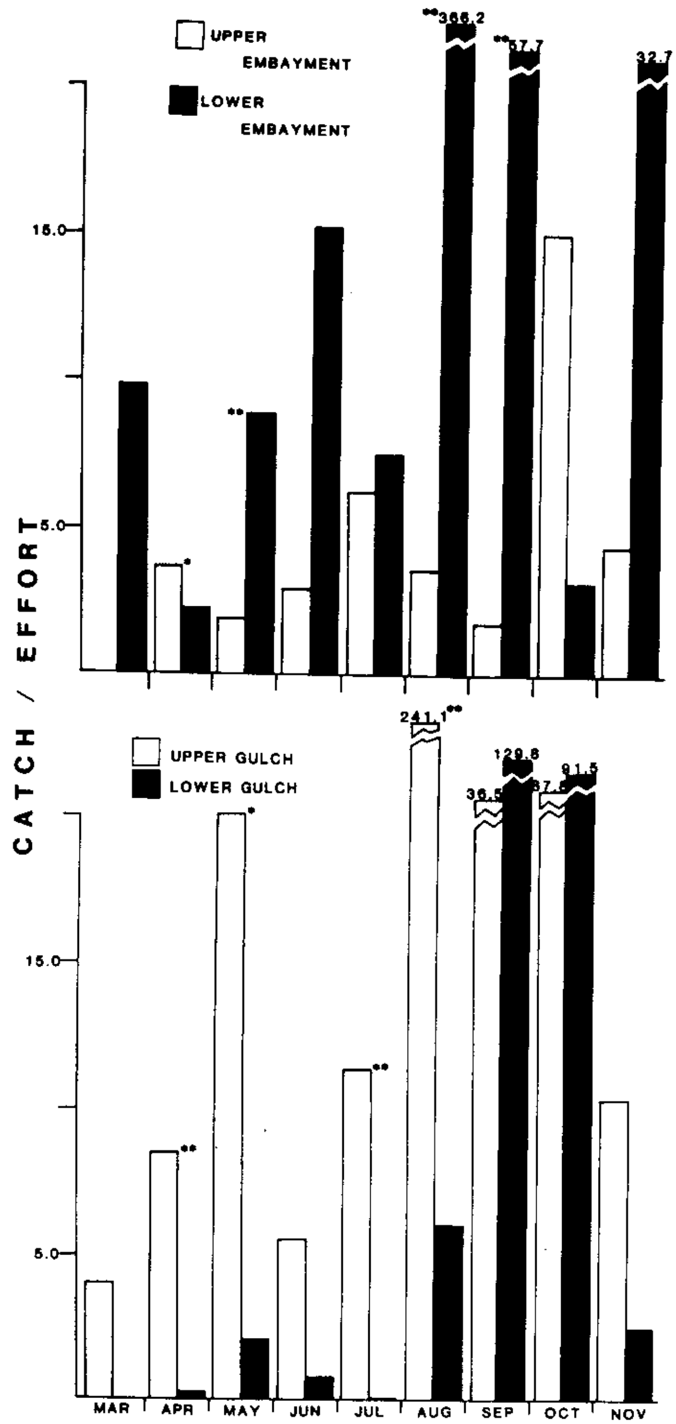

Figure 114. Monthly mean catch/effort (CPE) of young-of-year fishes collected by seining embayment and gulch habitats in Little Goose Reservoir, Washington, 1980. Significance differences in monthly mean CPE are shown for $P \leq 0.05$ (**) and $P \leq 0.15$ (*).

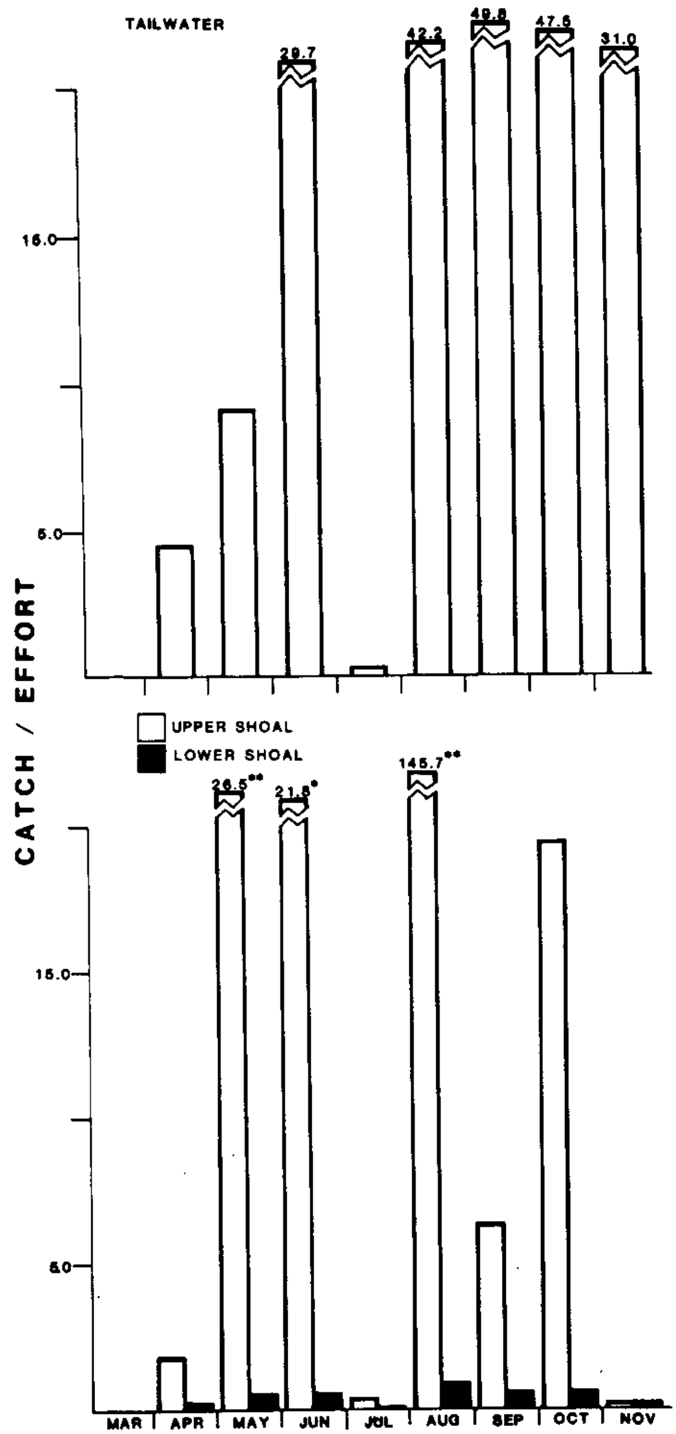

Figure 115. Monthly mean catch/effort (CPE) of young-of-year fishes collected by seining tailwater and shoal habitats in Little Goose Reservoir, Washington, 1980. Significance levels of differences in monthly mean CPE are shown for $P \leq 0.05$ (**) and $P \leq 0.15$ (*).

Temporal Abundance

Most YOY fishes were collected in Little Goose Reservoir during late summer and early fall (Fig. 116). The highest mean CPE of YOY fishes occurred during August. Significant differences ($P \leq 0.05$) in monthly mean CPE (based on ln (x+1) transformation) were: August vs. April, May, June, July, and November; September vs. April, June, July, and November; October vs. April, July, and November.

Monthly relative abundance estimates of YOY fishes from Little Goose Reservoir indicate wide temporal variations in abundance for most species (Fig. 117). Northern squawfish and peamouth were collected primarily from July through November, whereas redside shiners were relatively abundant from April through November. The northern squawfish and redside shiner complex comprised 67 and 49% of all YOY fishes collected during October and November, respectively. Other non-game species, especially bridgelip and largescale suckers, were relatively abundant only during early spring months. Few YOY suckers were collected after June.

Resident game species exhibited few trends in monthly relative abundance (Fig. 117). White and black crappies exhibited a peak in abundance during August, comprising approximately 39% of all YOY fishes collected during that month. Although few crappies were collected during September and October, an increase in relative abundance occurred during November. Smallmouth bass and bluegill were collected every month of the sampling duration, although the highest number of individuals of both species were collected during September. Smallmouth bass abundance increased continuously from March through September but decreased thereafter, whereas bluegill exhibited peaks in abundance during July, September, and November.

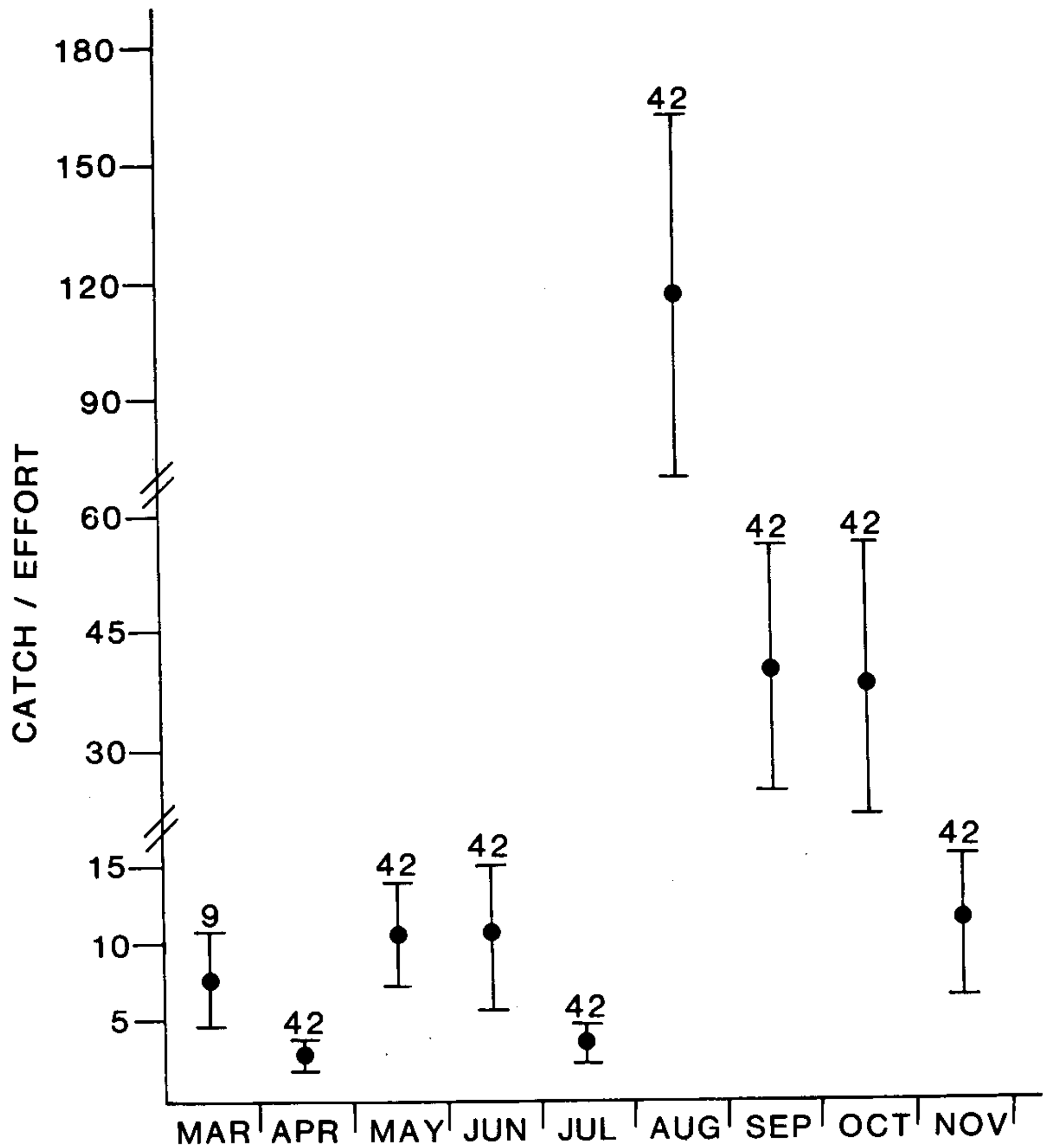

Figure 116. Monthly mean catch/effort (± one standard error) of young-of-year fishes collected by seining Little Goose Reservoir, Washington, 1980. Number of standard seine hauls is indicated. Significant differences ($P \leq 0.05$) were: August vs. April, May, June, July, and November; September vs. April, June, July, and November; October vs. April, July, and November.

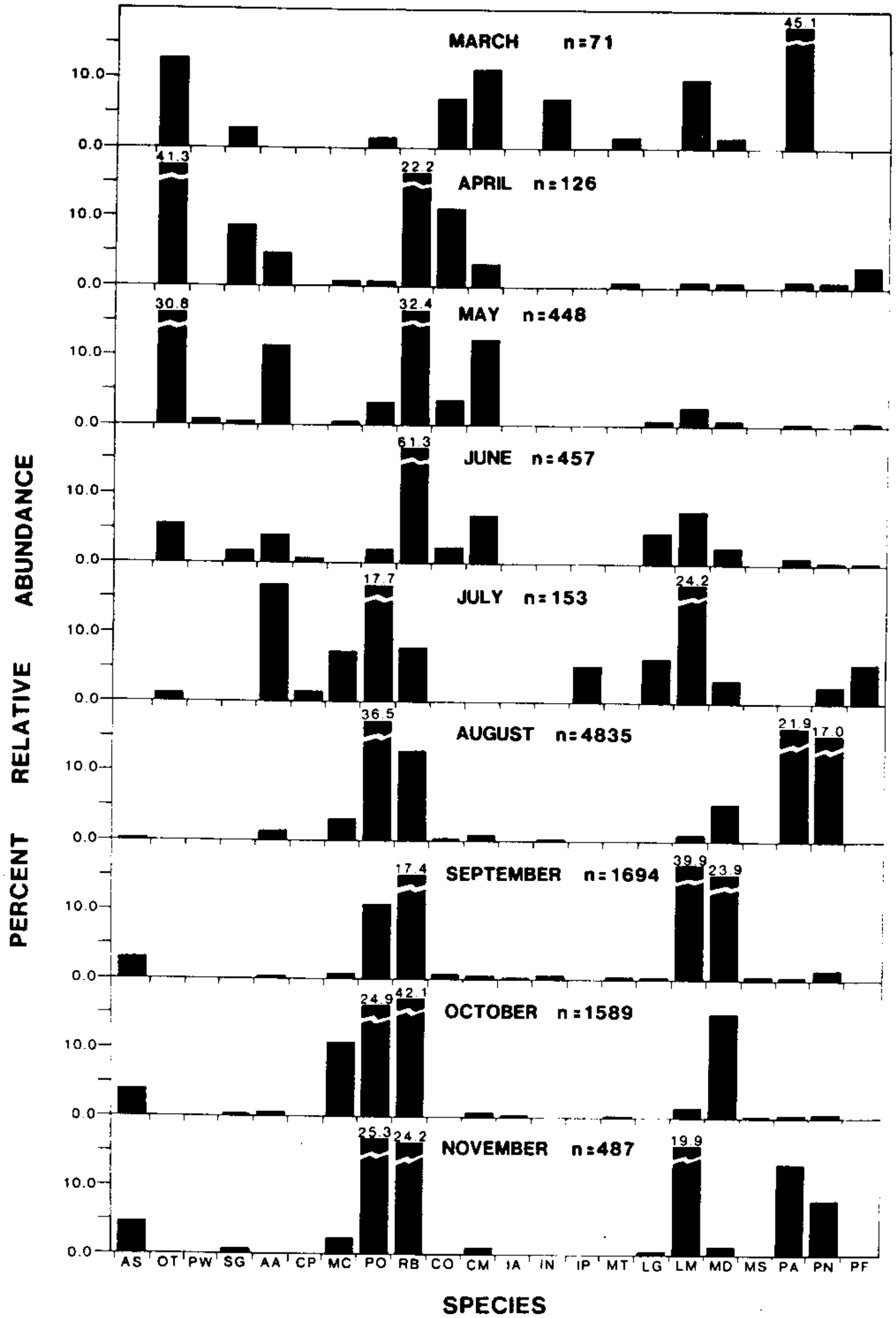

Figure 117. Monthly percent relative abundance of young-of-year fishes collected by seining Little Goose Reservoir, Washington, during 1980. Number of individuals collected during each month is indicated (n). Species abbreviations are: AS - American shad; OT - chinook salmon; PW - mountain whitefish; SG - rainbow trout; AA - chiselmouth; CP - carp; MC - peamouth; PO - northern squawfish; RB - redside shiner; CO - bridgelip sucker; CM - largescale sucker; IA - yellow bullhead; IN - brown bullhead; IP - channel catfish; MT - tadpole madtom; LG - pumpkinseed; LM - bluegill; MD - smallmouth bass; MS - largemouth bass; PA - white crappie; PN - black crappie; PF - yellow perch.

Young-of-year anadromous American shad and chinook salmon exhibited different trends in monthly relative abundance (Fig. 117). Young-of-year chinook salmon were relatively abundant in the collections from March through July, although no individuals were collected after July. In contrast, American shad were not collected prior to August. Peak relative abundance of YOY shad occurred in October and November.

Species Associations

Fourteen significant ($P<0.05$) species associations resulted from Pearson product-moment correlation analysis of sample frequencies of 12 species of YOY fishes collected by seining Little Goose Reservoir (Table 57). All significant associations between species were positive. The strength of the correlation was related to species occupying the same habitat types during the same monthly period of sampling. Correlation coefficients were low for northern squawfish and largescale sucker ($r=0.28$) but high ($r=0.99$) for white and black crappies. The abundance of northern squawfish was associated with the highest number of other species, including chiselmouth, peamouth, redside shiner, largescale sucker and smallmouth bass. Smallmouth bass also was associated with peamouth, redside shiner and, most highly ($r=0.65$), with bluegill. American shad did not exhibit any significant associations with other species.

Limnological Correlations

Sample frequencies of 12 species of YOY fishes in Little Goose Reservoir, correlated with five limnological characteristics produced 17 significant correlations (Table 58). Chiselmouth ($r=0.20$), northern squawfish ($r=0.32$), smallmouth bass ($r=0.27$), and black crappie ($r=0.19$)

Table 57. Pearson product-moment species associations ($P \leq 0.05$) for young-of-year fishes collected by seining Little Goose Reservoir, Washington, 1980.

	Species											
	AS	OT	AA	MC	PO	Rb	CO	CM	LM	MD	PA	PN
American shad (AS)												
chinook salmon (OT)												
chiselmouth (AA)												
peamouth (MC)												
northern squawfish (PO)			0.32	0.76								
redside shiner (Rb)			0.29	0.66	0.62							
bridgelip sucker (CO)												
largescale sucker (CM)		0.49	0.45		0.28		0.44					
bluegill (LM)												
smallmouth bass (MD)				0.48	0.48	0.27			0.65			
white crappie (PA)												
black crappie (PN)											0.99	

Table 58. Pearson product-moment correlations between limnological characteristics and sample frequencies of young-of-year fishes collected by seining in Little Goose Reservoir, Washington. Significance levels of correlations are $P \leq 0.05$ unless indicated (* = $P \leq 0.15$).

	Limnological Parameters				
Species	Water temperature	Water transparency	Water velocity	Littoral Reach	Aquatic macrophytes
American shad		0.20*			
chinook salmon		-0.34			0.27
chiselmouth	0.20*			0.28	0.40
peamouth			0.21*		
northern squawfish	0.32				0.22*
redside shiner		0.27	0.43		
bridgelip sucker		-0.41			
largescale sucker					
bluegill				0.22*	
smallmouth bass	0.27			0.35	0.28
white crappie					
black crappie	0.19*				

were positively correlated with water temperature. American shad (r=0.20) and redside shiner (r=0.27) were positively correlated with water transparency, whereas chinook salmon (r=-0.34) and bridgelip sucker (r=-0.41) were negatively correlated with water transparency. Redside shiners (r=0.43) and peamouths (r=0.21) collected primarily at upper reservoir sampling stations, were positively correlated with water velocity. Chiselmouth (r=0.28), bluegill (r=0.22) and smallmouth bass (r=0.35) were positively correlated with the amount of littoral habitat. Chinook salmon (r=0.27), chiselmouth (r=0.40), northern squawfish (r=0.22), and smallmouth bass (r=0.28) were positively correlated with aquatic macrophytes. Sample frequencies of YOY largescale suckers and white crappies were not significantly correlated with any limnological characteristics.

DISCUSSION

Reproductive Cycles

Examination of gonads indicated that the 12 species of resident fishes that we studied initiated reproductive development in the fall and spawned from early spring through late summer (Figs. 84-95). In several species, sizes of gonads in the fall were nearly equal to, or greater than, maximum GSI values immediately prior to spawning. We found no evidence that any species was spawning in the fall as all specimens examined during the fall were in the developing stage of their reproductive cycle.

The large size of gonads in the fall, in preparation for spawning the following year, has been observed in several species. Bennett and

Gibbons (1975) observed gonadal recrudescence in largemouth bass during September and October prior to spawning in March and April the next year. Morgan (1951b) found that gonads of black and white crappies increased considerably in the fall and concluded that some fishes are ready to spawn the following year with little further development. Dauble (1980) found male bridgelip suckers in the mid-Columbia River, Washington, exhibited large, ripe gonads in September.

The most plausible explanation for large gonad sites, especially in males, is associated with major histological changes in the gonads. For example, Turner (1919) reported that testes of yellow perch attained maximum weight about 1 November, and gradually declined in weight until spawning in late April or early May. Histologically, he observed that each testis contained numerous young, growing germ cells, or germ cells at their maximum size, transforming germ cells, spermatogonia and all ensuing stages of spermatogenesis, including spermatocytes, spermatids and mature spermatoza. A gradual decline in testis weight throughout the winter was associated with the disappearance of earlier stages of spermatogenesis. Although we did not perform histological examinations of the gonads of resident fishes in the lower Snake reservoirs, the changes in gonad sizes from fall to spring probably were related to changes in the stages of gametogenesis.

We found that most fishes exhibited high variation in gonad sizes and stages of reproductive development during a single month (Figs. 84-95). Several reasons probably account for this high variation. All sexually mature specimens were included in the monthly period regardless of the ovarian or testicular stage of development. For example, some specimens were in a ripe reproductive condition, while other specimens may have been in the developing or spent stages. Also, differential rates of development may have occurred from the warmer embayment versus the cooler main channel areas. Specimens from warmer areas may have experienced accelerated reproductive development. Another source of variation in monthly GSIs could have resulted from pooling samples from 1979 and 1980. We combined data for the two years of study to provide good sample sizes and thus, a general index to the reproductive cycles and spawning periods of selected resident fishes in the lower Snake reservoirs.

Temperature and photoperiod are key factors influencing the timing of the spawning of numerous fishes (Bullough 1939; Bennett and Gibbons 1975). The interaction of increasing temperature and photoperiod has been associated with maturation of the gonads and subsequent spawning of many fishes. Accurate definition of a spawning temperature is not feasible (Coutant 1975), although most fishes spawn within a certain range of water temperatures (Everhart et al. 1975). Since temperatures warm later in the year in northern latitudes than southern latitudes, spawning of fishes also is delayed.

The lower Snake River reservoirs are located within the more northerly portion of the range of many fishes which we examined. Consequently, many species that we studied were found to spawn later in the year than generally reported in the literature. Although spawning periods varied, all resident fish species examined in lower Snake River reservoirs spawned at times when extant water temperatures were fairly consistent with the range of spawning temperatures reported in the literature.

Northern Squawfish

Northern squawfish have been reported to spawn from May to early July (Carl et al. 1959) in lakes or tributary streams (Jeppson and Platts 1959; Patten and Rodman 1969). Few published reports are available regarding the spawning phenology of reservoir populations of northern squawfish. Casey (1962), however, reported that northern squawfish spawned during June, with peak spawning during the latter part of June in Cascade Reservoir, Idaho. In an impoundment on the Columbia River, Washington, the spawning season for northern squawfish extended from June to August (Horjt et al. 1981), very similar to the spawning period (June into early August) which we observed in lower Snake reservoirs (Fig. 84).

Water temperatures in lower Snake River reservoirs during the northern squawfish spawning season-ranged from 14.0 to 20.4 C. Previous reports indicate that northern squawfish spawning occurs at water temperatures of 14.5 to 16.7 C (Casey 1962) and 18.0 C (Stewart 1966).

Redside Shiner

Redside shiners in lower Snake reservoirs were found to be in spawning condition somewhat later in the year than reported elsewhere (Fig. 85). The spawning period of redside shiners extends from May to at least late July in Canada (Lindsey and Northcote 1963). In Post Creek, Montana, ripe individuals were collected from 20 May to 30 June, and through June in Flathead Lake, Montana (Weisel and Newman 1951). Also, in a slough fed by warm springs in western Montana, Weisel and Newman (1951) reported redside shiners spawned from April through mid-June. In lower Snake River reservoirs, we determined the redside shiner spawning period to be through July and into early August. Within the same geographical area larval redside shiners were collected from the lower Columbia River drainage from May through early August, indicating either site-specific spawning times or an extended spawning season (Horjt et al. 1981).

Ripe redside shiners were collected from lower Snake reservoirs when water temperatures ranged from 18.1 to 20.4 C. Little specific information is available regarding temperatures required for redside shiner spawning. Scott and Crossman (1973) stated that redside shiners move into spawning areas after water temperatures exceed 10 C, whereas Weisel and Newman (1951) reported redside shiners spawning at water temperatures of 17 to 18 C.

Suckers

Bridgelip suckers. Little information is available regarding the spawning of the bridgelip sucker (Scott and Crossman 1973). In British Columbia, the bridgelip sucker spawning season has been reported as late spring. Dauble (1980) found bridgelip suckers spawning from mid-April to mid-June in the central Columbia River, whereas Horjt et al. (1981) reported that bridgelip suckers spawn from March to June, with most spawning occurring during April in the lower Columbia River, Washington. Both reports are fairly consistent with the April and May spawning period which we observed in the lower Snake River reservoirs (Fig. 86). We observed bridgelip suckers in spawning condition when average water temperatures ranged from 10.2 to 12.2. C. Dauble (1980) reported bridgelip suckers spawning in the mid-Columbia River at water temperatures ranging from 6 to 13 C.

Largescale suckers. The few published reports available concerning the spawning of largescale suckers are inconsistent. We determined that the spawning period for the largescale sucker in lower Snake River reservoirs was May and June (Fig. 87). Largescale suckers usually spawn from mid-May to late June in British Columbia (Scott and Crossman 1973), mid to late June in the North Fork of the Payette River, Idaho (MacPhee 1960), and from early May to early August with a peak in late June or early July in the lower Columbia River, Washington (Horjt et al. 1981). Water temperatures during the spawning period of largescale suckers in lower Snake River reservoirs ranged from 12.2 to 15.8 C, whereas Scott and Crossman (1973) report largescale suckers enter spawning streams at water temperatures of 7.8 to 8.9 C.

Brown Bullhead

Based on the presence of ripe ova, we found brown bullhead to be in spawning condition during August in lower Snake River reservoirs (Fig. 88). Throughout the range of the brown bullhead, spawning has been reported to occur from late April (Harlan and Speaker 1951) to September (Swingle 1957). In addition, Breder (1935) stated that brown bullhead may spawn twice each year.

Water temperatures during the brown bullhead spawning season ranged from 20.4 to 21.7 C in lower Snake reservoirs. These temperatures are similar to those reported in the literature for brown bullhead spawning. Breder (1935) reported that brown bullhead spawned at water temperatures ranging from 21 to 25 C, and Scott and Crossman (1973) reported that 21.1 C was their spawning temperature.

Channel Catfish

We found that the spawning period for channel catfish was July and August in lower Snake reservoirs (Fig. 89), later in the year than that for channel catfish reported elsewhere. Jearld (1970) reported channel catfish spawning from late May to mid-June in Oklahoma. In Missouri, channel catfish spawn from late May through mid-July, with peaks in spawning activity during early and late June (Marzolf 1957).

Water temperatures in lower Snake reservoirs during the channel catfish spawning season were below, or at the lower extreme, of the range of water temperatures reportedly suitable for channel catfish spawning. Jearld (1970) observed channel catfish spawning when water temperatures ranged from about 20.0 to 23.5 C. Clemens and Sneed (1957) report channel catfish spawn from 21.1 to 29.4 C, with about 26.7 C being optimum. In comparison, water temperatures in lower Snake reservoirs during the channel catfish spawning season ranged from 18.1 to 21.7 C.

Pumpkinseed

Pumpkinseed have been reported to spawn between early May and August (Carlander 1977). In New York, Ingram and Odum (1941) found pumpkinseed exhibiting spawning behavior from late May to late July, similar to that reported by Adams and Hankinson (1928). From back-calculations of larval specimens, Horjt et al. (1981) determined the Lepomis sp. spawning period ranged from late May to mid or late August in Lake Umatilla, Washington, similar to the period of late June through early August which we found pumpkinseed in spawning condition in lower Snake reservoirs (Fig. 90).

We observed a relatively narrow range of water temperatures (18.1 to 19.6 C) in lower Snake reservoirs during the pumpkinseed spawning period. The water temperatures which we observed are within the approximate 13 to 28 C range of pumpkinseed spawning temperatures (Clark and Keenleyside 1967, Scott and Crossman 1973).

Bluegill

Northern populations of bluegill initiate spawning later and complete spawning earlier in the year than southern populations according to published reports. For example, in Texas, bluegill spawning commences as early as April and extends into September (Schloemer 1947). Bluegill spawning was found to occur from early May to mid-August in Ohio (Morgan 1951b), late May to August in Illinois (James 1946) and Canada (Clark and Keenleyside 1967). We found bluegill in spawning condition throughout July into August in lower Snake reservoirs (Fig. 91), which concurs with the period of peak spawning activity reported for bluegill in Potholes Reservoir, Washington (Zook 1978).

Water temperatures during the bluegill spawning period in lower Snake reservoirs ranged from 19.6 to 21.7 C. Bluegill have been reported to spawn at water temperatures ranging from 17 to 31 C (Morgan 1951b, Clark and Keenleyside 1967). Although water temperatures in lower Snake River reservoirs during the bluegill spawning season were within this range these temperatures were somewhat lower than those (about 19 to 27C) reported for most bluegill spawning (Curtis 1949, Morgan 1951b, Stevenson et al. 1969, Scott and Crossman 1973).

Smallmouth Bass

The spawning season of smallmouth bass in lower Snake reservoirs was later in the year than generally reported elsewhere. Smallmouth bass spawning occurs as early as the first of April (Pflieger 1975), whereas we determined the spawning season extended from early June through the latter part of July (Fig. 92). In the Columbia River, Washington, smallmouth bass spawning was observed until the latter part of July (Henderson and Foster 1957). Surber (1943) found that smallmouth bass exhibited a very short (3 or 4 day) spawning period in four Appalachian mountain streams. In contrast, the approximate 2 month spawning period of smallmouth bass in lower Snake River reservoirs more closely agrees with the spawning periods reported for Iowa (Cleary 1956), Missouri (Pflieger 1975) and Washington (Henderson and Foster 1957). According to Pflieger (1975), the spawning period of smallmouth bass may encompass up to 62 days.

The range of water temperatures (14.0 to 19.6 C) during the spawning season of smallmouth bass in lower Snake River reservoirs is well within the range of temperatures (12.8 to 26.7 C) reported elsewhere (Henderson and Foster 1957, Reynolds 1965) for smallmouth bass spawning. For example, several previous reports suggested that most smallmouth bass spawning occurred at water temperatures from about 15.0 to 18.3 C (Beeman 1924, Tester 1930, Cleary 1956, Raney 1959, Turner and MacCrimmon 1970, Coble 1975, Coutant 1975, Pflieger 1975).

White Crappie

Reported spawning periods of white crappie range from March (Schloemer 1947, Morgan 1951b) to late July (Morgan 1951b, Horjt et al. 1981) with northern populations spawning later in the year than southern populations (Hardy 1978). The spawning season of white crappie began early April and continued through mid-June in Mississippi flood control reservoirs (Schultz 1966). Nelson et al. (1967) found that the white crappie spawning season extended from mid-May through mid-July in Lewis and Clark Lake, an impoundment of the main stem Missouri River located on the Nebraska-South Dakota border. White crappie collected from lower Snake River reservoirs were in spawning condition from June into August (Fig. 93). Also, Horjt et al. (1981) reported that the white crappie spawning season ranged from late May to late July in an impoundment on the lower Columbia River, Washington.

Water temperatures in lower Snake reservoirs ranged from 15.8 to 20.4 C during the white crappie spawning season. White crappie have been reported to spawn at water temperatures ranging from 13.9 to 29.4 C (Schultz 1966), although published reports indicate water temperatures from about 16 to 21 C are optimal (Curtis 1949; Nelson et al. 1967; Siefert 1968).

Black Crappie

Black crappie exhibit a varied spawning season, depending upon geographical location. Similar to white crappie, southern populations of black crappie reportedly spawn earlier in the year than northern populations. Goodson (1966) reported that the black crappie spawning period varied from March to July in California, although black crappie are in spawning conditions as early as February in Florida (Huish 1958) and as late as August in northern states (Adams and Hankinson 1928). We found black crappie in spawning condition during June and July in lower Snake River reservoirs (Fig. 94). In Lake Umatilla, on the lower Columbia River, Washington, Horjt et al. (1981) reported the spawning period of black crappie was from early May to mid-July.

Water temperatures at which black crappie spawn reportedly range from 4.4 to 28 C (Morgan 1951b; Everhart 1958). The extremes of this range are not accepted by all investigations (Hardy 1978). Water temperatures in lower Snake River reservoirs ranged from 15.8 to 19.6 C during the black crappie spawning period. Most published reports indicate that black crappie spawn at water temperatures equal to, or slightly greater than, the water temperatures which we observed (Adams and Hankinson 1928; Breder 1936; Scott and Crossman 1973).

Yellow Perch

Yellow perch have been reported to commence spawning activity as early as February in the southern United States (Smith 1907; Mansueti 1964) and spawn to the end of June in Canada (Sheri and Power 1969), and perhaps into July (Scott and Crossman 1973). In Oneida Lake, New York, yellow perch spawn from mid to late April (Tarby 1974). Yellow perch were found to spawn from late March to mid-May in California (Coots 1956) and Washington (Horjt et al. 1981). In lower Snake reservoirs, we found most yellow perch spawning occurred in April and May (Fig. 95), similar to that reported for yellow perch in New York (Adams and Hankinson 1928).

Yellow perch in lower Snake reservoirs spawned at water temperatures (12.2 to 13.6 C) slightly higher than those reported. Yellow perch reportedly spawn at water temperatures ranging from 6.7 to 12.2 C (Scott and Crossman 1973) and 7.2 to 12.8 C (Curtis 1949). Hergenrader (1969) reported, however, yellow perch spawned at water temperatures to 14 C in laboratory aquaria.

Spawning Areas

Management of a resident fishery in a multiple use reservoir requires knowledge of the temporal, spatial, and vertical distribution of spawning activity. Prior to this study, no information was available regarding the spawning habits of resident fishes in lower Snake River reservoirs. Species important to the sport fisheries in the lower Snake reservoirs are members of the Centrarchidae family, which are reported to be shallow water spawners. Water level fluctuations up to 1.5 m in lower Snake River reservoirs have the potential to adversely affect the spawning success of centrarchid fishes.

Size and appearance of spawning nests were used as criteria for differentiating between smallmouth bass and sunfish nests. Smallmouth bass spawning nests range in diameter from 30.5 to 183 cm (Scott and Crossman 1973). In Little Goose Reservoir, smallmouth bass spawning nests ranged in diameter from 32 to 70 cm, with a mean diameter of 47 cm. We found smallmouth bass spawning nests to be significantly larger than those of sunfish. Reported pumpkinseed and bluegill sunfish spawning nest diameters are highly variable, and can be circular or oval in appearance (Richardson 1913; Coggeshall 1924; Breder 1936; Ingram and Odum 1941; Hardy 1978). Spawning nests of pumpkinseed and bluegill have been reported to range in diameter from 10 to 91 cm (Coggeshall 1924; Scott and Crossman 1973). Krecker (1916) reported two types of pumpkinseed spawning nests; large oval nests, approximately 69 by 91 cm, and small circular nests which averaged 19 cm in diameter. Sunfish spawning nests located in Little Goose Reservoir more closely resembled the latter type reported by Krecker (1916), roughly circular in appearance, from 15 to 35 cm in diameter with a mean diameter of 26 cm.

Substrate used by centrarchid fishes for spawning nest construction in Little Goose Reservoir was consistent with other published reports. Smallmouth bass spawn on substrates of silt, clay, shells, and detritus (Lydell 1906; Rawson 1938; Bennett and Childers 1957; Turner and MacCrimmon 1970) although most nesting usually occurs on sand, gravel, or rubble (Reighard 1905; Hubbs and Bailey 1938; Latta 1963; Mraz 1974; Coble 1975; Miller 1975). All observed smallmouth bass spawning nests in Little Goose Reservoir were constructed on low gradient shorelines of sand and/or gravel, although most (85%) spawning nests were found on gravel 6 to 50 mm in diameter. In comparison, approximately 55% of all sunfish spawning nests located in Little Goose Reservoir were constructed on gravel, 42% on mixed substrate (silt, sand, gravel, and organics), and 3% on silt or sand only. Bluegill and pumpkinseed reportedly utilize a variety of substrates for spawning including hardpan, clay, mud, muck, detritus, shells, sand, gravel, rocks, and rubble (Carbine 1939; Morgan 1951a; Langlois 1954; Emig 1966; Hubbell 1966; Scott and Crossman 1973; Bennett 1976).

We used spawning nest counts per unit survey effort to serve as an index of spawning activity in Little Goose Reservoir. The number of spawning nests observed in Little Goose Reservoir served as an index to the suitability of spawning habitat.

Centrarchid fishes usually spawn in protected areas of little perceptible current. Coble (1975) stated that smallmouth bass spawning nests were located away from strong current or wave action. Also, *Lepomis* sp. spawning is commonly associated with lentic systems or lotic systems of minimal water current (Scott and Crossman 1973). Bennett (1976) reported that sunfish (*Lepomis* sp.) in Leesville Lake, a pumped storage reservoir in Virginia, compensated for high water velocities by spawning on the downstream side of obstructions in the littoral area of the main reservoir or by spawning in cove areas sheltered from the current. In Little Goose Reservoir, smallmouth bass and sunfish spawning nests were observed most frequently in gulch and embayment areas of the lower reservoir zone. These nests, in gulch and embayment areas, were generally protected from direct wind and wave action and experienced little or no perceptible water current. In contrast, in the upper reservoir zone, smallmouth bass and sunfish nests were more commonly observed in shoal areas, usually exposed to wind, wave action, and/or increased water velocities. We believe that the relatively high percentage of smallmouth bass and sunfish spawning nests found in shoal areas of the upper reservoir zone probably does not reflect a preference but reflects the relative paucity of gulch and embayment areas within the upper reservoir zone. Shallow water (0 to 3 m) areas, including gulch, embayment, and shoal areas in Little Goose Reservoir are limited, comprising less than 6% of the total lake surface area. The lower reservoir zone contains several gulch and embayment areas with shallow littoral habitat. The upper reservoir zone, however, contains few gulch areas and two embayment areas, one of which is nearly devoid of water during low pool elevation (Penewawa).

Most centrarchid fishes spawn in relatively shallow, stable littoral areas in water depths of 2 m or less (Bennett 1976). Depth of smallmouth bass nests has been reported as 0.3 to 2 m (Beeman 1924; Stone et al. 1954; Watson 1955; Cleary 1956; Bennett and Childers 1957; Scott and Crossman 1973; Coble 1975), although Mraz (1964) reported smallmouth bass nesting at a depth of 6.1 m, also, Trautman (1981) reported a maximum spawning depth of 6.7 m in very clear waters. Although two smallmouth bass nests in Little Goose Reservoir were located at a depth of 5.3 m (relative to full pool), 84% were located at depths of 2 m or less. Sunfish spawning nest construction in Little Goose Reservoir also occurred at water depths within the range of depths reported elsewhere. Reports indicate that Lepomis sp. spawning nests occur in water from about 0.15 to 1.8 m deep (Richardson 1913; Breder 1936; Ingram and Odum 1941; Morgan 1951a; Emig 1966; Hubbell 1966; Clark and Keenleyside 1967). Swingle and Smith (1950) found sunfish spawning nests in water slightly over 3 m deep when dense growths of aquatic weeds covered shallow littoral areas. Coggeshall (1924) reported sunfish nests as deep as 3 m in highly clear waters. The highest depth of sunfish spawning was reported by Bennett (1976) for bluegill in Leesville Lake, Virginia, where bluegill spawn from 1.2 to 5.5 m below maximum pool elevation. This extreme depth of spawning was an apparent response to water level fluctuations up to 3.5 m.

In Little Goose Reservoir, centrarchid fishes are subjected to vertical water level fluctuations of more than 1.5 m during the spawning season. Fluctuating water levels can result in direct mortality to centrarchid embryos by exposing nests to desiccation and wave destruction, and indirect mortality by causing nest abandonment, which frequently results in predation (Watson 1955; Parsons 1957; Kramer and Smith 1962; Bulkley 1975; Eipper 1975; Bennett 1976). Other studies of lake populations of smallmouth bass indicate that 23 to 56% of observed spawning nests do not produce fry (Stone et al. 1954; Latta 1963; Turner and MacCrimmon 1970; Neves 1975). We did not make repeated observations of individual spawning nests in Little Goose Reservoir. Quantification of nest failures as a result of either direct mortality from desiccation or indirect mortality from nest abandonment was not determined. During the 1980 spawning season, however, 27% of all observed smallmouth bass spawning nests in Little Goose Reservoir were exposed to desiccation at the time of observation. The actual number of exposed spawning nests may have been much greater, since 75% of all observed smallmouth bass nests were located above minimum pool elevation and potentially exposed to desiccation (Fig. 97). In comparison, 7% of all observed sunfish spawning nests were exposed to desiccation at the time of observation, and 73% of all sunfish spawning nests were located above minimum pool elevation (Fig. 98).

The depth of spawning of centrarchid fishes in Little Goose Reservoir may be related to the magnitude and frequency of vertical water level fluctuations. For example, adjustment in spawning depth of centrarchid fishes has been shown to be related to water level fluctuations in other water bodies. Kramer and Smith (1962) reported a direct relationship between water level fluctuations of 12 cm and median depth of largemouth bass spawning in West Slough, Lake George, Minnesota. Bennett (1976) suggested an adjustment in spawning depth of largemouth bass and bluegill sunfish relative to the maximum daily water level fluctuations up to 3.5 m in Leesville Lake, Virginia. Our observations in Little Goose Reservoir suggest that adjustment in spawning depth of smallmouth bass and sunfish to extant water levels may have occurred. For example, during the spawning season, relatively high and stable water levels from several days to more than a week, followed by rapidly descending water levels of up to 1 m in magnitude usually resulted in exposure of centrarchid fish spawning nests to desiccation. Therefore, a period of high and stable water followed by a pronounced reduction in water levels may have deleterious effects on the spawning success of smallmouth bass and sunfish in Little Goose Reservoir.

Our data suggests that spawning success of smallmouth bass and sunfish in Little Goose Reservoir could be increased by modification of present power generation modes and subsequent water level fluctuations. Operational modifications potentially beneficial to the spawning success of smallmouth bass and sunfish could be accomplished. For example, water level fluctuations of reduced magnitude during the spawning season could increase spawning success by providing a more stable spawning environment and decreasing the occurrence of exposure of nests to desiccation. Stable water levels of reduced magnitude, however, may not be necessary to increase spawning success. If smallmouth bass and sunfish can adjust their depth of spawning to extant water level fluctuations, power production modes producing water level fluctuations of similar magnitude and regular, rapid frequency could increase spawning success. Either operational modification could improve the spawning success of smallmouth bass and sunfish in Little Goose Reservoir, provided the adopted method was of sufficient duration to permit embryonic development, hatching and larval fish dispersal.

Larval and Young-of-Year Fish Abundance and Distribution

Species Composition

Catch composition was generally similar between larval fishes collected by tow netting and young-of-year (YOY) fishes collected by beach seining in Little Goose Reservoir. Relatively few taxa of resident fishes were dominant in the larval (Fig. 100) and YOY fish collections (Fig. 108). Although 8 families of fishes were represented in the collections, one family, Cyprinidae, accounted for 64 and 53% of all larval and YOY fishes collected, respectively. Centrarchidae was the other dominant family, comprising 22% of all larvae and 40% of all YOY fish collected. Collectively, these cyprinid and centrarchid fishes accounted for greater than 86% of all larval and 93% of all YOY fishes collected in Little Goose Reservoir.

Other investigators also have reported relatively few taxa dominating collections of larval and YOY fishes. For example, Gallagher and Conner (1980) collected 10 families of larval fish in the lower Mississippi River, Louisiana; four families accounted for approximately 98% of all fish collected. Kindschi et al. (1979) found that 4 of 26 taxa of larval and juvenile fishes collected in an impoundment of the Rough River, Kentucky, represented more than 99% of the total number of fish collected. Also, shad (Dorosoma sp.), sunfish (Lepomis sp.), and crappie (Pomoxis sp.) comprised greater than 97% of all larval fish collected by Krause and Van Den Avyle (1979) in Center Hill Reservoir, Tennessee. Faber (1967) found that yellow perch, black crappie and Lepomis sp. dominated larval fish collections in two northern Wisconsin Lakes.

Relative Abundance

Relative abundance of certain taxa of game and non-game fishes varied considerably between larval and YOY fish collections in Little Goose Reservoir. Smallmouth bass were rarely present in the larval fish collections (Fig. 104), yet accounted for approximately 22% of all YOY game fish collected (Fig. 112). In contrast, sculpins (Cottus sp.) comprised nearly 7% of all non-game larvae collected, although no YOY specimens were collected in Little Goose Reservoir.

Previous studies also have reported the absence of larval or YOY specimens of fish known to be present in subsequent life history stages. In 5 years of sampling Lake Oahe, a main stem Missouri River Reservoir, Beckman and Elrod (1971) found no YOY specimens of four species of resident fish, although adults of these species were observed. Krause (1979) did not collect any larval specimens of Micropterus sp., a genus of fish known to be abundant in Center Hill Reservoir, Tennessee. Smallmouth bass, among other larvae, were not collected from two northern Wisconsin lakes. This led Faber (1967) to assume that smallmouth bass larvae are littoral and do not venture into limnetic regions. Kindschi et al. (1979) suggested that low spawning success, spawning in areas which were not sampled, or occurrence of larvae in some undetermined habitat for food and/or protection were possible reasons for not collecting substantial numbers of larvae of species common to Rough River Lake, Kentucky.

The collection of substantial numbers of sculpins, as larvae, and smallmouth bass, as YOYs, in Little Goose Reservoir demonstrates that certain species are not susceptible to certain gear types during specific developmental phases. For example, our data suggests that smallmouth bass are generally unavailable to tow net sampling throughout most larval developmental phases, whereas the YOY are available to the seine. The behavior and size of smallmouth bass probably is the major reason for this. The adult male smallmouth bass guards the recently hatched larvae while they remain in the spawning nest absorbing the attached yolk (Coble 1975). Following yolk absorption, smallmouth bass larvae rise and swim above the spawning nest in a school which gradually becomes more diffuse as the fry disperse (Turner and MacCrimmon 1970; Coble 1975). Once dispersed, young smallmouth bass are too large to be available to tow netting. Hence, in Little Goose Reservoir, smallmouth bass were primarily present in the beach seine collections, subsequent to fry dispersal. Sculpins (*Cottus* sp.), in contrast to smallmouth bass, were susceptible to the tow nets as larvae but not collected by beach seining in Little Goose Reservoir. Sculpins were available to our sampling gear only during the pelagic, larval stage of development. Several species of sculpins known to be present in the general geographical area of Little Goose Reservoir have been reported to be pelagic during the larval stage. For example, coastrange sculpins (*Cottus aleuticus*), mottled sculpins (*C. bairdi*) and prickly sculpins (*C. asper*) have been reported by Heard (1965), Faber (1967), and Northcote and Hartman (1959), respectively, to be pelagic for a short period of time following hatching. In addition, larval sculpins were found to be the most abundant taxa collected in Lake Umatilla, Washington (Horjt et al. 1981).

Temporal Abundance

Temporal distribution patterns of larval and YOY fishes in Little Goose Reservoir were generally similar, although a lag occurred between larval and YOY abundance. For example, we observed larval fishes to be most abundant in Little Goose Reservoir during June, July and August (Fig. 101), whereas YOY abundance was highest during August, September and October (Fig. 116). Furthermore, greatest monthly CPEs were observed during July for larvae and during August for YOY fishes in Little Goose Reservoir.

Comparison of temporal abundance of larval and YOY fishes collected by different sampling methods must be made with caution, as gear selectivity influences the results. Absence of certain taxa of fishes in the early months of sampling probably was a result of sampling prior to spawning (Mayhew 1974). Low or zero catches of larval fishes in the later sampling periods may not reflect low populations, but decreased availability of larvae to the sampling gear employed.

The collecting gear and techniques we employed were used to minimize net avoidance of larval fishes. Our use of unbridled ichthyoplankton nets, towed away from the boat and prop wash and towed at a relatively high rate of speed (1.3 m/sec), are important factors in minimizing the nonvisually incited avoidance capabilities of larval fishes (Graser, Cada et al. 1980). Also, our use of night collections was an attempt to minimize visually incited net avoidance by larval fishes. Although higher densities of many taxa of freshwater larval fishes have been collected at night than during the day (Faber 1967; Houde 1969; Kindschi et al. 1979), larval clupeids have been collected in higher densities during daylight hours (Storck et al. 1978; Graser 1979; Tuberville 1979). We made only night collections and made no attempt to assess diurnal variations of larval fish abundance in Little Goose Reservoir.

In spite of our efforts to maximize sampling efficiency, gear avoidance is the most probable explanation for the disappearance of certain taxa of larval fishes from the tow net collections. The presence of the same taxa as young-of-years in the beach seine collections during subsequent sampling periods supports this hypothesis since swimming mobility increases concomitantly with increased length of larvae (Graser 1979); larger larvae are more capable of net avoidance (Graser 1979; Cada et al. 1980). Houser and Netsch (1971) found decreased efficiency of meter tow netting as larval gizzard (Dorosoma cepedianum) and threadfin shad (D. petenense) grew larger and attained juvenile size. Obviously, no single method of sampling is sufficient for collecting various early life stages of all fish taxa (Krause 1979). However, our early life history investigations, conducted over a relatively extended sampling period and using tow netting and seining, may be less affected by sampling bias than similar studies that use only a single gear type.

Trends in temporal distribution of various taxa of larval and YOY fishes in Little Goose Reservoir generally corresponded with the spawning periods as determined by examination of gonads. For example, bridgelip and largescale suckers spawned during April and May, and May and June (Figs. 86 and 87), respectively, whereas larval suckers (Catostomus sp.) were first collected during May and maximum densities were observed during July (Fig. 105). Gonads of two species of cyprinids, northern squawfish and redside shiner, were examined for reproductive information. Northern squawfish spawned from June into early August (Fig. 84) and redside shiners (Fig. 85) spawned from July into early August. Cyprinid larvae, however, first appeared in the collections at low densities during late May, maximum larval densities occurred during July, and YOY cyprinids were relatively abundant from August through November (Fig. 105). The appearance of cyprinid larvae in May probably was the result of an early spawning cyprinid species which was not examined for reproductive information.

Spawning periods and trends in temporal distributions of larval and YOY resident game fishes were generally found to be sequenced. Yellow perch spawned during April and May (Fig. 95), larval perch were first collected and most abundant during May (Fig. 105), and YOY yellow perch experienced highest relative abundance during July (Fig. 112). A similar sequence was observed for bullheads and channel catfish. Catfishes (Ictalurus sp.) spawned during July and August (Fig. 88 and 89), larval catfishes first appeared and were most abundant in the collections during August (Fig. 105), and YOY catfishes manifested greatest relative abundance during September (Fig. 117). Smallmouth bass spawned from early June through late July (Fig. 92). The few bass larvae captured were present in the collections during July and August (Fig. 106), whereas YOY smallmouth bass were relatively abundant during August, September and October (Fig. 117). Crappies and sunfish manifested similar trends in temporal distribution. Crappies and sunfish commenced spawning in June and continued spawning into August (Figs. 90, 91 and 93). Larval crappies and sunfish were first collected in late June and greatest larval densities were observed during August (Fig. 106). Young-of-year crappies exhibited a peak in abundance during August and few were collected until November (Fig. 117). Also, YOY bluegill were relatively abundant only during the months of July, September and November.

Trends in temporal distribution of YOY crappies and sunfish in Little Goose Reservoir may be a result of their limnetic distribution. Similar trends in temporal distribution of crappies and sunfish have been reported. For example, Carlander (1977) reported that crappie fry migrate to limnetic areas following hatching. In addition, larval bluegill also migrate from littoral areas to limnetic areas and then return to littoral areas (Werner 1967, 1969; Beard 1982). Our larval and YOY collections of crappies and sunfish reflect these changes in behavior (Figs. 106 and 117). Therefore, trends in temporal distribution must be viewed cautiously and with knowledge of the behavior of larval and YOY fishes.

Locational Abundance

Comparison of trends in locational distributions of taxa of larval and YOY fishes in Little Goose Reservoir indicate few changes in habitat utilization during different early life stages. Larval and YOY cyprinids were collected at all sampling stations, although cyprinid larvae and YOYs were considerably more abundant at upper reservoir sampling stations (Figs. 102 and 117). Catostomids were widely distributed as larvae and YOY and exhibited no trends in abundance throughout the reservoir. The distributions of cyprinids and catostomids, the two major groups of resident non-game fishes, suggest that little dispersal into different habitats occurs between the larval and YOY stages.

Distribution of resident game fishes generally were similar between larval and young-of-year stages. Larval and YOY yellow perch were primarily collected at the lower embayment; also, Beckman and Elrod (1971) found embayments to be the most important nursery areas for yellow perch in Lake Oahe, a main stem Missouri River Reservoir in North and South Dakota. Larval and YOY catfishes were primarily collected at the embayment sampling stations in Little Goose Reservoir, although few YOY catfishes were collected during the study.

Protected backwater areas were the most important rearing areas for all taxa of centrarchid fishes, the dominant group of resident game fishes, in Little Goose Reservoir. Most larval and YOY crappies and sunfish were collected at embayment and gulch sampling stations (Figs. 104 and 112). Larval and YOY crappies and sunfish were considerably more abundant in the lower embayment sampling station than all other stations in Little Goose Reservoir. Mayhew (1974) found that larval crappies and bluegill were most abundant in embayments and in shallow water habitats in Lake Rathbun, Iowa. Also, similar to our observations, highest abundance of YOY crappies and bluegill occurred in the major tributary embayments of Lake Oahe, North and South Dakota (Beckman and Elrod 1971). Although few larval smallmouth bass were collected, the upper and lower gulch sampling stations in Little Goose Reservoir appeared to be important nursery areas for YOY smallmouth bass. Our data indicate that the abundance of larval and YOY resident game fishes in Little Goose Reservoir is associated with the availability of protected backwater habitats.

Taxon Associations

Our utilization of different taxonomic classifications of larval and YOY fishes as a result of limitations in larval fish identification make comparisons of taxon associations between larval and YOY fishes in Little Goose Reservoir difficult. The positive correlations (Table 57) between fish taxon probably reflect habitat suitability for the species (Jenkins 1975), and/or a similar response to environmental factors (Houde 1969).

Limnological Correlations

Spatial and temporal variations in distribution of larval and YOY fishes probably reflect a response to some environmental factor or combination of factors. In an effort to identify important environmental factors, we assessed the relationships between limnological characteristics and sample frequencies of larval and YOY fishes by correlation analysis. Assessment of the relationships between larval and YOY fish sample frequencies and various limnological characteristics by correlation analysis does not imply causal relationships, rather a measure of closeness of the relationships (Rainwater and Houser 1975). For this reason, few of the correlations between YOY and larval fishes and limnological factors were similar (Tables 55 and 58).

SUMMARY

1) To evaluate the reproductive cycles and spawning habitat preferences of selected warmwater fishes in lower Snake River reservoirs, gonads were examined during 1979 and 1980 and larval and young-of-year fishes were collected during 1980 at representative stations.

2) Twelve species of resident fish were studied; all initiated reproductive development in the fall and spawned from early spring through late summer. In general, native fishes spawned earlier in the year, and introduced game fishes spawned later.

3) Spawning nests of smallmouth bass and sunfish were observed most frequently in gulch and embayment areas in the lower portions of Little Goose Reservoir, whereas shoal areas were more commonly used for spawning in the upper reservoir.

4) Vertical water level fluctuations of more than 1 m during the spawning season had the potential to expose 75% of all smallmouth bass and 73% of all sunfish spawning nests to desiccation. Depth of spawning data suggested that increased spawning success could occur with operational modifications in present power generating modes.

5) The catch composition of larval fishes and YOY fishes generally was similar in Little Goose Reservoir. Eight fish families were represented in the collections; members of the family Cyprinidae accounted for 64 and 53% of all larval and young-of-year fishes. The highest densities of larval and YOY fishes were found in gulch and embayment habitats.

6) Species associations and correlations with limnological parameters were computed and reflect habitat suitability for the various species and/or similarity in responses to environmental factors.

7) The relative abundance of larval and young-of-year sport fishes emphasized the importance of maintaining the quality of spawning and rearing habitats in gulch and embayment areas in lower Snake River reservoirs.

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Subobjective 5

To correlate fish behavior with limnological characteristics of lower Snake River reservoirs.

To effectively manage anadromous and resident fisheries, information on limnological factors that can adversely affect those fisheries must be known. Funk and Falter (1980) provided limited information on water temperature, dissolved oxygen, water transparency, and aquatic macrophytes in selected lower Snake River reservoirs. Although valuable, this information is inadequate to provide fishery managers with necessary water quality data. Because of the interrelationships of limnological data and resident fish behavior, additional limnological information was obtained.

METHODS

Limnological Sampling

Water temperature and dissolved oxygen profiles were measured on all lower Snake River reservoirs. Biweekly measurements were collected on Little Goose Reservoir at the six major sampling stations from June, 1979 through November, 1980 (excluding winter months) and at two embayment areas (upper embayment and Flagpole embayment (3 km east of Little Goose Dam)) and three main channel locations (Central Ferry, Penawawa and Swift Bar (9 km upriver from Penawawa)) (Fig. 2) from June, 1980 through November, 1980. Seasonal measurements were collected during 1980 at fish sampling stations on Lower Granite, Lower Monumental and Ice Harbor reservoirs. Dissolved oxygen (mg/l) and water temperature (C) profiles were collected at 1 m increments from the surface to reservoir bottom using a YSI Model 57 dissolved oxygen and temperature meter. The oxygen meter was calibrated bimonthly using a standard Winkler titration procedure (APHA 1976). All measurements were taken in the afternoon between 1300 and 1700 hours.

Additional characteristics measured at the six major sampling stations on Little Goose Reservoir included water transparency, water velocity, aquatic macrophyte distribution, water depth, bottom slope and littoral reach. Water transparency was measured to the nearest 0.1 m at biweekly intervals using a secchi disc. Secchi disc measurements were taken in the shade of the boat between 1300 and 1700 hours. Water velocity was measured seasonally during 1980 using an electronic flow meter. Subsurface velocity measurements at 0.5 m depth were taken 10-20 m offshore. Distribution of aquatic macrophytes was determined in August, 1980 by plotting macrophyte occurrences on an enlarged map of each sampling station. The size of areas inhabited by various kinds of macrophytes was then determined by planimetry. Morphological characteristics, including water depth, bottom slope and littoral reach were measured with ecosounder tracings. Ecosounder tracings extended 61 m in a perpendicular direction from the shoreline and were taken every 300 m of shoreline at each sampling station.

Limnological Correlation Analysis

To determine relationships between fish distribution and abundance and various limnological characteristics in Little Goose Reservoir, Pearson product-moment correlations were calculated between species sample frequencies and selected limnological parameters. Species sample frequencies for each sampling station were obtained from relative abundance calculations. Limnological characteristics included in the correlation analysis were water temperature, water transparency, aquatic macrophyte distribution, water velocity, maximum water depth and littoral reach. Values for limnological characteristics in the correlation analysis were expressed as follows: water temperature - mean temperature (C) of top 7 m (water which usually became thermally layered); water transparency - mean transparency from secchi disc (m); aquatic macrophyte distribution - percent area coverage; water velocity - ranks based on velocity measurements (station with highest water velocity given highest rank); maximum water depth - mean water depth 61 m from shoreline; littoral reach - distance which the littoral zone (<2 m depth) extended in a perpendicular direction from the shoreline.

Two limnological parameters not included in the correlation analysis were dissolved oxygen and bottom slope. Dissolved oxygen was omitted because critical levels for resident fishes were never measured and it was negatively correlated with water temperature ($r = -0.96$; $P < .011$). Bottom slope was omitted because it was positively correlated with maximum water depth ($r = 0.96$; $P < .001$) and negatively correlated with littoral reach ($r = -0.80$; $P < .001$).

RESULTS

Limnological Characteristics

Water Temperature and Dissolved Oxygen

Homothermous characteristics prevailed at all areas within Little Goose Reservoir during late fall and early spring in 1979 and 1980. Thermal layering was evident at the forebay and embayment areas beginning in May, whereas the majority of the reservoir became thermally layered by June (Figs. 118 and 119). During the summer in both years, water temperatures were more variable with depth at the forebay and embayment areas of the reservoir than at the tailwater, where homothermous characteristics prevailed. Water temperatures in summer and early fall at all areas in 1979 averaged 2-3 C warmer than water temperatures recorded during the same period in 1980. In both years, homothermous conditions prevailed throughout the reservoir by October.

Dissolved oxygen levels in Little Goose Reservoir were negatively correlated with water temperatures. During 1979 and 1980, fairly high oxygen levels remained at all areas through early summer (Figs. 119 and 120). When water temperatures exceeded 20 C, however, lower dissolved oxygen occurred by the end of July in both years, with lowest levels observed in deep waters of the forebay during August, 1979 when water temperatures exceeded 22 C throughout most of the reservoir. Dissolved oxygen levels showed replenishment by September in 1980 and by October in 1979.

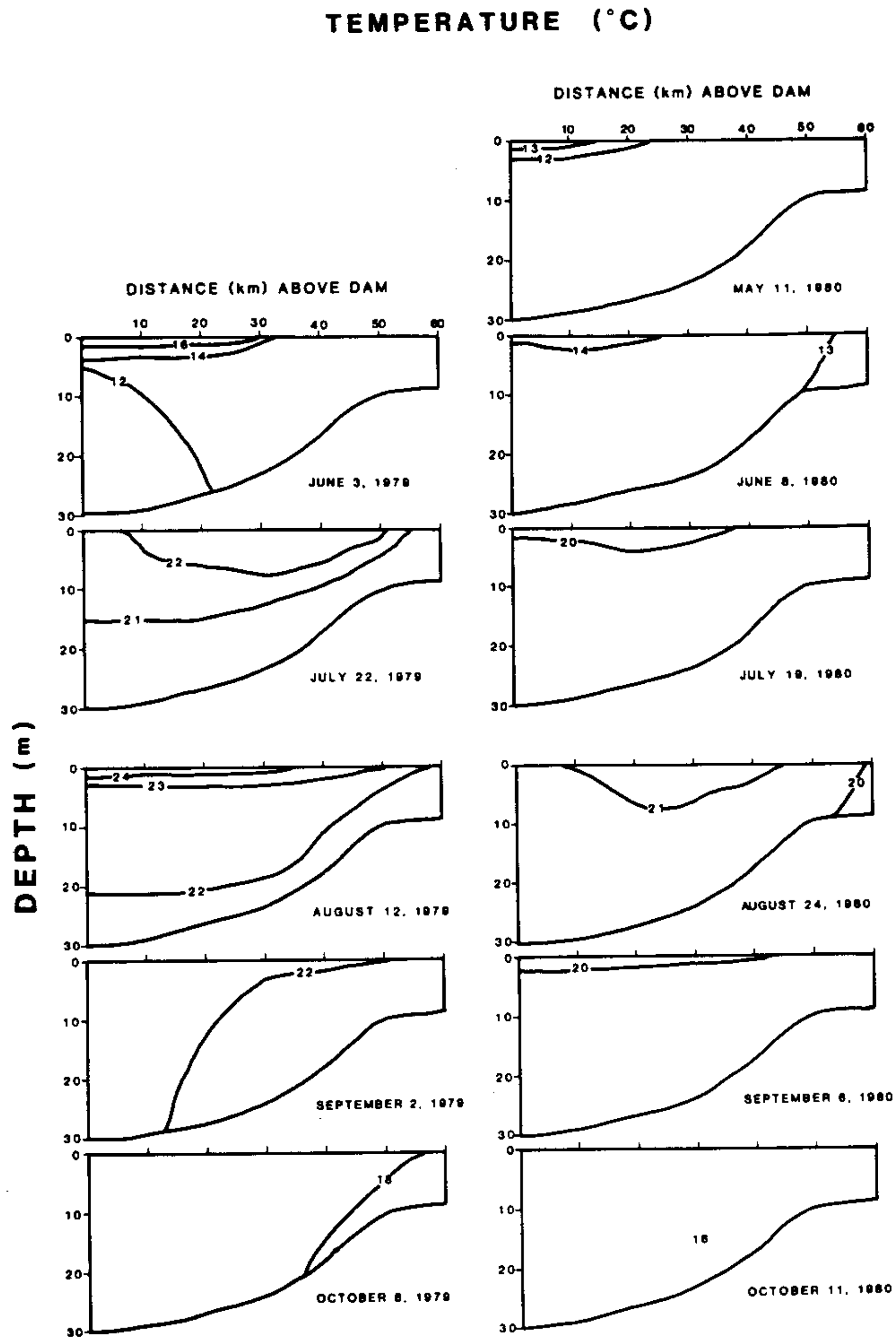

Figure 118. Water temperature (C) isopleths for main channel areas from Little Goose Reservoir, Washington, during 1979 and 1980.

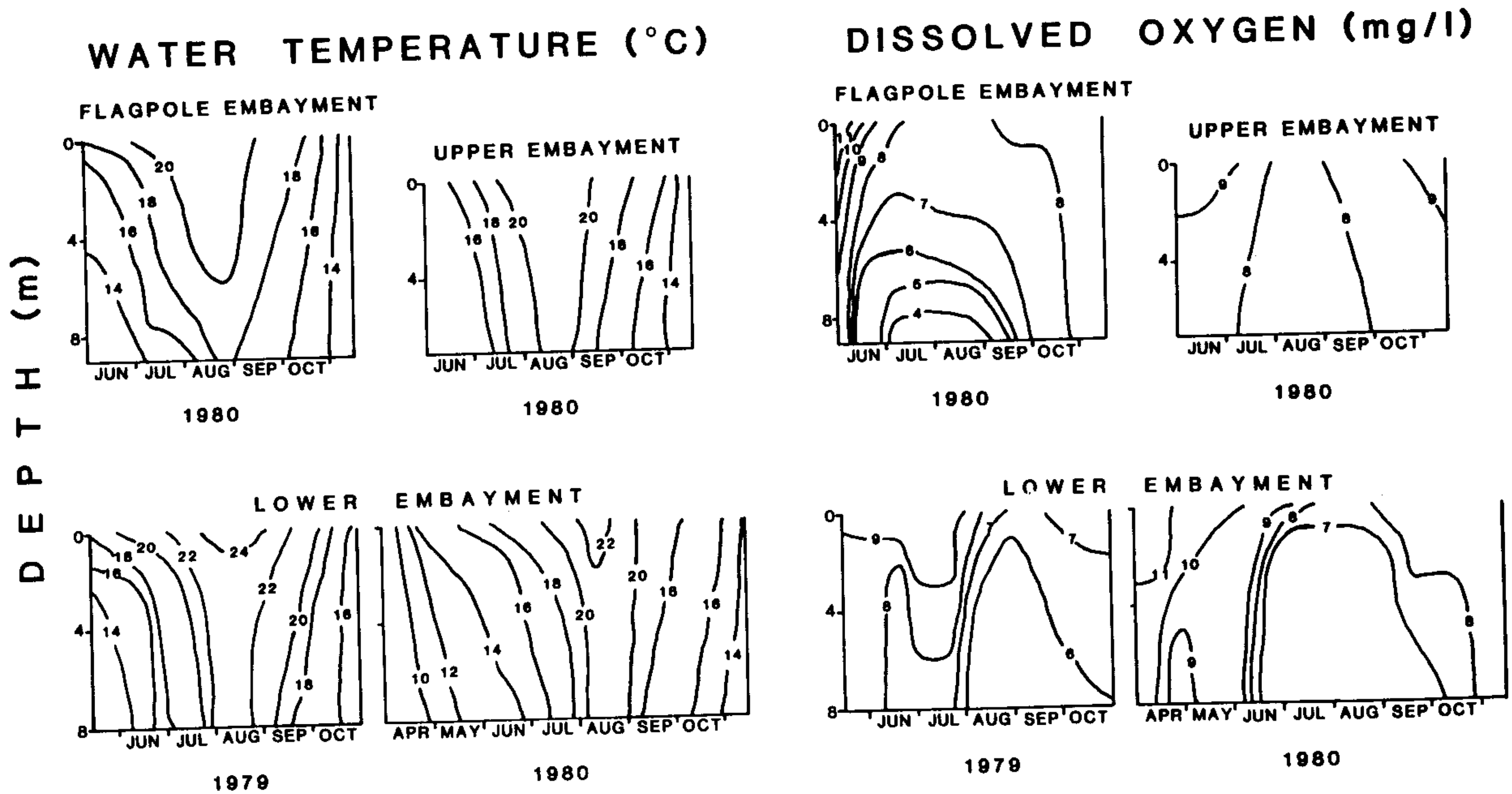

Figure 119. Water temperature (C) and dissolved oxygen (mg/1) isopleths for embayment areas from Little Goose Reservoir, Washington, during 1979 and 1980.

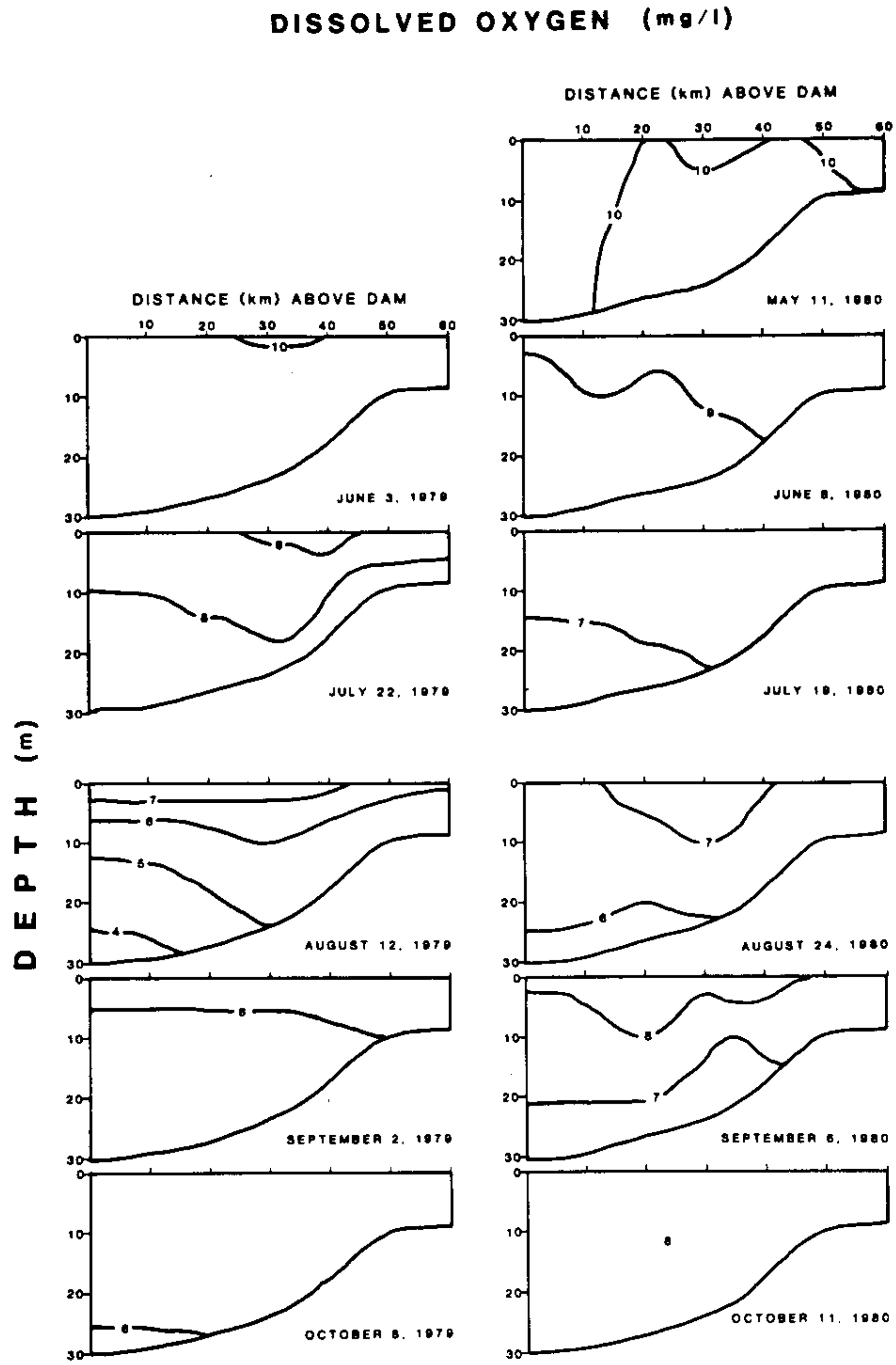

Figure 120. Dissolved oxygen (mg/l) isopleths for main channel areas from Little Goose Reservoir, Washington, during 1979 and 1980.

Water temperature and dissolved oxygen profiles collected seasonally during 1980 on Lower Granite, Lower Monumental and Ice Harbor reservoirs exhibited similar conditions to those measured on Little Goose Reservoir during the same periods. Lowest dissolved oxygen levels occurred when highest water temperatures prevailed in late summer (Fig. 121).

Water Transparency

Water transparency in Little Goose Reservoir was lowest in the spring when water flows were high. Average secchi readings in the lower embayment and main channel areas were 0.7 m and 1.1 m, respectively (Table 59). Water transparency increased through summer and fall with maximum secchi readings of 4.2 and 1.7 m recorded for main channel and lower embayment stations, respectively. Summer plankton abundance in various areas produced wide fluctuations in secchi disc readings and accounted for most decreases in transparency during summer and early fall.

Aquatic Macrophyte Distribution

Aquatic macrophytes inhabited most littoral areas in Little Goose Reservoir and were found at all stations except the deepwater and tail-water habitats. Percent area covered was highest at the lower gulch station followed by the upper shoal, lower embayment and lower shoal stations (Table 59).

Water Velocity

Water velocities in Little Goose Reservoir were highest during spring and were measurable at all main channel stations except the lower gulch (Table 59). During summer and fall, however, measurable water velocities occurred only at the upper shoal and tailwater stations.

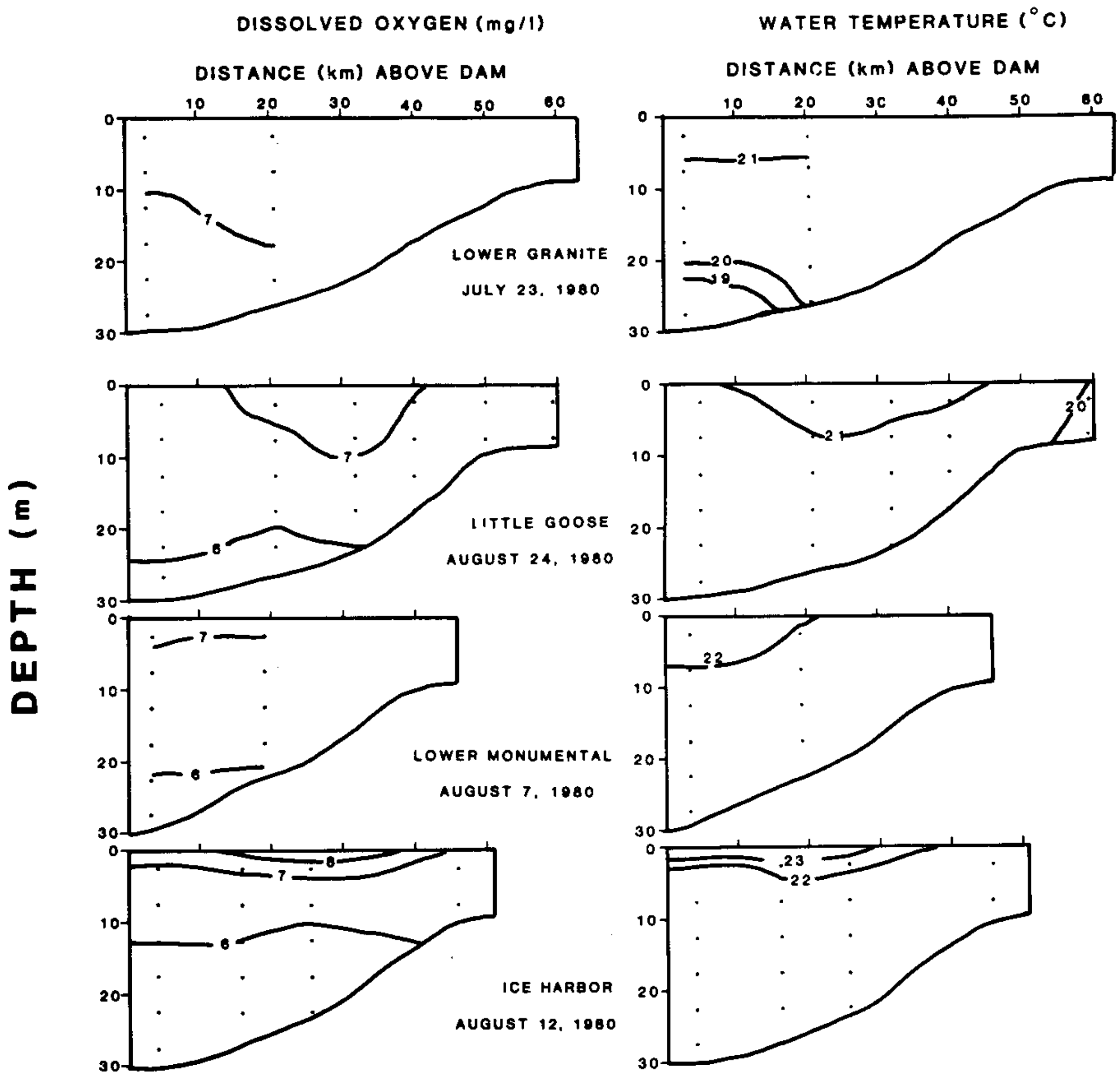

Figure 121. Dissolved oxygen (mg/l) and water temperature (C) isopleths for main channel areas from Lower Granite, Little Goose, Lower Monumental, and Ice Harbor reservoirs, Washington, during late summer in 1980. Dots represent locations of measurements.

Table 59. Limnological characteristics at major sampling stations on Little Goose Reservoir, Washington.

LIMNOLOGICAL CHARACTERISTIC	Lower Embayment	Lower Gulch	Deepwater	Lower Shoal	Upper Shoal	Tailwater
Maximum Water Depth (m)[a]	4	4	30	10	8	10
Littoral Reach (m)[b]	29	42	3	10	12	6
Average Slope of Bottom (degrees)	4	4	27	9	8	12
Water Velocity (m/second)	0	0	0-0.3	0-0.3	0-0.9	0-1.7
Aquatic Macrophyte Coverage (%)	3.7	11.8	0	3.3	9.7	0
Mean Water Transparency (m)						
Spring	0.7	1.1	1.2	1.2	1.1	1.1
Summer	1.0	2.1	2.2	2.2	2.0	1.9
Fall	1.4	2.8	3.1	3.1	2.5	2.4

[a]Mean water depth 61m from shoreline.
[b]Distance which the littoral zone (<2m depth) extended in a perpendicular direction from the shoreline.

Highest water velocities were always in the tailwater directly below the powerhouse although no measurable velocity was present at the north side (boat lock) of the dam.

Morphological Characteristics

Morphological characteristics, including water depth, littoral reach and bottom slope, described the extent of the littoral area at each sampling station in Little Goose Reservoir (Table 59). Most extensive littoral areas were located at the lower embayment and lower gulch stations. No littoral area, other than the immediate shoreline, was present at the deepwater station.

Limnological Correlation Analysis

Twenty-seven significant correlations were obtained between six limnological characteristics and sample frequencies of 16 fish species in Little Goose Reservoir (Table 60). Highest correlations were obtained for species occurring primarily in lotic areas of the reservoir. The abundance of white sturgeon, chiselmouth, northern squawfish and redside shiner was positively correlated with water velocity. Species negatively correlated with water velocity were found primarily in the lower embayment; these were brown bullhead, pumpkinseed, bluegill and white crappie.

Sample frequencies of nine species were correlated with various morphological characteristics. Carp, largescale sucker, brown bullhead and yellow perch generally preferred littoral habitats and were negatively correlated with water depth. Yellow bullhead and smallmouth bass were common along the rip-rap shoreline of the deepwater station and therefore, were positively correlated with water depth. Two littoral species,

Table 60. Pearson product-moment correlations ($P < 0.05$) between limnological characteristics and sample frequencies of fish species in Little Goose Reservoir, Washington.

SPECIES	Water Temperature	Water Transparency	Aquatic Macrophytes	Water Velocity	Max. Water Depth	Littoral Reach
white sturgeon	NS	NS	-0.39	0.57	NS	-0.33
chiselmouth	NS	NS	NS	0.68	NS	-0.34
carp	0.43	0.30	0.35	NS	-0.39	NS
northern squawfish	NS	NS	NS	0.50	NS	NS
redside shiner	NS	NS	NS	0.61	NS	NS
bridgelip sucker	NS	NS	NS	NS	NS	NS
largescale sucker	NS	NS	NS	NS	-0.42	NS
yellow bullhead	0.39	NS	NS	NS	0.34	NS
brown bullhead	NS	NS	NS	-0.36	-0.32	0.33
channel catfish	NS	NS	NS	NS	NS	NS
pumpkinseed	NS	-0.32	NS	-0.41	NS	0.30
bluegill	NS	NS	NS	-0.31	NS	NS
smallmouth bass	NS	NS	-0.34	NS	0.45	NS
white crappie	NS	NS	NS	-0.32	NS	NS
black crappie	NS	NS	NS	NS	NS	NS
yellow perch	NS	-0.46	0.30	NS	-0.39	NS

brown bullhead and pumpkinseed, were positively correlated with littoral reach. Two lotic species however, white sturgeon and chiselmouth, were negative correlated with littoral reach.

Few species were positively correlated with aquatic macrophyte distribution, water transparency and water temperature. Sample frequencies of carp were correlated with all three characteristics. Abundance of yellow bullhead was correlated with water temperature and that of yellow perch with aquatic macrophyte distribution. No significant correlations were obtained between any limnological characteristic and sample frequencies of bridgelip sucker, channel catfish and black crappie.

DISCUSSION

Fish Distribution and Abundance

Selectivity of Sampling Gear

Several types of sampling gear were employed on lower Snake reservoirs to determine species composition and estimate relative abundance of each fish species. Catch per effort of age I and older fish with each gear type at sampling stations (Appendix Tables III) indicated, however, that gear types employed were selective toward different fish species. Species and size selectivity is an inherent problem with sampling gear. This has been the subject of many fishery investigations (McCombie and Berst 1969; Gabel 1974; McWilliams et al. 1974; Hamley 1975). To obtain reliable estimates of species composition and relative abundance on lower Snake reservoirs, selectivity of the sampling gear was analyzed. Absolute selectivity of fishing gear can only be determined when the actual population structure is known (Powell et al. 1971). Since this was not possible, we analyzed the relative or differential selectivity of sampling gear by comparing the catch of each gear type with that of all gear employed (Appendix Tables III). Results of this analysis enables us to select gear types that most effectively sampled various size groups of a given species. As a result of this gear selectivity and the difficulty in comparing catches from multiple gear types (Ricker 1975), we devised a procedure to obtain estimates of relative abundance on lower Snake reservoirs. The strength of this method is that it permitted us to estimate relative abundance with catch data from more than one gear type.

Comparison of Reservoir Fish Abundance

Five species of fish exhibited trends in abundance when species sample frequencies and catch per effort fro effective gear types were compared among similar habitats in lower Snake reservoirs (Figs. 36-39). Smallmouth bass, white crappie and pumpkinseed were more abundant in downriver reservoirs. We feel that differences in abundance of these species among lower Snake reservoirs are probably attributed to variations in environmental factors such as sedimentation, aging of the reservoirs and extent of various habitat types present (embayment, gulch, shoal, etc.).

Sediment deposited from surrounding farm land and/or tributary streams has reduced the quality and quantity of littoral habitat. Sediment accumulations were present along the shoreline and in embayment areas in each reservoir; however, older downriver reservoirs had the largest accumulations. Smallmouth bass, a species which prefers a substrate of rock or gravel (Reynolds 1964; Munther 1970) could have been adversely affected by heavier sediment accumulations at main channel areas in downriver reservoirs. We feel this is probably why higher densities of smallmouth bass occurred at main channel stations in upriver reservoirs (Fig. 25 and 26). Also, abundance of white crappie and pumpkinseed, two species found primarily in embayment habitats, was probably affected by sediment accumulations and the amount of embayment habitat present in each reservoir. Abundance of these species was highest at the embayment station on Little Goose Reservoir, the largest and deepest embayment sampled, and lowest at the embayment station on Ice Harbor Reservoir, the smallest and shallowest embayment sampled (Figs. 26 and 28). Sediment accumulations and the amount of embayment habitat available probably affects the abundance of white crappie and pumpkinseed by limiting spawning and nursery habitat. This has been found elsewhere in heavily sedimented embayment areas on Missouri River reservoirs where Walburg (1977) found declining populations of crappies and other shallow water spawners.

In contrast, some resident species are less affected by sedimentation. For example, carp and channel catfish can apparently tolerate heavier sediment accumulations present in downriver reservoirs (Fig. 28). Carp can survive in habitat unsuitable for other game fish and, in addition, degrade that habitat by uprooting aquatic vegetation and increasing siltation (Sigler 1958). Channel catfish, although sometimes considered a clearwater species, often are abundant in muddy sections of streams and rivers (Miller 1966). Channel catfish are abundant in several sections of the Colorado River drainage that carry heavy silt loads (Dill 1944).

Spatial Distribution of Fish

Occurrence of fish species and species complexes in various habitats were generally predictable throughout Little Goose Reservoir. Each habitat type generally had a characteristic species complement and as a result, sample frequencies of a number of species were correlated with limnological factors (Table 60). Highest correlations were obtained for water velocity, thus, water velocity was an important limnological characteristic positively affecting the spatial distribution of some species and negatively influencing the distribution of others. Patten et al. (1970) concluded that water velocity was a dominant influence affecting the distribution and abundance of fish in the Yakima River. For example, in our study, fishes found primarily in lotic environments which had sample frequencies positively correlated with water velocity were white sturgeon, chiselmouth, northern squawfish and redside shiner (Table 60). Species preferring higher water velocities in the Yakima River included chiselmouth, northern squawfish and redside shiner (Patten et al. 1970). In British Columbia, chiselmouth occur primarily in warmer areas of streams with moderately fast to fast water (Moodie 1966). Immediately after impoundment of Lower Granite Dam, Coon et al. (1977) observed that white sturgeon, equipped with sonic transmitters, migrated upstream and remained above impounded waters which suggests white sturgeon may prefer flowing to standing water.

The abundance of a number of species was negatively correlated with water velocity. Fish species primarily found at the lower embayment station in Little Goose Reservoir had sample frequencies negatively correlated with water velocity; these included white crappie, pumpkinseed, bluegill and brown bullhead (Table 60). Other species not correlated with water velocity or not included in the analysis that were most frequently captured at the lower embayment included largemouth bass, black crappie, warmouth and tadpole madtom (Fig. 28). Other fishery investigators have noted that brown bullhead (Emig 1966; Imamura 1975; Pflieger 1975), white crappie (Trautman 1957; Siefert 1969), pumpkinseed (Trautman 1957; Hubbell 1966; Patten et al. 1970), bluegill (Trautman 1957; Hubbel 1966; Pflieger 1975), and tadpole madtom (Trautman 1957; Pflieger 1975; Wydoski and Whitney 1979) prefer lentic environments of sloughs and backwaters to that of moving waters.

Some fish species were correlated with morphometric characteristics of the habitats sampled. Species with sample frequencies negatively correlated with maximum water depth or positively correlated with littoral reach primarily occurred at stations with fairly extensive littoral areas; these included carp, largescale sucker, brown bullhead, yellow perch and pumpkinseed (Table 60). Smallmouth bass and yellow bullhead were common along the rip-rap shoreline of the deepwater station and had sample frequencies positively correlated with maximum water depth (Table 60). In addition to deep water at this station, large boulders were present along the shoreline which were used as cover by these species. We feel the rocky protective nature of the shoreline was probably more responsible for the occurrence of these species at the deepwater station than deep water. This interpretation is supported by the findings of other fishery investigators. For example, in the middle Snake River, Munther (1970) found highest densities of smallmouth bass over broken rock substrate. Also, in five northeast Minnesota lakes, electrofishing for smallmouth bass was 5.8 times more effective over boulder-rubble as either sand or muck substrates (Johnson and Hale, unpublished data; paper presented at the 25th Midwest Wildlife Conference).

Seasonal Distribution of Fish

Seasonal fluctuations in fish abundance in Little Goose Reservoir (Figs. 29-34) often were related to spawning activity or feeding movements. Abundance of yellow perch was highest during their spring spawning season at stations with aquatic vegetation. This is probably why sample frequencies of yellow perch were positively correlated with the presence of aquatic macrophytes (Table 60). Areas on Little Goose Reservoir that had high catch rates of yellow perch during spring were probably being utilized for spawning since yellow perch usually spawn near rooted aquatic vegetation or other submerged structures (Muncy 1962; Coots 1966). Protected areas with aquatic vegetation were important to other fish species for rearing. Numerous subadult pumpkinseed, bluegill, white crappie, black crappie, largemouth bass, brown bullhead and bridge-lip suckers were collected in shallow vegetated areas of the lower embayment station on Little Goose Reservoir during the summer months (Fig. 29). These areas probably provide abundant food supplies and protective cover from predators.

The seasonal distribution and abundance of white crappie, channel catfish and northern squawfish probably were related to feeding activity. Abundance of white crappie was highest during spring at the lower embayment station on Little Goose Reservoir (Fig. 29). Higher abundance during spring may be attributed to feeding activity initiated by warmer water temperatures. Goodson (1966) noted most crappie fisheries in California were seasonal in nature; white and black crappie were most readily caught by anglers during the spring. Higher abundance of channel catfish and northern squawfish at the tailwater station during spring may be attributed to prey availability since chinook salmon and steelhead smolts were migrating downstream through the reservoirs during April and May. Presence of anadromous smolts, however, may not be the only reason for the abundance of channel catfish in the tailwater during this time. Elrod (1974) reported a similar, but unexplained cycle of spring abundance for channel catfish in the Oahe tailwater on the Missouri River.

The abundance of rainbow trout also varied seasonally in Little Goose Reservoir. Catch per effort for rainbow trout between 250 and 400 mm (total length) was highest from fall through spring and almost nonexistent during summer (Appendix Tables III). The reason for this fluctuation in abundance is unclear; however, we hypothesize that perhaps not all steelhead smolts migrate downstream in late spring and that some spend the summer in the Clearwater River where environmental conditions are favorable. In all, as river temperatures decrease, some of these fish move downstream and overwinter in the lower Snake reservoirs. From our catches, it appears these fish remain in the reservoirs until late spring. From spring to summer catches decline suggesting that these rainbow trout may either continue their migration to the ocean or migrate to habitats that provide more favorable conditions.

Vertical Distribution of Fish

We did not find any relationship between water temperature or dissolved oxygen levels and the vertical distribution of fishes in deepwater areas of lower Snake reservoirs. The lack of a relationship was not surprising since variations in water temperature generally were less than 3 C from the surface to reservoir bottom and dissolved oxygen levels were not critical to most warmwater species. In other studies, however, where fish could select from a wide range of temperatures (Ferguson 1958; Horak and Tanner 1964; Eley et al. 1967; Gebhart and

Summerfelt 1975) or when dissolved oxygen levels dropped below 2 mg/l (Borges 1950; Eley et al. 1967; Gebhart and Summerfelt 1975), distribution of warmwater fishes has been directly correlated with these limnological characteristics. In lower Snake reservoirs, other environmental factors which may have influenced fish depth distribution include light transmission, other physiochemical factors and biological factors. The distribution of northern squawfish, redside shiner and chiselmouth in the upper 10 m of the water column may be related to food availability since insects, zooplankton, diatoms and algae are among food items consumed by these species (Objective 3; Wydoski and Whitney 1979). Channel catfish and white sturgeon are typically bottom dwellers which explains their distribution in the lower 10 m of the water column in lower Snake reservoirs (Figs. 40-41).

Water Quality

Water temperature and dissolved oxygen levels in lower Snake reservoirs (Figs. 118-121) are suitable for resident warmwater species, although high water temperatures and low dissolved oxygen during late summer in some years may limit salmonid abundance. In Little Goose Reservoir, late summer water temperatures and dissolved oxygen levels were less critical to salmonids during 1980 than in 1979. Mild air temperatures during 1980 resulted in late summer water temperatures generally less than 21 C and dissolved oxygen levels exceeding 6 mg/l. After warmer air temperatures in 1979, however, late summer water temperatures averaged more than 22 C and dissolved oxygen levels dropped below 6 mg/l throughout most of the reservoir. Water temperature and dissolved oxygen levels during late summer, especially in 1979, border the established tolerance limits for salmonids. Salmonids are classified as temperate stenotherms by Hokanson (1977) and have physiological optima less than 20 C and upper incipient lethal temperatures less than 26 C. Dissolved oxygen criteria established by Davis (1975), set 5.26 mg/l as an oxygen level where an "average" salmonid in a mixed species population will exhibit symptoms of oxygen distress. Our water quality data indicate that water temperature and dissolved oxygen levels in Little Goose Reservoir are marginal for salmonid fishes during warmer years (Figs. 118-120). Because this study only was of two years duration in the field, we do not have any information regarding the frequency of years that marginal salmonid conditions would occur in lower Snake reservoirs. We believe, however, that conditions of higher water temperature and low dissolved oxygen may coincide with warmer air temperatures and possibly with longer water retention time in the reservoirs during years of low flow.

SUMMARY

1) Limnological sampling was conducted in lower Snake River reservoirs from June, 1979 through November 1980 (excluding winter months). Dissolved oxygen and water temperature profiles were taken at 1 m increments. Additional characteristics measured in Little Goose Reservoir included water transparency, water velocity, aquatic macrophyte distribution, water depth, bottom slope, and littoral reach.

2) To determine relationships between fish distribution and abundance and various limnological characteristics, Pearson product-moment correlations were calculated between sample frequencies of fish and selected limnological parameters.

3) Homothermous temperature conditions prevailed in Little Goose Reservoir from October to June. Temperature layering occurred from June into September in all areas except the tailwater, which remained homothermous throughout the year. Water temperatures averaged 2-3 C warmer in 1979 than 1980 with highs exceeding 22 C.

4) Dissolved oxygen levels in Little Goose Reservoir were negatively correlated with water temperature. When water temperatures exceeded 20 C, oxygen levels decreased through August when lowest levels were observed in the deep waters. Oxygen levels increased again in September 1980 and October 1979.

5) Seasonal sampling on Lower Granite, Lower Monumental, and Ice Harbor indicated that water temperature and dissolved oxygen conditions were similar to those in Little Goose Reservoir.

6) Occurrence of fish species and species complexes in various habitats generally were predictable throughout Little Goose Reservoir. Each habitat type generally had a characteristic species complement and, as a result, the abundance of a number of species was correlated with limnological factors.

7) We did not find any relationship between water temperature or dissolved oxygen levels and the vertical distribution of fishes in deepwater areas. The lack of a relationship was attributed to slight vertical differences in water temperature (3 C), and the dissolved oxygen levels were not critical to most warmwater species.

8) Occurrence of water temperatures that border established tolerance limits and dissolved oxygen concentrations that may cause oxygen stress for salmonid fishes suggests that lower Snake River reservoirs should be managed for warm/coolwater fishes.

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RECOMMENDATIONS

1) Because of the importance of backwater habitats (embayments, gulches, coves, etc.) in the lower Snake River reservoirs for spawning and rearing of warmwater sport fishes, the quality of these habitats must be maintained. Sediment entering these habitats from surrounding agricultural lands and highway construction and maintenance activities has the potential to degrade these habitats where the abundance of resident fish stocks could be severely impacted. Therefore, if the quality of these habitats cannot be maintained through land management activities, we recommend construction of backwater habitats in suitable main channel areas.

2) Because of high water temperatures and low dissolved oxygen regimens in the lower Snake River reservoirs, fisheries management activities should emphasize warm and cool water resident fishes and not resident salmonid fishes. However, the stocking of catchable sized salmonid fishes should be tried experimentally during the spring and fall when habitat conditions are suitable to assess the feasibility of this management practice.

3) Because much of the sports fishery in the lower Snake River reservoirs is concentrated in backwater areas and a number of these areas exist on the northside of Little Goose and Lower Monumental reservoirs, angling opportunities could be enhanced by increasing land and water access to these habitats. Also, angling opportunities and fishing

success could be increased by installation of floating docks in embayment habitats on lower Snake River reservoirs.

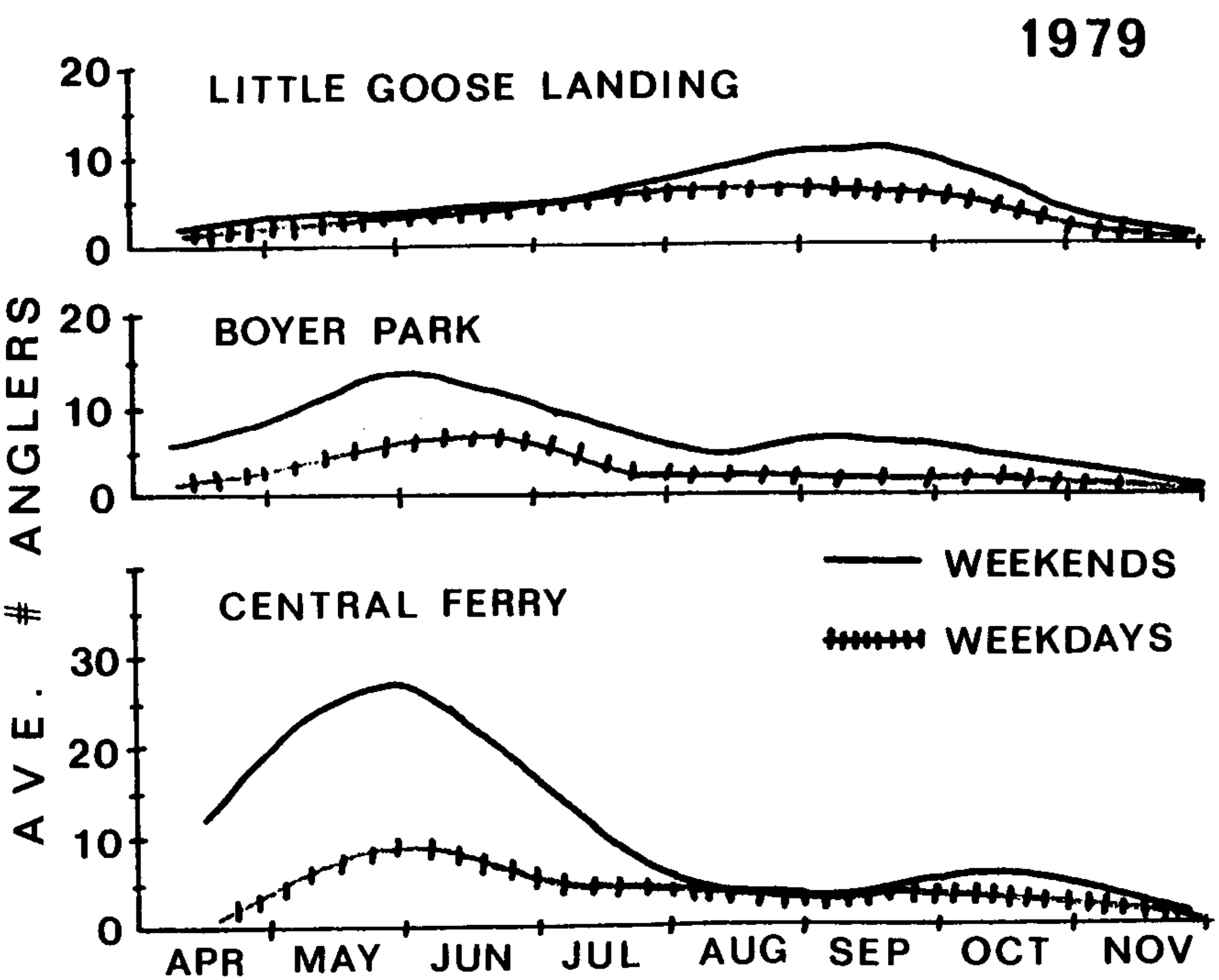
4) Conflicts between anglers and other reservoir user groups could be reduced by restricting to wake speeds in backwater habitats. Because backwater habitats provide the bulk of angling opportunities, speed regulation would aleviate tensions among reservoir users and increase fishing opportunities.

5) At present, fishermen are uninformed about angling opportunities in the lower Snake River reservoirs. Programs should be developed to inform and educate sports fishermen about the species of sport fishes available in the lower Snake River reservoirs and fishing methods required to catch these fish.

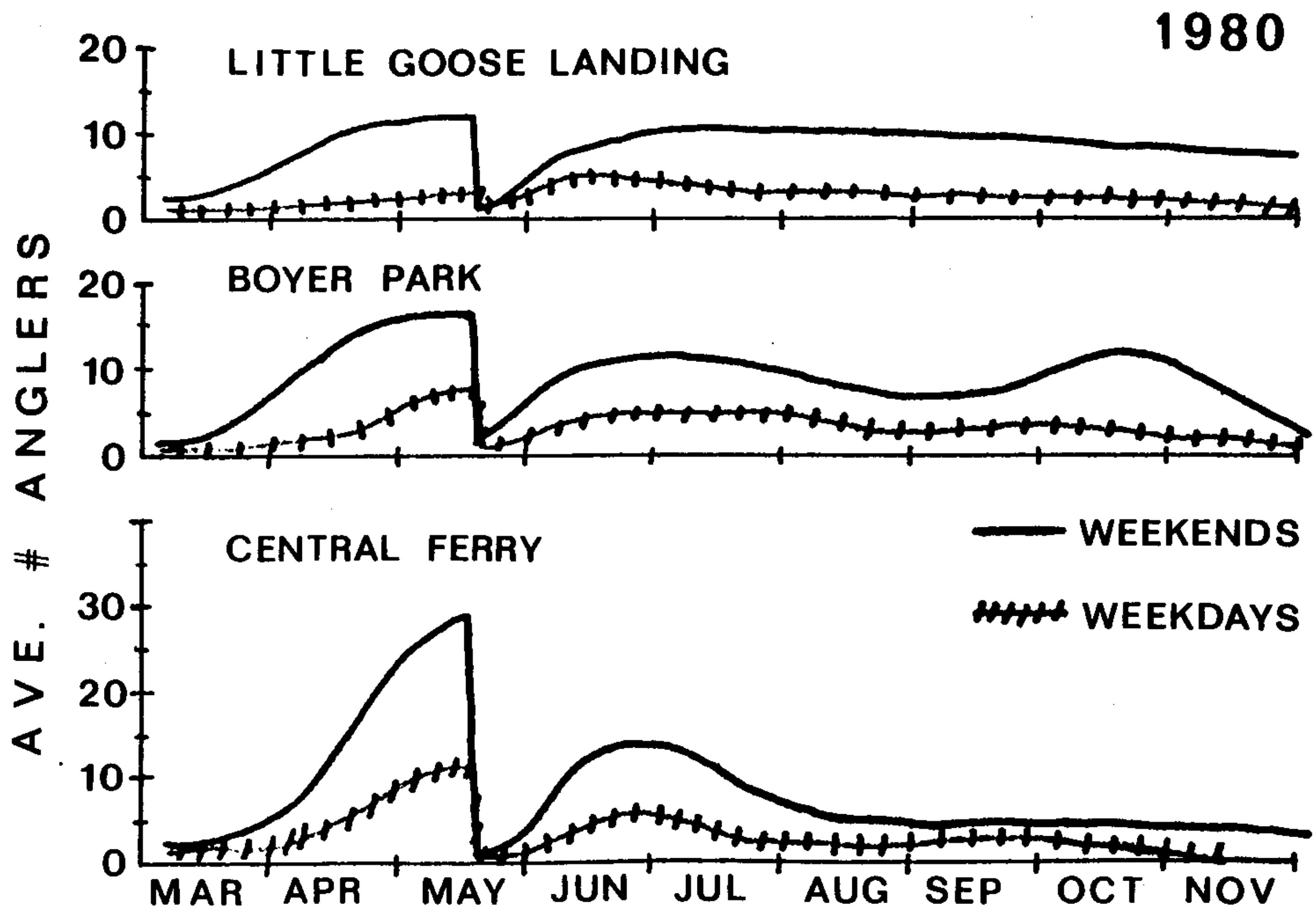
6) To maintain adequate recruitment and, thus, the quality of the sports fishery in the lower Snake River reservoirs, water level fluctuations during May, June, and July must be of concern to fishery resource managers. Under present electrical power operating modes, however, our data does not indicate that present water level fluctuations are limiting recruitment and therefore, adversely affecting the quality of the resident sports fishery. Changes in power operation modes, however, could seriously decrease recruitment and adversely affect the quality of the resident sports fishery.

7) Our results suggest that habitat improvement structures (wing dams, rock jetties, artificial reefs, and stake beds) could increase production of resident game fishes in each of the lower Snake River reservoirs. However, the sport fishery benefits and effects on the dynamics of the fish stocks should be experimentally evaluated before a major effort was undertaken.

8) This study provided valuable baseline data on characteristics of the sports fishery and resident species in lower Snake River reservoirs. To more effectively manage these fisheries, more intensive investigations should be conducted on the following:
   a) the dynamics of white sturgeon stocks in each of the lower Snake River reservoirs;
   b) the dynamics and nature of salmonid smolt predation by channel catfish in the tailwaters of lower Snake River reservoirs;
   c) the potential and importance of natural production of chinook salmon in lower Snake River reservoirs;
   d) the benefits of installation of habitat improvement structures (#7) to selected game fishes in lower Snake River reservoirs;
   e) the relationship between water level fluctuations and recruitment of shallow water spawning game fishes; and,
   f) the importance of lower Snake reservoirs for spring and fall rearing of juvenile steelhead trout.



Appendix Figure I. Seasonal angler use patterns at major access zones on Little Goose Reservoir, for 1979.



Appendix Figure I. Seasonal angler use patterns at major access zones on Little Goose Reservoir, for 1980.

Appendix II
Table 1. Estimates of Total Angler Use on Little Goose Reservoir, 1979.

	Boat Anglers		Shore Anglers		Total Anglers	
	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	11853.61	4900.28	12035.91	4666.88	23889.52	7283.11
Weekends-Holidays	8417.91	1775.85	13444.81	2647.29	21862.72	3301.43
Totals	20271.52	5212.13	25480.72	5365.43	45752.24	7996.44

Appendix II
Table 2. Estimates of Total Boat Use on Little Goose Reservoir, 1979.

	Fishing Boats		Pleasure Boats	
	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	5229.12	2216.99	4681.58	2075.98
Weekends-Holidays	3635.37	724.16	12520.25	2609.06
Totals	8864.49	2332.26	17201.83	3334.20

Appendix II

Table 3. Estimates of Angler Use at Central Ferry - Port of Garfield Zone, 1979.

Sample		Period	n^a	m^b	Boat Anglers: Estimated hours	Boat Anglers: Bound on error of estimation	Shore Anglers: Estimated hours	Shore Anglers: Bound on error of estimation	Total Anglers: Estimated hours	Total Anglers: Bound on error of estimation
May-June	Weekdays	AM	8	64	413.88	188.88	849.25	356.39	1263.13	432.73
		PM	5	40	464.40	351.84	1608.20	661.55	2072.60	993.25
		TOTAL			878.28	399.33	2457.45	751.44	3335.73	1083.42
	Weekends-Holidays	AM	8	64	1059.75	234.44	1446.75	404.69	2506.50	588.46
		PM	9	72	762.00	265.46	1934.00	429.05	2696.00	643.29
		TOTAL			1821.75	354.16	3380.75	589.80	5202.50	871.84
April & July-November	Weekdays	AM	8	61	877.30	845.54	1164.41	1068.86	2041.71	1745.72
		PM	9	69	1358.23	1348.51	1184.84	1112.80	2543.07	2019.04
		TOTAL			2235.53	1591.67	2349.25	1542.98	4584.78	2669.09
	Weekends-Holidays	AM	4	31	447.48	522.43	763.36	477.53	1210.84	903.04
		PM	9	70	1043.43	420.25	1156.07	431.65	2199.50	582.93
		TOTAL			1490.91	670.48	1919.43	643.70	3410.34	1074.84
1979 Totals		Weekdays			3113.80	1641.00	4806.70	1716.23	7920.50	2880.60
		Weekends			3312.66	758.27	5300.18	873.05	8612.84	1383.98
		Total			6426.46	1807.72	10106.88	1925.53	16533.34	3195.82

[a] n = number of ½-day clusters in sample.

[b] m = number of instantaneous counts in sample.

Appendix II

Table 4. Estimates of Angler Use at Boyer Park - Illia Landing Zone, 1979.

Sample Period		n[a]	m[b]	Boat Anglers		Shore Anglers		Total Anglers	
				Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	AM[c]		10	921.90	1567.08	2370.60	3148.78	3292.50	4648.88
	PM	4	32	1215.28	2048.89	2011.50	1873.08	3226.78	2892.94
	TOTAL			2137.18	2579.48	4382.10	3663.77	6519.28	5475.51
Weekends-Holidays	AM	9	68	527.65	268.47	1534.23	646.61	2061.88	747.46
	PM	8	63	1268.84	715.19	4054.97	1605.16	5323.81	1365.81
	TOTAL			1796.49	763.92	5589.20	1730.51	7385.69	1556.96
1979 Totals				3933.67	2690.22	9971.30	4051.90	13906.97	5692.57

[a] n = number of ½-day clusters in sample.

[b] m = number of instantaneous counts in sample.

[c] Estimates of use on weekday mornings were calculated from a simple random sample of 10 instantaneous counts on randomly selected days.

Appendix II

Table 5. Estimates of Angler Use at Little Goose Landing Zone, 1979.

Sample Period		n^a	m^b	Boat Anglers: Estimated hours	Boat Anglers: Bound on error of estimation	Shore Anglers: Estimated hours	Shore Anglers: Bound on error of estimation	Total Anglers: Estimated hours	Total Anglers: Bound on error of estimation
Weekdays	AM	4	31	722.23	920.24	169.94	338.46	892.16	1217.55
	PM	5	40	3888.90	2931.89	905.18	937.49	4794.08	2892.37
	TOTAL			4611.13	3072.92	1075.11	996.72	5686.24	3138.18
Weekends-Holidays	AM	9	67	1639.52	747.19	395.46	456.15	2034.99	947.52
	PM	7	54	1459.61	1124.08	910.96	761.96	2370.57	1770.16
	TOTAL			3099.13	1349.75	1306.42	888.07	4405.56	2013.97
1979 Totals				7710.26	3356.29	2381.54	1334.96	10091.80	3728.84

[a] n = number of ½-day clusters in sample.

[b] m = number of instantaneous counts in sample.

Appendix II

Table 6. Estimates of Angler Use at Willow Landing - Penawawa Zone, 1979.

Sample Period		n[a]	Boat Anglers		Shore Anglers		Total Anglers	
			Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	AM	6	1097.50	1426.02	878.00	1108.06	1975.50	1314.00
	PM	3	894.00	1786.00	894.00	1786.00	1788.00	1786.00
	TOTAL		1991.50	2285.46	1772.00	2101.80	3763.50	2217.29
Weekends-Holidays	AM	4	0.0	0.0	690.00	1374.99	690.00	1374.99
	PM	8	209.62	416.24	559.00	756.32	768.62	783.11
	TOTAL		209.62	416.24	1249.00	1569.27	1458.62	1582.36
1979 Totals			2201.12	2323.05	3021.00	2623.01	5222.12	2724.01

[a] n = number of instantaneous counts in a simple random sample.

Appendix II

Table 7. Estimates of Boat Use at Central Ferry - Port of Garfield Zone, 1979.

		Sample Period	n[a]	m[b]	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
May-June	Weekdays	AM	8	64	188.13	76.10	1263.13	432.73
		PM	5	40	206.40	149.95	275.20	223.75
		TOTAL			394.53	168.15	1538.33	487.15
	Weekends-Holidays	AM	8	64	488.25	102.11	83.25	35.11
		PM	9	72	348.00	126.50	2696.00	643.29
		TOTAL			836.25	162.57	2779.25	644.24
April & July - November	Weekdays	AM	8	61	494.48	464.26	494.47	418.08
		PM	9	69	635.77	539.16	462.38	406.15
		TOTAL			1130.25	711.50	956.85	582.87
	Weekends-Holidays	AM	4	31	184.26	203.45	684.39	766.96
		PM	9	70	403.14	154.09	2460.36	1561.72
		TOTAL			587.40	255.22	3144.75	1739.88
1979 Totals		Weekdays			1524.77	731.10	2495.18	759.64
		Weekends			1423.65	302.59	5923.99	1855.33
		Totals			2948.42	791.25	8419.17	2004.82

[a] n = number of ½-day clusters in sample.

[b] m = number of instantaneous counts in sample.

Appendix II

Table 8. Estimates of Boat Use at Boyer Park - Illia Landing Zone, 1979.

Sample Period		n[a]	m[b]	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
Weekdays	AM[c]		10	526.80	801.64	790.20	891.98
	PM	4	32	628.59	1066.68	796.22	1512.55
	TOTAL			1155.39	1334.33	1586.42	1755.97
Weekends-Holidays	AM	9	68	300.35	135.48	649.41	232.01
	PM	8	63	567.87	268.32	2768.38	1618.44
	TOTAL			868.23	300.59	3417.79	1634.99
1979 Totals				2023.62	1367.77	5004.21	2399.29

[a] n = number of ½-day clusters in sample.

[b] m = number of instantaneous counts in sample.

[c] Estimates of use on weekday mornings were calculated from a simple random sample of 10 instantaneous counts on randomly selected days.

Appendix II
Table 9. Estimates of Boat Use at Little Goose Landing Zone, 1979.

Sample Period		n^a	m^b	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
Weekdays	AM	4	31	254.90	306.01	127.45	253.84
	PM	5	40	1408.05	1184.08	33.53	68.19
	TOTAL			1662.95	1222.98	160.98	262.84
Weekends-Holidays	AM	9	67	634.39	294.88	683.82	616.85
	PM	7	54	569.35	422.53	269.15	212.69
	TOTAL			1203.74	515.25	952.97	652.49
1979	Totals			2866.69	1327.09	1113.95	703.44

Appendix II
Table 10. Estimates of Boat Use at Willow Landing - Penawawa Zone, 1979.

Sample Period		n[a]	Fishing Boats		Pleasure Boats	
			Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	AM	6	439.00	554.03	439.00	876.00
	PM	3	447.00	893.00	0.0	0.0
	TOTAL		886.00	1050.90	439.00	876.00
Weekends-Holidays	AM	4	0.0	0.0	828.00	317.54
	PM	8	139.75	277.49	1397.50	726.65
	TOTAL		139.75	277.49	2225.50	793.00
1979 Totals			1025.75	1086.92	2664.50	1181.62

[a] n = number of instantaneous counts in a simple random sample.

Appendix II
Table 11. Estimates of Total Angler Use on Little Goose Reservoir, 1980.

	Boat Anglers		Shore Anglers		Total Anglers	
	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	7727.65	3241.10	19414.86	3131.78	27142.51	4820.94
Weekends-Holidays	24406.58	4656.52	28056.06	4938.13	52462.64	7561.93
Totals	32134.23	5673.44	47470.92	5847.49	79605.15	8967.96

Appendix II
Table 12. Estimates of Total Boat Use on Little Goose Reservoir, 1980.

	Fishing Boats		Pleasure Boats	
	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	3811.79	1343.21	4486.79	1605.85
Weekends-Holidays	10922.18	2128.39	16436.63	4359.60
Totals	14733.97	2516.79	20923.42	4645.95

Appendix II
Table 13. Estimates of Angler Use at Central Ferry - Port of Garfield Zone, 1980.

Sample Period			n	Boat Anglers: Estimated hours	Boat Anglers: Bound on error of estimation	Shore Anglers: Estimated hours	Shore Anglers: Bound on error of estimation	Total Anglers: Estimated hours	Total Anglers: Bound on error of estimation
May-June	Weekdays	AM	10	369.60	361.88	840.00	618.19	1209.60	905.44
		PM	8	420.00	660.98	1344.00	469.48	1764.00	1047.92
		TOTAL		789.60	753.56	2184.00	776.26	2973.60	1384.90
	Weekends-Holidays	AM	6	709.33	677.95	810.67	623.38	1520.00	1238.03
		PM	12	1241.33	564.22	2799.33	805.00	4040.67	1160.62
		TOTAL		1950.67	882.02	3610.00	1018.15	5560.67	1696.99
March-April & July-November	Weekdays	AM	35	539.14	423.63	2029.72	924.24	2568.86	1132.11
		PM	36	586.36	374.41	2839.22	1298.77	3425.58	1476.20
		TOTAL		1125.50	565.37	4868.94	1594.06	5994.44	1860.33
	Weekends-Holidays	AM	16	3180.00	1441.45	3510.00	2348.18	6690.00	3643.84
		PM	14	1371.43	1039.29	2400.00	1595.78	3771.43	2316.66
		TOTAL		4551.43	1777.05	5910.00	2839.09	10461.43	4317.93
1980 Totals		Weekdays		1915.10	942.07	7052.94	1773.02	8968.04	2319.22
		Weekends		6502.10	1983.90	9520.00	3016.14	16022.09	4639.43
		Total		8417.20	2196.22	16572.94	3498.67	24990.13	5186.82

Appendix II
Table 14. Estimates of Angler Use at Boyer Park - Illia Landing Zone - 1980.

Sample Period			n	Boat Anglers Estimated hours	Boat Anglers Bound on error of estimation	Shore Anglers Estimated hours	Shore Anglers Bound on error of estimation	Total Anglers Estimated hours	Total Anglers Bound on error of estimation
May-June	Weekdays	AM	9	112.00	220.98	1306.67	792.49	1418.67	825.19
		PM	8	1008.00	1391.59	1680.00	1086.65	2688.00	1601.96
		TOTAL		1120.00	1409.02	2986.67	1344.93	4106.67	1902.00
	Weekends-Holidays	AM	6	253.33	284.39	1393.33	723.35	1646.67	801.00
		PM	11	428.36	327.52	2307.64	807.00	2736.00	902.02
		TOTAL		681.70	433.76	3700.97	1083.74	4382.67	1206.33
March-April & July-November	Weedays	AM	24	555.00	591.11	1341.25	934.43	1896.25	1002.09
		PM	24	416.63	369.78	2870.08	1129.69	3286.71	1070.53
		TOTAL		971.63	697.24	4211.33	1466.07	5182.96	1466.36
	Weekends-Holidays	AM	14	2537.14	1162.42	2502.86	1251.02	5040.00	2009.61
		PM	10	1344.00	811.02	3840.00	2731.27	5184.00	2831.49
		TOTAL		3881.14	1417.38	6342.86	3004.15	10224.00	3472.15
1980 Totals		Weekdays		2091.62	1572.10	7198.00	1989.52	9289.62	2323.24
		Weekends		4562.84	1482.26	10043.83	3193.65	14606.67	3675.74
		Total		6654.46	2160.69	17241.83	3762.66	23896.29	4348.39

Appendix II
Table 15. Estimates of Angler Use at Little Goose Landing Zone, 1980.

Sample		Period	n	Boat Anglers		Shore Anglers		Total Anglers	
				Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
March-July & October-November	Weekdays	AM	23	627.39	659.88	1110.00	552.47	1737.39	849.46
		PM	22	202.00	276.01	1717.00	865.16	1919.00	972.92
		TOTAL		829.39	715.27	2827.00	1026.51	3656.39	1291.57
	Weekends-Holidays	AM	19	328.42	288.25	1440.00	857.33	1768.42	904.49
		PM	18	1306.67	649.69	1866.67	816.14	3173.33	1047.17
		TOTAL		1635.09	710.77	3306.67	1183.68	4941.75	1383.71
August-September	Weekdays	AM	16	126.00	132.18	210.00	188.13	336.00	231.86
		PM	15	246.40	163.00	380.80	306.52	627.20	338.38
		TOTAL		372.40	209.86	590.80	359.65	963.20	410.19
	Weekends-Holidays	AM	12	278.67	229.48	405.33	244.45	684.00	440.57
		PM	11	373.09	314.27	442.18	285.94	815.27	373.03
		TOTAL		651.76	389.14	847.51	376.19	1499.27	577.28
1980 Totals		Weekdays		1201.79	745.43	3417.80	1087.69	4619.59	1355.14
		Weekends		2286.85	810.32	4154.18	1242.02	6441.02	1499.30
		Total		3488.64	1101.04	7571.98	1650.96	11060.61	2020.97

Appendix II

Table 16. Estimates of Angler Use at Willow Landing - Penawawa Zone, 1980.

Sample		Period	n	Boat Anglers Estimated hours	Boat Anglers Bound on error of estimation	Shore Anglers Estimated hours	Shore Anglers Bound on error of estimation	Total Anglers Estimated hours	Total Anglers Bound on error of estimation
May-June	Weekdays	AM	4	168.00	333.99	0.0	0.0	168.00	333.99
		PM	2	0.00	0.00	336.00	670.00	336.00	670.00
		TOTAL		168.00	333.99	336.00	670.00	504.00	748.63
	Weekends- Holidays	AM	5	121.60	239.17	182.40	146.46	304.00	267.40
		PM	11	110.55	112.30	276.36	171.27	386.91	169.18
		TOTAL		232.15	264.22	458.76	225.35	690.91	316.42
March-April & July-November	Weekdays	AM	22	100.91	199.81	655.91	553.67	756.82	668.76
		PM	20	0.00	0.00	111.10	220.19	111.10	220.19
		TOTAL		100.91	199.81	767.01	595.85	867.92	704.07
	Weekends- Holidays	AM	14	514.285	426.08	274.285	237.03	788.57	60.92
		PM	9	740.67	1043.21	1357.89	1265.78	2098.56	1823.55
		TOTAL		1254.95	1126.87	1632.17	1287.78	2887.13	1880.89
1980 Totals		Weekdays		268.91	389.20	1103.01	896.62	1371.92	1027.70
		Weekends		1487.10	1157.43	2090.94	1307.35	3578.04	1907.32
		Total		1756.01	1221.11	3193.95	1585.28	4949.95	2166.58

Appendix II

Table 17. Estimates of Angler Use at Areas Not Counted During Ground Surveys, 1980.

Sample Period		n	Boat Anglers: Estimated hours	Boat Anglers: Bound on error of estimation	Shore Anglers: Estimated hours	Shore Anglers: Bound on error of estimation	Total Anglers: Estimated hours	Total Anglers: Bound on error of estimation
Weekdays	AM	6	964.00	1216.84	0.00	0.00	964.00	1216.84
	PM	9	1286.22	2226.64	643.11	848.11	1929.33	2844.63
	TOTAL		2250.22	2537.44	643.11	848.11	2893.33	3093.97
Weekends-Holidays	AM	12	5214.00	2960.73	842.67	760.17	6056.67	3248.84
	PM	9	4353.78	2188.16	1404.44	1122.04	5758.22	2388.88
	TOTAL		9567.78	3681.57	2247.11	1355.30	11814.89	4032.58
	Totals		11818.00	4471.31	2890.22	1598.79	14708.22	5082.75

Appendix II

Table 18. Estimates of Boat Use at Central Ferry - Port of Garfield, 1980.

Sample Period			n	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
May-June	Weekdays	AM	10	201.60	202.22	0.00	0.00
		PM	8	168.00	250.95	84.00	108.66
		TOTAL		369.60	322.29	84.00	108.66
	Weekends-Holidays	AM	6	329.33	321.04	126.67	142.19
		PM	12	519.33	255.10	354.67	165.87
		TOTAL		848.67	410.06	481.33	218.48
March-April & July-November	Weekdays	AM	35	317.14	246.45	253.71	201.98
		PM	36	339.47	210.07	524.64	448.16
		TOTAL		656.61	323.83	778.35	491.57
	Weekends-Holidays	AM	16	1320.00	664.63	570.00	396.90
		PM	14	582.86	422.77	1714.29	1655.40
		TOTAL		1902.86	787.69	2284.29	1702.31
1980 Totals		Weekdays		1026.21	456.88	862.35	503.44
		Weekends		2751.52	888.04	2765.62	1716.28
		Total		3777.74	998.67	3627.97	1788.59

Appendix II

Table 19. Estimates of Boat Use at Boyer Park - Illia Landing Zone - 1980.

Sample Period			n	Fishing Boats Estimated hours	Fishing Boats Bound on error of estimation	Pleasure Boats Estimated hours	Pleasure Boats Bound on error of estimation
May-June	Weekdays	AM	9	37.33	73.66	0.0	0.0
		PM	8	462.00	651.23	546.00	574.14
		TOTAL		499.33	655.39	546.00	574.14
	Weekends-Holidays	AM	6	152.00	188.43	202.67	183.12
		PM	11	165.82	121.39	1243.63	581.34
		TOTAL		317.82	224.15	1446.30	609.50
March-April & July-November	Weekdays	AM	24	370.00	389.11	601.25	457.47
		PM	24	277.75	238.50	1018.42	619.35
		TOTAL		647.75	456.39	1619.67	769.98
	Weekends-Holidays	AM	14	1268.57	557.46	1200.00	655.86
		PM	10	672.00	405.51	3792.00	2699.70
		TOTAL		1940.57	689.35	4992.00	2778.23
1980 Totals		Weekdays		1147.08	798.64	2165.67	1310.50
		Weekends		2258.39	724.88	6438.30	2844.30
		Total		3405.47	1078.55	8603.97	3131.68

Appendix II
Table 20. Estimates of Boat Use at Little Goose Landing Zone, 1980.

Sample Period			n	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
March-July & October-November	Weekends	AM	23	241.30	237.49	241.30	193.19
		PM	22	101.00	138.01	0.00	0.00
		TOTAL		342.30	274.67	241.30	193.19
	Weekends-Holidays	AM	19	151.58	125.70	353.68	267.67
		PM	18	533.33	262.54	346.67	338.86
		TOTAL		684.91	291.08	700.35	431.83
August-September	Weekdays	AM	16	63.00	66.09	21.00	40.99
		PM	15	134.40	86.00	44.80	59.67
		TOTAL		197.40	108.46	65.80	72.39
	Weekends-Holidays	AM	12	101.33	74.76	50.67	41.47
		PM	11	152.00	124.85	124.36	86.66
		TOTAL		253.33	145.52	175.03	96.07
1980 Totals		Weekdays		539.70	295.31	307.10	206.31
		Weekends		938.25	325.43	875.38	442.38
		Total		1477.95	439.45	1182.49	488.13

Appendix II
Table 21. Estimates of Boat Use at Willow Landing - Penawawa Zone, 1980.

Sample Period			n	Fishing Boats: Estimated hours	Fishing Boats: Bound on error of estimation	Pleasure Boats: Estimated hours	Pleasure Boats: Bound on error of estimation
May-June	Weekdays	AM	4	84.00	167.00	0.00	0.00
		PM	2	0.00	0.00	0.00	0.00
		TOTAL		84.00	167.00	0.00	0.00
	Weekends-Holidays	AM	5	60.80	119.58	0.00	0.00
		PM	11	55.27	59.52	69.09	82.47
		TOTAL		116.07	133.58	69.09	82.47
March-April & July-November	Weekdays	AM	22	50.45	99.90	100.91	137.88
		PM	20	0.00	0.00	166.65	240.94
		TOTAL		50.45	99.90	267.56	277.60
	Weekends-Holidays	AM	14	274.29	237.03	68.57	91.80
		PM	9	370.33	521.60	1111.00	1166.34
		TOTAL		644.62	572.94	1179.57	1169.95
1980 Totals		Weekdays		134.45	194.60	267.56	277.60
		Weekends		760.69	588.30	1248.66	1172.85
		Total		895.14	619.65	1516.22	1205.26

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Shoal station, Lower Granite Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets (lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 monofilament) and trap nets; and, the mean of three seine hauls.

	Electrofishing			Trap nets						Gill nets					Beach seine			
	1980			1979		1980				1979	1980				1980			
	Sum	Fall	X̄	Sum	Fall	Spr	Sum	Fall	X̄	Sum	Spr		Sum	X̄	Spr	Sum	Fall	X̄
Species										lmu	lmo	lmu	lmo					
rainbow trout						0.1			0.02									
chiselmouth	31.0	34.8	32.9			0.5			0.1	1.8	2.2	8.0	0.4	3.1	0.2		0.2	0.1
carp				6.8	0.1	0.1	0.1		1.4	0.6	1.8	0.7	5.2	2.1		0.2		0.07
peamouth										0.6				0.2				
northern squawfish	37.9	82.6	60.3	3.4	1.5	1.3	0.1	1.2	1.5	10.5	1.8	3.6	7.3	5.8				
redside shiner	100.0	69.6	84.8							1.2	1.8	3.6	0.3	1.7			0.2	0.07
bridgelip sucker	3.4	47.8	25.6	0.2	1.2	0.7	0.1	0.3	0.5	1.2	0.7	2.9		1.2				
largescale sucker	100.0	243.5	171.8	15.8	6.0	3.3	6.5	18.1	9.9	22.8	7.6	9.8	10.5	12.7	0.3		0.2	0.2
yellow bullhead													0.3	0.08				
brown bullhead				0.4		0.3	1.0	0.1	0.4				0.3	0.08				
channel catfish							0.1		0.02				0.3	0.08				
pumpkinseed							0.1	0.1	0.04	0.6				0.2		0.2		0.07
bluegill				0.2		0.1	0.1		0.08							0.3		0.1
smallmouth bass	41.4	113.0	77.2	0.4		0.9	0.1		0.3	2.3	0.4	0.7	0.1	0.9		0.5		0.2
white crappie				1.0	0.1	0.9	1.7		0.7	1.8		0.4	1.0	0.8				
black crappie				2.0	0.1	1.9	1.7	0.9	1.3		0.4	0.7		0.3				
yellow perch								0.4	0.08	11.1	1.1	0.4	1.3	3.5				

Appendix Table III. Seasonal (Spr = Spring; Sum = summer) catch per effort of age I and older fish from Deepwater and Central Ferry stations, Little Goose Reservoir, Washington. One unit of effort for electrofishing was 1 hour and 24 hours for vertical gill nets.

	Electrofishing						Vertical Gill Net								
	Deepwater										Central Ferry				
	1979		1980				1979		1980		1979		1980		
Species	Sum	Fall	Spr	Sum	Fall	$\bar{X}$	Sum	Fall	Spr	Sum	Sum	Fall	Spr	Sum	$\bar{X}$
white sturgeon											3.0	0.4	0.3	4.7	1.1
chinook salmon			3.8			0.8		2.1	0.1			0.4		0.5	0.4
rainbow trout		1.1	2.1	5.9	3.1	2.4									
chiselmouth	4.0	5.7	15.8	29.4	36.7	18.3	1.8	0.5		2.4	3.0	0.4		1.1	1.2
carp	2.0	1.1		1.0	2.0	1.2	1.8	0.5	0.4	1.6	5.2	1.9	0.5	3.7	2.0
peamouth										0.8		0.4	0.3		0.2
northern squawfish	4.0	6.8	29.1	51.0	33.7	24.9	2.1	2.4	0.3	8.8	5.2	7.4	0.6	5.3	4.0
redside shiner	4.0	12.5	73.1	99.0	57.1	49.1		0.8	0.8	2.4	3.0	3.3	0.6	5.3	2.0
bridgelip sucker	217.3	194.3	21.4	106.9	137.8	135.5		0.5		0.3	1.5				0.3
largescale sucker	106.6	51.1	32.5	75.5	12.2	55.6	0.3		0.3	1.1	14.8	0.4	0.2	5.8	2.9
yellow bullhead		1.1	0.4	7.8	12.2	4.3					1.5				0.2
brown bullhead				2.0		0.4									
channel catfish							1.2	1.1	0.2	0.3		0.4	0.2	0.5	0.5
pumpkinseed	14.0	3.4	3.0	4.9	3.1	5.7									
bluegill			1.3	1.0	3.1	1.1									
smallmouth bass	307.8	75.0	45.3	147.1	76.5	130.3					0.7				0.09
largemouth bass				1.0		0.2									
white crappie		1.1				0.2					1.5				0.2
black crappie					1.0	0.2									
yellow perch										0.8	0.7				0.2
sculpin			5.1	8.8	10.2	4.8									

Appendix II

Table 22. Estimates of Boat Use at Areas Not Counted During Ground Surveys, 1980.

Sample Period		n	Fishing Boats		Pleasure Boats	
			Estimated hours	Bound on error of estimation	Estimated hours	Bound on error of estimation
Weekdays	AM	6	482.00	608.42	241.00	481.00
	PM	9	482.33	680.00	643.11	506.84
	TOTAL		964.33	912.45	884.11	698.75
Weekends-Holidays	AM	12	2317.33	1292.39	2159.33	1976.24
	PM	9	1896.00	1045.81	2949.33	1579.13
	TOTAL		4213.33	1662.52	5108.67	2529.66
	Totals		5177.67	1896.46	5992.78	2624.39

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Gulch station, Lower Granite Reservoir, Washington. One unit of effort was: electrofishing 1 hour; trap and gill nets (lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament) 24 hours; and, the mean of three seine hauls.

Species	Electrofishing 1979 Sum	Electrofishing 1980 Spr	Electrofishing 1980 Sum	Electrofishing 1980 Fall	Electrofishing $\bar{X}$	Trap nets 1979 Fall	Trap nets 1980 Spr	Trap nets 1980 Sum	Trap nets 1980 Fall	Trap nets $\bar{X}$	Gill nets 1979 Sum lmo	Gill nets 1980 Spr lmo	Gill nets 1980 Spr lmu	Gill nets 1980 Sum lmu	Gill nets $\bar{X}$	Beach seine 1980 Spr	Beach seine 1980 Sum	Beach seine 1980 Fall	Beach seine $\bar{X}$
chinook salmon		7.7			1.9														
rainbow trout		2.6			0.7						0.5				0.1				
chiselmouth	100.0	107.7	46.3	143.8	99.5						2.6	6.2		6.0	3.7			0.3	0.1
carp	4.5			6.3	2.7			0.3		0.08	10.4	2.5		1.8	3.7				
peamouth											0.5				0.1				
northern squawfish	22.7	30.8	7.3	46.9	26.9	0.5		0.3	0.3	0.3	12.5	1.8	0.7	21.6	9.2	0.3			0.1
redside shiner	50.0	71.8	31.7	56.3	52.5						6.8	2.5	0.4	2.4	3.0				
bridgelip sucker	4.5	12.8	4.9	43.8	16.5	0.5			0.3	0.2		0.4	0.7	0.3	0.4				
largescale sucker	195.5	253.8	63.4	396.9	227.4	4.3	0.3	6.2	4.6	3.9	32.3	4.0	5.1	10.5	13.0	0.3		0.3	0.2
yellow bullhead				3.1	0.8			0.3		0.08									
brown bullhead							0.2	0.3	0.3	0.2			0.4	0.6	0.3			2.3	0.8
channel catfish		2.6			0.7									0.3	0.08				
pumpkinseed	4.5		4.9		2.4								0.4	0.3	0.2	0.3			0.1
bluegill		5.1		12.5	4.4													0.3	0.1
smallmouth bass	36.4	17.9	51.2	143.8	62.3				0.3	0.08	2.1	0.4		0.3	0.7		0.3		0.1
white crappie	13.6			6.3	5.0		0.5	0.9		0.4	1.0	0.7	2.5	1.8	1.5				
black crappie		7.7	7.3	334.4	87.4	1.0	0.7	0.9		0.7									
yellow perch						1.0				0.3	4.2	0.7	5.1	2.1	3.0				

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Shoal station, Little Goose Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets, (lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament) and trap nets; and, the mean of three seine hauls.

	Electrofishing				Trap nets				Gill nets					Beach seine			
	1980				1980				1980					1980			
									Spr		Sum						
	Spr	Sum	Fall	$\bar{X}$	Spr	Sum	Fall	$\bar{X}$	lmo	lmu	lmo	lmu	$\bar{X}$	Spr	Sum	Fall	$\bar{X}$
white sturgeon											0.2	0.2	0.1				
rainbow trout					0.3		0.7	0.3									
chiselmouth	7.1	11.4	1.19	10.1	0.1	0.1		0.07	0.6		2.1	1.9	1.2				
carp		2.9		1.0	0.1	0.3	0.1	0.2	2.7	0.9	4.0	2.5	2.5		0.2		0.07
peamouth			1.5	0.5					0.1		0.2		0.08				
northern squawfish	16.7	20.0	20.9	19.2	0.2	0.2	0.1	0.2	1.3	2.2	3.3	5.2	3.0				
redside shiner	109.5	13.3	34.3	52.4					1.8	4.6	0.8	1.4	2.2				
bridgelip sucker	57.1	57.1	170.1	94.8	0.8	1.0	1.6	1.1	2.1	3.1	0.2	0.8	1.6	0.08	0.06		0.05
largescale sucker	28.6	72.4	17.9	39.6	2.1	3.8	12.4	6.1	4.0	3.4	4.4	3.7	3.9	0.2	0.3	0.1	0.2
yellow bullhead						0.2		0.07			0.2		0.05				
brown bullhead					0.2	0.3	0.2	0.2			0.2	0.2	0.1				
channel catfish			1.5	0.5		0.2		0.07	0.6	1.0	0.4	1.2	0.8				
pumpkinseed		4.8	1.5	2.1		0.2		0.07				0.6	0.2				
bluegill					0.1			0.03									
smallmouth bass	21.4	47.6	11.9	27.0	0.1	0.1		0.07			0.2	0.6	0.2		0.06		0.02
white crappie		1.0		0.3	1.4	0.9		0.8	0.3	0.6	0.2	2.1	0.8				
black crappie		1.9		0.6	0.3			0.1	0.6	1.9			0.6				
yellow perch					0.1		0.1	0.07	3.1			2.7	1.5				
sculpin		1.9	4.5	2.1						0.1			0.03				

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Embayment station, Little Goose Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets (smo = 38 x 1.8 m monofilament; lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament) and trap nets (lg = 1.2 m mouth x 3.81 cm mesh, sm = 0.9 m mouth x 2.54 cm mesh); and, the mean of three seine hauls.

Species	Electrofishing 1979 Spr	1979 Sum	1979 Fall	1980 Spr	1980 Sum	1980 Fall	X̄
white sturgeon							
mountain whitefish					0.2		0.03
chinook salmon				0.4	0.5		0.2
rainbow trout					0.2	1.0	0.2
chiselmouth	2.5	3.3		0.4	6.9	4.8	3.0
carp			1.9	2.2	6.2	3.3	2.3
peamouth				0.4	0.2		0.1
northern squawfish	1.3	6.4	14.8	2.2	3.2	8.6	6.1
redside shiner	3.8	3.9	20.4	4.4	9.6	48.3	15.1
bridgelip sucker	26.3	14.4	37.0	38.5	7.7	10.5	22.4
largescale sucker	27.6	49.7	111.1	38.1	27.2	40.7	49.1
yellow bullhead				1.8	9.2	15.3	4.4
brown bullhead		2.7				1.0	0.6
channel catfish					8.6	2.9	1.9
tadpole madtom					2.9	14.8	3.0
pumpkinseed	18.8	56.3	14.8	18.1	104.4	100.0	52.1
warmouth					1.2	2.4	0.6
bluegill	21.3	19.3	85.2	27.0	64.0	93.3	51.7
smallmouth bass	8.8	65.9	42.6	93.4	80.2	164.6	75.9
largemouth bass	1.3	1.2	5.6	2.2	4.7	5.7	3.5
white crappie	16.3	34.7	135.2	44.7	92.8	109.1	72.1
black crappie	7.5	0.7	157.4	24.3	52.3	265.6	84.6
yellow perch	6.3	5.4	100.0	36.3	56.5	63.2	44.6
sculpin	2.5	0.6	31.5	15.5	4.0	11.5	10.9

Species	Trap nets 1979 Spr lg	1979 Sum lg	1979 Sum sm	1979 Fall lg	1979 Fall sm	1980 Spr lg	1980 Spr sm	1980 Sum lg	1980 Sum sm	1980 Fall lg	1980 Fall sm	X̄
white sturgeon												
mountain whitefish												
chinook salmon												
rainbow trout							0.1			0.1	0.3	0.05
chiselmouth							0.1					0.01
carp	0.3	0.5	0.3	0.1		0.2	0.1	0.2				0.2
peamouth												
northern squawfish		0.2	0.5	1.2		0.2	0.2	0.1	4.0	1.2	1.6	0.8
redside shiner			0.1				1.2		0.1			0.1
bridgelip sucker	0.1	0.1	0.4	1.1	2.2	1.7	2.3	0.2		1.4		0.9
largescale sucker	2.9	7.1	2.5	11.6		1.3	0.9	5.6	2.5	7.7	4.3	4.2
yellow bullhead		0.1	1.4			0.1	0.3	0.1	0.8			0.3
brown bullhead	0.2	1.1	1.8	1.5		0.4	0.1	0.4	0.8	0.4		0.6
channel catfish	0.1	0.5				0.1		0.3	0.8	0.3		0.2
tadpole madtom												
pumpkinseed		0.1	7.4	0.3	0.1	0.3	1.7	0.3	4.5	0.2	1.4	1.5
warmouth												
bluegill		0.3	0.3	0.1		0.3	0.3	0.1	0.8	0.1		0.2
smallmouth bass		0.1							0.1			0.02
largemouth bass												
white crappie	10.0	11.2	9.4	10.2	5.5	23.0	42.4	5.4	8.6	5.3	5.7	12.4
black crappie	1.7	1.2	0.3	1.6	0.6	3.5	2.2	1.2	2.8	0.9	0.5	1.5
yellow perch		0.1	13.8		5.0	1.0	27.0		3.3	0.1	8.1	5.3
sculpin												

Species	Gill nets 1979 Spr smo	1979 Sum smo	1979 Sum lmo	1979 Sum lmu	1979 Fall lmo	1980 Spr lmo	1980 Spr lmu	1980 Sum lmo	1980 Sum lmu	X̄	Beach seine 1980 Spr	1980 Sum	1980 Fall	X̄
white sturgeon		0.2		0.2		0.4				0.09				
mountain whitefish														
chinook salmon												0.1		0.03
rainbow trout						0.1	0.6			0.08				
chiselmouth		1.6	0.4	0.3		0.3	0.2	1.8		0.5	0.1	1.1		0.4
carp	0.5	0.6	2.8	1.3	8.8	3.8	0.5	5.0	3.6	3.0		0.3	0.3	0.2
peamouth			0.1		0.5	0.4		0.2		0.1				
northern squawfish	0.5	5.6	0.7	0.8	16.5	2.5	0.6	5.7	3.5	4.0	0.2	0.2	0.1	0.2
redside shiner	1.4	4.3	0.3	0.6	0.5	1.7	1.3	3.7	4.9	2.1	0.6	4.1	0.1	1.6
bridgelip sucker	3.5	0.7	0.4	0.4	3.8	4.6	0.3	0.2	0.2	1.6	7.1	29.7	0.8	12.5
largescale sucker	3.5	17.8	3.7	5.3	10.4	0.7	1.8	3.7	3.6	5.6	0.3	7.1	0.9	2.8
yellow bullhead		2.9		1.1					0.2	0.5		0.3		0.1
brown bullhead	0.2	1.3	0.2	0.3						0.2	0.7	4.5		1.7
channel catfish	2.4	3.3	1.9	11.0		1.3	0.6	2.0	7.4	3.3		3.1		1.0
tadpole madtom											0.1		0.4	0.2
pumpkinseed		1.9		0.1				0.2	0.3	0.3	0.6	9.7		3.4
warmouth														
bluegill											0.1	14.2	0.1	4.8
smallmouth bass											0.2	0.8	0.3	0.4
largemouth bass													0.2	0.1
white crappie	1.4	22.5	2.0	4.7	7.7		6.9	4.2	7.2	6.3	4.3	48.9	0.4	7.9
black crappie		1.7		0.1		0.3	0.5	0.2	0.2	0.3	0.9	14.9	0.2	5.3
yellow perch	9.2	22.5	26.6	6.9	15.4	0.8	0.3	2.8	5.6	10.0	2.3	7.2	0.1	3.2
sculpin		0.2								0.02				

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Upper Shoal station, Little Goose Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets (smo = 38 x 1.8 m; lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 monofilament) and trap nets; and, the mean of three seine hauls.

Species	Electrofishing 1979 Spr	Electrofishing 1979 Fall	Electrofishing 1980 Spr	Electrofishing 1980 Sum	Electrofishing 1980 Fall	Electrofishing $\bar{X}$	Trap nets 1979 Spr	Trap nets 1979 Sum	Trap nets 1979 Fall	Trap nets 1980 Spr	Trap nets 1980 Sum	Trap nets 1980 Fall	Trap nets $\bar{X}$
white sturgeon													
mountain whitefish			0.6	1.7		0.5							
chinook salmon			9.2	1.7		2.2							
rainbow trout		2.0	8.1	5.0	11.0	5.2			0.1			0.1	0.03
chiselmouth	29.4	2.0	21.4	29.4	8.3	18.1							
carp	2.7	5.9		2.5		2.2	1.6	0.3	0.1	0.2	0.5	0.1	0.5
peamouth				0.8	2.1	0.6							
northern squawfish	120.3	19.6	85.5	70.6	22.8	63.8		0.1		0.3	0.1	0.1	0.1
redside shiner	278.1	17.6	110.4	69.7	19.3	99.0							
bridgelip sucker	9.4	21.6	55.5	36.1	78.6	40.2	1.6	0.8	1.7	2.0	1.7	1.6	1.6
largescale sucker	121.7	41.2	50.3	68.9	8.3	58.1	16.8	7.4	7.4	5.4	9.8	3.7	8.4
yellow bullhead											0.1		0.02
brown bullhead							0.8	1.4	0.1	0.1	0.2	0.1	0.5
channel catfish		2.0			0.7	0.5		0.5	0.1		0.4	0.1	0.2
pumpkinseed			0.6	4.2	0.7	1.1		0.1			0.1		0.03
bluegill													
smallmouth bass	22.7	5.9	27.2	45.4	25.5	25.3				0.1	0.1		0.03
white crappie				0.8		0.2		0.5	0.1	0.1	0.2	0.2	0.2
black crappie	4.0		0.6	2.5		1.4	1.6	0.6	1.0	0.2	1.5	0.5	0.9
yellow perch	2.7			0.8		0.7		0.1			0.1		0.03
sculpin	1.3		3.5	1.7	2.1	1.7							

Species	Gill nets 1979 Spr smo	Gill nets 1979 Sum smo	Gill nets 1979 Sum lmu	Gill nets 1979 Fall lmo	Gill nets 1980 Spr lmo	Gill nets 1980 Spr lmu	Gill nets 1980 Sum lmo	Gill nets 1980 Sum lmu	Gill nets $\bar{X}$	Beach seine 1980 Spr	Beach seine 1980 Sum	Beach seine 1980 Fall	Beach seine $\bar{X}$
white sturgeon			1.0				0.5	0.3	0.2				
mountain whitefish		0.2	0.1						0.04			0.1	0.03
chinook salmon										0.08			0.03
rainbow trout				0.8	0.6	0.1			0.2		0.3		0.1
chiselmouth	4.6	2.1	1.2	0.3	1.8	0.7	4.6	3.2	2.3	0.2	0.6		0.3
carp	2.3	4.1	2.1	9.2	3.4	0.6	3.6	3.5	3.6		0.06		0.02
peamouth		0.8	0.1		0.2	0.7	0.7	0.3	0.4	0.08		0.06	0.05
northern squawfish	7.0	7.6	2.2	9.7	1.5	3.1	7.2	6.6	5.6	0.8	1.0		0.6
redside shiner	19.8	11.5	0.2	0.6	2.0	3.9	1.3	3.6	5.4	4.6	5.1	0.7	3.5
bridgelip sucker	9.3	3.5	0.9	3.3	2.9	3.1	1.1	2.6	3.3		0.1		0.03
largescale sucker	43.0	22.4	3.0	24.4	7.3	4.9	7.5	6.3	14.9	0.08	0.06	0.2	0.1
yellow bullhead							0.1	0.1	0.03				
brown bullhead		0.6			0.1		0.1	0.2	0.1				
channel catfish	1.2	3.8	3.2	0.6	0.8	2.0	0.7	2.3	1.8				
pumpkinseed								0.3	0.04		0.06		0.02
bluegill											0.2		0.07
smallmouth bass	1.2	1.2	0.1	1.1		0.3	0.1	0.4	0.6		0.06		0.02
white crappie		3.6	0.4	0.3	0.2	0.9	0.1	1.2	0.8				
black crappie					0.1				0.01		0.1		0.03
yellow perch	9.3	4.1		6.7	2.6	11.9	2.1	7.2	5.5				
sculpin													

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Gulch station, Little Goose Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets (smo = 38 x 1.8 m monofilament; lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament) and trap nets ; and, the mean of three seine hauls.

Species	Electrofishing						Trap nets							Gill nets									Beach seine			
	1979		1980				1979			1980				1979				1980					1980			
	Sum	Fall	Spr	Sum	Fall	$\bar{X}$	Spr	Sum	Fall	Spr	Sum	Fall	$\bar{X}$	Spr	Sum		Fall	Spr		Sum		$\bar{X}$	Spr	Sum	Fall	$\bar{X}$
														smo	lmu	lmo	lmo	lmo	lmu	lmo	lmu					
white sturgeon															0.6	0.3				0.6	0.4	0.2				
American shad																0.4					0.4	0.1				
mountain whitefish			2.9	1.4		0.9								0.4	0.1			0.1	0.1			0.09	0.08			0.03
sockeye salmon												0.1	0.02													
chinook salmon															0.1							0.01				
rainbow trout					1.3	0.3			0.8	0.5	0.1	0.6	0.3			0.1		0.3	0.1			0.06		0.06	0.06	0.04
chiselmouth	1.3	7.2	2.9	4.9	2.5	3.8	0.1	0.1		0.1	0.1	0.1	0.08	3.8	0.5	1.4	4.4	0.6	1.9	2.3	1.7	2.1	0.2			0.07
carp	5.1	2.9	7.1	5.6	6.3	5.4	0.2	0.2		0.2	0.2	0.1	0.2	2.5	1.6	2.1	7.7	2.6	1.0	5.6	5.3	3.6	0.6	0.1	0.06	0.3
peamouth														0.6		0.8	1.1	0.1		0.2	0.2	0.4		0.06	0.3	0.1
northern squawfish	3.8	17.4	2.9	35.2	24.1	16.7	0.1	0.2		0.2	0.3	0.1	0.2	3.6	0.8	9.8	16.6	2.6	2.0	5.4	5.3	5.8	0.6		0.3	0.3
redside shiner		42.0	107.9	16.9	7.6	34.9								6.6	0.1	1.5	2.2	0.9	4.8		0.2	2.0	2.0		0.9	1.0
bridgelip sucker	17.9	50.7	30.0	56.3	189.9	69.0	0.8	0.4	1.8	0.8	0.4	1.3	0.9	10.8	0.2	0.9	11.0	2.3	5.0	1.3	3.0	4.3			0.06	0.02
largescale sucker	66.4	69.6	99.3	112.0	40.5	77.6	2.3	10.2	15.3	2.0	9.8	9.5	8.2	20.9	3.7	13.9	18.2	2.8	2.6	7.7	3.8	9.2	0.8	0.5	0.4	0.6
yellow bullhead		1.4	0.7	1.4	2.5	1.2		0.2			0.1		0.05		0.1				0.1		0.2	0.05				
brown bullhead	1.3					0.3	1.7	1.5	0.5	0.2	0.5	0.2	0.8	1.3		0.1					0.2	0.2			0.06	0.02
channel catfish				0.7	12.7	2.7		0.4			0.3		0.1	0.8	3.7	2.3	0.6	0.3	0.4	4.8	1.9	1.9				
pumpkinseed	5.1			1.4		1.3		0.2			0.2		0.07										0.08			0.03
bluegill	1.3			2.1	1.3	0.9	0.1	0.1			0.1		0.05										0.08			0.03
smallmouth bass	38.3	13.0	20.7	61.3	96.2	45.9	0.1	0.1			0.2		0.07	0.6	0.1	1.3		0.3	0.1			0.3	0.2	0.7	0.2	0.4
white crappie		1.4	0.7		1.3	0.7	2.2	1.5		0.6	2.4		1.1	2.3	0.9	0.8		0.4	0.4	1.0	1.3	0.9	0.7	0.06		0.3
black crappie					2.5	0.5	0.2	0.6		0.4	0.8		0.3			0.3			0.1			0.05	0.08			0.03
yellow perch			1.4			0.3	0.2			0.2		0.1	0.08	9.2	0.4	6.1		1.5	7.3	2.1	4.2	3.9	0.08			0.03
sculpin			1.4	2.8	10.1	2.9																				

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Tallwater station, Little Goose Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for gill nets (smo = 38 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 monofilament) and trap nets; and, the mean of three seine hauls.

Species	Electrofishing						Trap nets				Gill nets								Beach seine			
	1979		1980				1979		1980		1979			1980					1980			
	Sum	Fall	Spr	Sum	Fall	$\bar{X}$	Sum	Fall	Spr	$\bar{X}$	Sum		Fall	Spr		Sum		$\bar{X}$	Spr	Sum	Fall	$\bar{X}$
											smo	lmu	lmo	lmo	lmu	lmo	lmu					
white sturgeon											1.3	2.8		2.3	2.2	9.4	8.8	3.8				
mountain whitefish		4.5	1.7	3.7	1.2	2.2					0.2							0.03	0.08		0.06	0.05
chinook salmon			15.4			3.1																
rainbow trout		6.1	11.4	1.2	4.7	4.7													0.08			0.03
chiselmouth	70.9	183.3	86.3	57.3	43.5	88.3					13.1	10.9	1.7		1.1	4.0	3.8	4.9	0.3	1.6		0.6
carp	1.2			2.4	1.2	1.0	0.4			0.1	1.4	1.6	7.7	1.7		5.4	2.5	2.9	0.2		0.06	0.09
peamouth	1.2		0.6			0.4					0.2				0.4			0.09	0.08			0.03
northern squawfish	60.1	34.8	113.1	120.7	56.5	77.0	0.2	0.6	1.5	0.8	5.6	1.3	4.5	2.6	10.8	4.7	4.8	4.9	2.1	0.7		0.9
redside shiner	245.2	140.9	424.6	570.7	324.7	341.2					2.2	1.7		1.0	7.5		2.3	2.1	10.6	8.0	1.1	6.6
bridgelip sucker	44.5	148.5	25.1	84.1	60.0	72.4	4.0	3.9	1.3	3.1	3.7	1.1	4.5	0.9	2.2	0.7	1.1	2.0		0.06	0.1	0.05
largescale sucker	101.0	39.4	43.4	111.0	27.1	64.4	9.1	8.7	5.2	7.7	10.6	1.5	2.3	1.7	3.7	1.6	1.1	3.2		0.3	0.7	0.3
yellow bullhead		1.5		1.2		0.5																
brown bullhead	2.4					0.5									1.1		0.7	0.3				
channel catfish							0.4			0.1	0.7	0.5	0.3	7.4	11.9	3.6	7.9	4.6				
pumpkinseed	1.2	1.5				0.5																
bluegill																					0.6	0.2
smallmouth bass	42.1	9.1	54.3	63.4	87.1	51.2	0.2	0.3		0.2	1.8	0.1			0.7			0.4		0.06	0.1	0.05
white crappie				1.2	4.7	1.2	0.2	0.3		0.2	10.3	2.8	1.4	0.3	0.4	0.2	0.7	2.3				
black crappie	4.8	1.5	1.2			1.5	0.6	1.1		0.6	0.2						0.2	0.06		0.06		0.02
yellow perch			3.4			0.7						0.7		0.6	3.0			0.6				
sculpin	1.2		5.7		3.5	2.1																

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Embayment station, Lower Monumental Reservoir, Washington. One unit of effort was: electrofishing 1 hour; trap nets (lg = 1.2 m mouth x 3.81 cm mesh; sm = 0.9 m mouth x 2.54 cm mesh) and gill nets (lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament) 24 hours; and, the mean of three seine hauls.

	Electrofishing						Trap nets											Gill nets						Beach seine		
	1979		1980				1979				1980							1979	1980					1980		
	Sum	Fall	Spr	Sum	Fall	X̄	Sum		Fall		Spr		Sum		Fall		X̄	Sum	Spr		Sum		X̄	Sum	Fall	X̄
Species							lg	sm	lg	sm	lg	sm	lg	sm	lg	sm		lmo	lmo	lmu	lmo	lmu				
chinook salmon					2.4	0.5																				
rainbow trout																				0.5			0.1			
chiselmouth	7.0	22.6	17.1	55.8	26.8	25.9				0.6		0.4				0.6	0.2	20.9	8.2	1.6		0.6	6.3	2.3		1.2
carp	3.5		11.4	11.6	12.2	7.7	0.2			1.3	0.2	0.4	0.5		0.6		0.3	7.6	7.1	4.4	4.5	6.3	6.0			
peamouth	1.8					0.4												0.6	5.5	1.6			1.5		0.3	0.2
northern squawfish	45.6	60.4	48.6	204.7	41.5	80.2	1.0		4.9	33.1	0.1	1.1	0.3		0.6	2.4	4.4	10.8	11.5	4.4	2.2	5.7	6.9	9.3		4.7
redside shiner		17.0	28.6	11.6	58.5	23.1													0.5	4.9		7.4	2.6			
bridgelip sucker			2.9	2.3	29.3	6.9	0.2	1.2	0.3		0.1						0.2			1.6	0.6	0.6	0.6			
largescale sucker	42.1	41.5	22.9	7.0	17.1	26.1	14.6	21.7	5.1	4.3	2.5			3.8	2.4	1.2	5.6	10.8	2.2	1.6	3.9	2.3	4.2	0.3		0.2
yellow bullhead	1.8		11.4	2.3	9.8	5.1		2.4				1.1					0.4					0.6	0.1			
brown bullhead		1.9		14.0		3.2	0.2	1.2	0.3	0.6	0.7	0.7				0.6	0.4	1.3			0.6	0.6	0.5			
channel catfish				2.3		0.5		1.2			1.8		0.5				0.4	3.8	2.2	2.2	1.7	5.7	3.1			
tadpole madtom					2.4	0.5																				
pumpkinseed		1.9	2.9	11.6	61.0	15.5		3.6		0.6	0.1	0.7	0.3	1.1		1.8	0.8							32.7		16.4
bluegill					56.1	11.2																		0.7		0.4
smallmouth bass	36.8	9.4	165.7	100.0	397.6	141.9		2.4			1.2	2.1					0.6	1.3	0.5				0.4	1.3	1.0	1.2
white crappie	1.8			4.7	4.9	2.3	8.4	13.3	10.5	5.0	15.3	8.1	3.8	29.2	10.3	19.4	12.3	1.9		3.8	8.4	5.1	3.8	1.3	1.3	1.3
black crappie			2.9	4.7	68.3	15.2		3.6	0.3		7.1	14.1	0.3	2.2	0.6		2.8			0.5			0.1	0.3		0.2
yellow perch	1.8	147.2	11.4	44.2	209.8	82.9		2.4		1.3		1.4		2.7		17.0	2.5	7.6	1.1	3.3	1.1	10.9	4.8	3.7	33.0	18.4
sculpin	1.8		17.1	23.3	56.1	19.7																				

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Shoal and Deepwater (in Forebay) stations, Lower Monumental Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for trap nets, vertical gill nets and horizontal gill nets (lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 m monofilament); and, the mean of three seine hauls.

	Lower Shoal																Deepwater			
	Electrofishing				Trap nets				Gill nets					Beach seine			Vertical gill nets			
	1980				1980				1980					1980			1979		1980	
	Spr	Sum	Fall	$\bar{X}$	Spr	Sum	Fall	$\bar{X}$	Spr		Sum		$\bar{X}$	Sum	Fall	$\bar{X}$	Sum	Fall	Sum	$\bar{X}$
Species									lmo	lmu	lmo	lmu								
white sturgeon												2.5	0.6							
American shad			3.2	1.1		0.2		0.07			1.2		0.3							
mountain whitefish					0.5			0.2												
rainbow trout			29.0	9.7		0.6		0.2			1.2	1.2	0.6							
chiselmouth	9.1	35.7	19.4	21.4	0.9	0.2		0.4	4.4	2.8	7.2	18.5	8.2				5.8	1.8	3.0	3.5
carp	20.5		3.2	7.9		0.6		0.2	1.8	1.8	8.4	6.2	4.6				9.1	0.6	1.2	3.6
peamouth	2.3			0.8													0.8		0.6	0.5
northern squawfish	25.0	35.7	41.9	34.2	0.5	0.6		0.4	1.8	1.8	16.8	9.8	7.6				43.9	7.7	7.7	19.8
redside shiner	2.3	9.5	12.9	8.2														0.6		0.2
bridgelip sucker	50.0	33.3	125.8	69.7	0.5	1.2	0.3	0.7	6.2	5.5	4.8	12.3	7.2							
largescale sucker	75.0	47.6	41.9	54.8	0.9	15.3	2.7	6.3	5.3	6.5	10.8	2.5	6.3		0.7	0.4			0.6	0.2
yellow bullhead	4.5			1.5			0.3	0.1												
brown bullhead							0.3	0.1		0.9			0.2							
channel catfish			3.2	1.1		1.6	0.9	0.8		4.6	9.6	4.9	4.8				0.8		0.6	0.5
pumpkinseed	2.3			0.8																
smallmouth bass	27.3	11.9	6.5	15.2		0.2	0.3	0.2	1.8			4.9	1.7							
white crappie	4.5			1.5	0.5	0.4	0.6	0.5	1.8				0.5							
black crappie					0.5			0.2												
yellow perch	2.3	2.4	6.5	3.7			0.3	0.1	5.3	1.8	1.2		2.1						0.3	0.1
sculpin	38.6	2.4	16.1	19.0																

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Upper Shoal and Tailwater stations, Lower Monumental Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for trap nets and gill nets (lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 m monofilament); and, the mean of three seine hauls.

	Upper Shoal																			Tailwater			
	Electrofishing					Trap nets					Gill nets						Beach seine			Electrofishing			
	1979	1980				1979	1980				1979	1980					1980			1980			
	Fall	Spr	Sum	Fall	X̄	Fall	Spr	Sum	Fall	X̄	Sum lmu	Spr lmo	Spr lmu	Sum lmo	Sum lmu	X̄	Sum	Fall	X̄	Spr	Sum	Fall	X̄
white sturgeon															1.5	0.3							
mountain whitefish							0.09			0.02													
rainbow trout			2.4		0.6			0.8	0.3	0.3				1.5		0.3							
chiselmouth	80.6	92.1	45.2	183.9	100.5		0.5		0.3	0.2	1.5	2.2	1.8	9.0	4.5	3.8				13.3	41.9	41.0	32.1
carp		2.6			0.7	0.2	0.4	1.5		0.5	8.3	4.8	2.2	18.0	12.0	9.1							
peamouth											0.8	1.1	0.4			0.5							
northern squawfish	55.6	57.9	35.7	38.7	47.0	0.7	0.5	1.0	0.3	0.6	10.5	5.5	4.8	19.5	7.5	9.6				130.0	83.7	112.8	108.8
redside shiner	2.8		7.1	6.5	4.1							0.4	0.7		1.5	0.5				151.7	88.4	2.6	80.9
bridgelip sucker	33.3	115.8	28.6	161.3	84.8	1.3	1.2	0.6	1.5	1.2	4.5	2.6	4.0	1.5	3.0	3.1				61.7	86.0	279.5	142.4
largescale sucker	58.3	44.7	97.6	35.5	59.0	6.9	4.7	24.0	4.6	10.1	2.3	5.1	6.2	13.5	6.0	6.6				11.7	83.7	17.9	37.8
yellow bullhead				3.2	0.8		0.09			0.02			0.4			0.08							
brown bullhead				3.2	0.8	0.2	0.3			0.1								0.3	0.2				
channel catfish						1.1	0.7	0.6		0.6	2.3	1.5	1.1	3.0	16.5	4.9							
pumpkinseed			2.4		0.6																		
smallmouth bass	11.1	86.8	45.2	80.6	55.9		0.09			0.02	3.0				3.0	1.2	1.3	0.3	0.8	23.3	25.6	30.8	26.6
white crappie	8.3		2.4		2.7	1.3	0.7	0.2		0.6	0.8	0.4				0.2							
black crappie	2.8	7.9	4.8	3.2	4.7	0.5	0.2			0.2										1.7			0.6
yellow perch		2.6	2.4	6.5	2.9				0.3	0.08	1.5	2.2	2.9		3.0	1.9						2.6	0.9
sculpin			7.1	9.7	4.2															6.7	11.6	7.7	8.7

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Lower Shoal and Deepwater stations, Ice Harbor Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for trap nets, vertical gill nets and horizontal gill nets (lmu = 61 x 1.8 m multifilament; lmo = 61 x 1.8 m monofilament); and, the mean of three seine hauls.

	Lower Shoal																		Deepwater		
	Electrofishing				Trap nets				Gill nets					Beach seine				Vertical gill nets		
	1980				1980				1980					1980				1979	1980	
									Spr		Sum									
Species	Spr	Sum	Fall	X̄	Spr	Sum	Fall	X̄	lmo	lmu	lmo	lmu	X̄	Spr	Sum	Fall	X̄	Fall	Sum	X̄
white sturgeon																				
chinook salmon																		1.0		0.5
mountain whitefish	2.9			1.0																
rainbow trout			2.9	1.0		0.1	0.2	0.1												
chiselmouth		5.3	26.5	10.6			0.2	0.07	1.6	3.0		2.2	1.7	0.2			0.07		0.6	0.3
carp			2.9	1.0	2.5	1.4	0.4	1.4	6.3	4.6	36.0	22.5	17.4	0.3			0.1		2.7	1.4
peamouth		2.6		0.9						0.8			0.2						1.5	0.8
northern squawfish	5.9	31.6	38.2	25.2		0.7	0.4	0.4		0.3	7.0	1.4	2.2	5.2			1.7	3.0	3.7	3.4
redside shiner	5.9	55.3	85.3	48.8					0.5	0.5	1.2	5.1	1.8	0.2			0.07		0.3	0.2
bridgelip sucker	94.1	31.6	144.1	89.9	0.7	0.3	0.2	0.4		1.6		1.4	0.8	3.8			1.3			
largescale sucker	150.0	68.4	94.1	104.2	16.9	4.7	15.0	12.2	11.5	10.8	12.8	4.3	9.9	2.5			0.8			
brown bullhead					0.2			0.07												
channel catfish		2.6	38.2	13.6	2.0	0.6	0.8	1.1	7.8	3.2	1.2	5.8	4.5						3.7	1.9
tadpole madtom			2.9	1.0																
pumpkinseed									0.5				0.1	0.7			0.2			
bluegill		2.6		0.9																
smallmouth bass	38.2	55.3	11.8	35.1	0.7			0.2		0.5			0.1	0.2	0.2		0.1			
largemouth bass						0.1		0.03												
white crappie		2.6		0.9	1.4	0.1	0.4	0.6	2.1	0.8			0.7	0.5			0.2			
black crappie		5.3	5.9	3.7	0.4	0.1		0.2	0.5	0.5		0.7	0.4	0.5			0.2			
yellow perch		18.4	2.9	7.1					3.6	4.9		0.7	2.3	1.3			0.4			
sculpin		2.6	38.2	13.6										0.2			0.07			

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Embayment station, Ice Harbor Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for trap nets (lg = 1.2 m mouth x 3.81 cm mesh; sm = 0.9 m mouth x 2.54 cm mesh) and gill nets (lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament); and, the mean of three seine hauls.

	Electrofishing				Trap nets							Gill nets			Beach seine			
	1980				1980							1980			1980			
	Spr	Sum	Fall	$\bar{X}$	Spr		Sum		Fall		$\bar{X}$	Spr		$\bar{X}$	Spr	Sum	Fall	$\bar{X}$
Species					lg	sm	lg	sm	lg	sm		lmo	lmu					
chiselmouth		8.1		2.7								1.1	3.2	2.2				
carp	35.7		15.0	16.9	6.8		1.1				1.3	4.8	5.3	5.1	1.0		0.3	0.4
peamouth			7.5	2.5											1.0			0.3
northern squawfish		51.4	5.0	18.8											0.3			0.1
redside shiner			2.5	0.8									0.5	0.3	0.3			0.1
bridgelip sucker		8.1	37.5	15.2		0.5			0.4		0.2		1.1	0.6	1.3			0.4
largescale sucker	42.9	10.8	37.5	30.4	6.3	4.7		1.7	4.3	19.9	6.2	2.7	6.4	4.6				
brown bullhead		5.4		1.8	2.1	1.0		0.6			0.6					3.0		1.0
channel catfish		94.6	12.5	35.7		0.5	1.1	0.6		2.8	0.8	5.9	4.3	5.1	1.0	0.7		0.6
pumpkinseed		32.4	15.0	15.8	2.1	10.4		4.5		0.6	2.9	0.5		0.3	2.3	3.0		1.8
bluegill		27.0	7.5	11.5	2.1						0.4				1.3			0.4
smallmouth bass	7.1	35.1	17.5	19.9	1.0	0.5					0.3		1.1	0.6	0.3	0.3		0.2
largemouth bass		54.1	20.0	24.7												1.3	1.0	0.8
white crappie		29.7	12.5	14.1	14.1	5.7		8.4	0.4	2.3	5.2	1.6		0.8	5.0	0.3		1.8
black crappie		16.2	52.5	22.9	17.7	8.9	1.1	1.7		0.6	5.0	0.5	0.5	0.5	4.3			1.4
yellow perch		175.7	37.5	71.1		5.2				1.1	1.1	2.7	3.7	3.2	0.7			0.2

Appendix Table III. Seasonal (Spr = spring; Sum = summer) catch per effort of age I and older fish from the Tailwater station, Ice Harbor Reservoir, Washington. One unit of effort was: electrofishing 1 hour; 24 hours for trap nets (lg = 1.2 m mouth x 3.81 cm mesh; Sm = 0.9 m mouth x 2.54 cm mesh) and gill nets (lmo = 61 x 1.8 m monofilament; lmu = 61 x 1.8 m multifilament); and, the mean of three seine hauls.

	Electrofishing					
	1979		1980			
Species	Sum	Fall	Spr	Sum	Fall	X̄
white sturgeon						
chinook salmon		1.2				0.2
mountain whitefish		2.4			6.7	1.8
rainbow trout		1.2	2.4			0.7
chiselmouth	5.1	15.5	28.6	19.0	86.7	31.0
carp	18.6	3.6	9.5			6.3
peamouth	1.7		11.9	4.8	6.7	5.0
northern squawfish	23.7	65.5	247.6	64.3	56.7	91.6
redside shiner	84.7	160.7	161.9	485.7	653.3	309.3
bridgelip sucker	49.2	47.6	161.9	54.8	173.3	97.4
largescale sucker	88.1	83.3	204.8	97.6	53.3	105.4
yellow bullhead						
brown bullhead						
channel catfish		3.6	2.4	2.4	6.7	3.0
flathead catfish						
pumpkinseed				2.4		0.5
smallmouth bass	6.8	10.7	50.0	9.5	13.3	18.1
white crappie		2.4	2.4			1.0
black crappie	5.1	7.1	2.4	2.4		3.4
yellow perch			11.9			2.4
sculpin			38.1	2.4	16.7	11.4

	Trap nets									
	1979				1980					
	Sum		Fall		Spr		Sum		Fall	X̄
Species	lg	sm	lg	sm	lg	sm	lg	sm	lg	
white sturgeon										
chinook salmon										
mountain whitefish			0.2							0.02
rainbow trout			0.1							0.01
chiselmouth						1.0				0.1
carp	2.8		0.5		5.8	1.0	0.9		0.5	1.3
peamouth										
northern squawfish			0.1			1.9				0.2
redside shiner						7.7				0.9
bridgelip sucker	1.1	1.7	0.4	5.6	1.4		0.3	0.7	1.0	1.5
largescale sucker	36.9	5.2	21.5	15.0	41.8	10.6	0.6	8.0	13.0	17.0
yellow bullhead										
brown bullhead		1.7				1.0				0.3
channel catfish	0.6		0.5	0.6	4.8	5.8		1.1		1.5
flathead catfish		1.7					0.3			0.2
pumpkinseed					0.5					0.06
smallmouth bass					1.4	1.0				0.3
white crappie			0.4				0.3		0.5	0.1
black crappie	4.5		2.2	0.6	1.4		1.8	0.4		1.2
yellow perch				1.1		1.9				0.3
sculpin										

	Gill nets						Beach seine			
	1979	1980					1980			
	Sum	Spr		Sum		X̄	Spr	Sum	Fall	X̄
Species	lmo	lmo	lmu	lmo	lmu					
white sturgeon			1.0			0.2				
chinook salmon										
mountain whitefish										
rainbow trout										
chiselmouth			1.0			0.2				
carp	9.8	7.7	1.0	6.0	7.5	6.4			0.3	0.1
peamouth	1.2					0.2				
northern squawfish	1.2	2.9	5.8	6.0	1.5	3.5				
redside shiner	1.2		1.9			0.6				
bridgelip sucker	3.1	1.0	1.9		4.5	2.1				
largescale sucker	8.0	10.6	8.7	1.5	7.5	7.3			0.7	0.2
yellow bullhead			1.0			0.2				
brown bullhead										
channel catfish	1.8	8.7	18.3	6.0	22.4	11.4			0.3	0.1
flathead catfish										
pumpkinseed										
smallmouth bass	0.6	1.9				0.5			2.3	0.8
white crappie				1.5		0.3				
black crappie										
yellow perch			9.6			1.9				
sculpin										