POPULATION DYNAMICS OF SMALLMOUTH BASS (*Micropterus dolomieui*) IN THE GALENA (FEVER) RIVER AND ONE OF ITS TRIBUTARIES

Technical Bulletin No. 165
Department of Natural Resources
Madison, Wisconsin 53707

1989

COVER: *Electroshocking in the Galena (Fever) River.*

ABSTRACT

The smallmouth bass fishery of the Galena (Fever) River in southwestern Wisconsin maintained a favorable reputation among anglers through the 1970s when dramatic population declines were suspected in other streams in the region. However, little was known about this smallmouth bass population, the associated sport fisheries, and the smallmouth bass populations in tributary streams of the Galena River. Consequently, I sampled populations in the Galena River and one of its tributaries, Pats Creek, from 1981-84. Population estimates by age group revealed interesting differences between the river and tributary populations. Although both populations were dominated by the exceptional 1980 year class in 1981 and 1982 samples, many fish from this cohort remained in the river throughout the study period, while the tributary supported few fish after 1982. This observation, coupled with data from other year classes and comparisons of habitat, temperature, and flow characteristics between the river and its tributary, suggested that Pats Creek serves as spawning and nursery habitat and that bass move to more suitable adult habitat after age 2 or 3. However, selective mortality of these older fish cannot be eliminated as a possible factor in determining the age structure of the Pats Creek population. Population density and biomass estimates for Galena River smallmouth bass equaled or exceeded those for other stream populations in Wisconsin and adjacent states. Other population and fishery parameters in the Galena River (growth, mortality, fishing pressure, harvest) were generally intermediate in value compared to data from other populations. Smallmouth bass growth was excellent in Pats Creek up to age 3, but was low for those few fish that remained as adults. Mortality estimates were more variable in the Pats Creek population, and fishing pressure was negligible or absent. Results of this study enabled managers to partially assess a fish kill that occurred in the Galena River after the study was completed. Population density, but not size structure, appeared to be suppressed one month after the kill. Management recommendations resulting from this study included the following: continued, regular population assessments by personnel of the DNR Bureau of Fisheries Management; continued support for fish managers to purchase streamside easements and to facilitate the improvement of bank condition and riparian-zone land management; and continued or increased support for programs to reduce nonpoint source impacts on stream water quality and habitat. The study results did not indicate that additional restrictive fishing regulations are needed to protect total population size.

KEY WORDS: Galena River watershed, population density and biomass, fishing pressure and harvest, habitat characteristics, year class variability, population age structure, fish kill, streams, smallmouth bass, *Micropterus dolomieui.*

Population Dynamics of Smallmouth Bass (*Micropterus dolomieui*) in the Galena (Fever) River and One of Its Tributaries

By Anne M. Forbes

Technical Bulletin No. 165
Department of Natural Resources
P.O. Box 7921
Madison, Wisconsin 53707

1989

CONTENTS

INTRODUCTION

Although smallmouth bass (*Micropterus dolomieui*) are distributed in warmwater lakes and streams throughout Wisconsin, stream habitat suitable for smallmouth bass is most abundant in southwestern Wisconsin including Grant, Lafayette, and Iowa counties (Fig. 1). Wisconsin has 3,514 miles of smallmouth bass stream habitat, of which 821 miles (23%) are located within this three-county area (Wis. Dep. Nat. Resour. 1978*a*). During the 1950s and 1960s, the smallmouth bass fisheries in these counties were highly regarded by anglers (Ellis 1968, Forbes 1985).

Concern arose in the late 1970s over the status of smallmouth bass in the unglaciated or driftless region of Wisconsin and adjacent states. The results of field surveys showed that the once productive smallmouth bass fishery in the Livingston Branch (Iowa County) had vanished (Forbes 1985) and that the once popular Apple River fishery (Jo Davies County, Illinois) had suffered a tremendous decline with no evidence of smallmouth bass reproduction (A. Pulley, Ill. Dep. Conserv., unpubl. data). Anglers reported that streams once known for their smallmouth bass fisheries were no longer worth fishing (R. Kerr, G. Van Dyck, Wis. Dep. Nat. Resour., and A. Pulley, pers. comm., 1982). The results of surveys in 1984-85 confirmed that some streams in the region no longer supported fishable smallmouth bass populations (R. Kerr, Wis. Dep. Nat. Resour., unpubl. data). Similar information came from Michigan, where Dewberry (1978) claimed that the Grand, Kalamazoo, and St. Joseph rivers, known nationally for smallmouth bass fifty years ago, had experienced population declines.

Smallmouth bass reproductive success varies highly from year to year. Strong fingerling cohorts are often produced 2, 3, or 4 years apart. In the absence of human-induced disturbances, fingerling production and first year survival are maximized under certain climatic conditions. Both a long, warm growing season (Shuter et al. 1980, Forbes 1981, Serns 1982) and moderate but relatively stable stream flows (Cleary 1956, Montgomery et al. 1980, Swenson et al. 1981, 1982) are essential to the establishment of strong smallmouth bass year classes in streams. Given this relationship between climatic factors and year class strength, smallmouth bass populations should be observed for several years to accurately assess population status and fishery potential. However, smallmouth bass populations in Wisconsin streams have rarely been studied this way. In southwestern Wisconsin, long-term population data for smallmouth bass have been collected only in the Livingston Branch (J. Truog and C. Brynildson, Wis. Dep. Nat. Resour., unpubl. data.), which no longer supports a smallmouth bass fishery (Forbes 1985). Quantitative records of population size, usually from a single year, exist in the survey records for six other southwestern Wisconsin streams, although size or age structure and catch per stream mile were reported for many others (Forbes 1985). There are no past records of fishing pressure or harvest in southwestern Wisconsin.

Despite declines in smallmouth bass populations in many southwestern Wisconsin streams, the smallmouth bass fishery in the Galena River (known historically and locally as the Fever River) in Lafayette County has remained productive (R. Kerr, unpubl. data and pers. comm., 1982). However, knowledge of this fishery has been limited. Researchers have not had baseline data that could be used to protect or enhance driftless area streams where smallmouth bass populations have thrived or to restore populations in streams where fisheries have been lost. A three to four-year study of the population dynamics of smallmouth bass following several year classes of bass was needed. Consequently, in 1981 staff from the DNR Bureau of Research and Southern District began a study of the smallmouth bass populations and fisheries of the Galena River and one of its tributaries, Pats Creek. The objectives of this study were to quantify the density, biomass, size structure, and growth of the smallmouth bass populations in both the river and the stream and to document fishing pressure and harvest in the Galena River. Simultaneously, DNR staff began three other efforts: (1) management surveys of smallmouth bass populations in a number of other southwestern Wisconsin streams (R. Kerr, unpubl. data); (2) an assessment of potential research approaches to water quality and habitat problems in streams harboring smallmouth bass (J. Mason, pers. comm.); and (3) an examination of fish species assemblages compared to smallmouth bass distribution and environmental characteristics (Lyons et al. 1987).

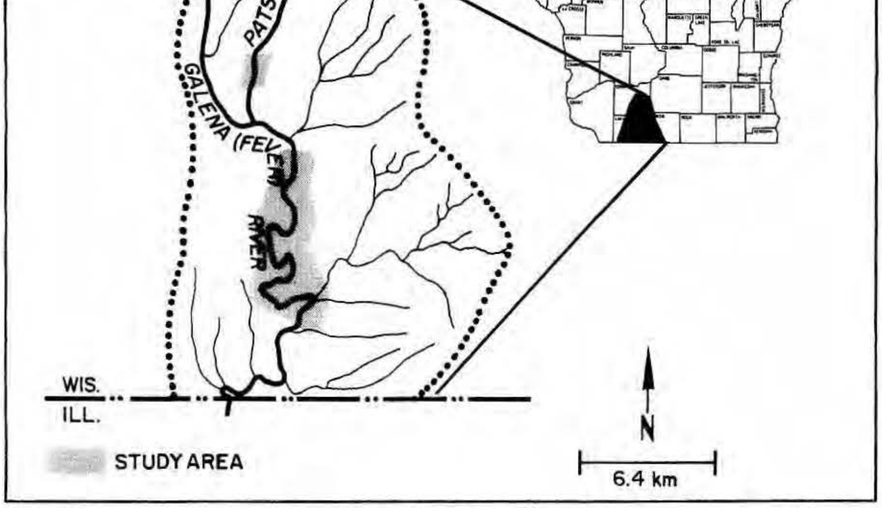

FIGURE 1. *Location of study areas in the Galena River watershed, LaFayette County, Wisconsin.*

STUDY AREA

THE GALENA RIVER WATERSHED

The Galena River drains a 324-km^2 area (Holmstrom et al. 1983) within the driftless region of southwestern Wisconsin (Fig. 1). The driftless area remained ice-free during the most recent glacial period and is characterized by rolling topography (Wis. Dep. Nat. Resour. 1978*b*). The pre-settlement vegetation of the Galena River watershed was a mixture of prairie, dense stands of oak forest, and mixed stands of oak, aspen, linden, and elm (Trewartha 1940). The conversion of native land cover to continuously cultivated fields resulted in increased flooding, erosion, and sedimentation in the Platte River watershed, located just west and north of the Galena River watershed (Knox 1977). Stream channels were extensively altered with headwater and tributary channels becoming wider and shallower and downstream main channels becoming narrower and deeper.

About 85% of the Galena River watershed is now used for agriculture (Wis. Dep. Nat. Resour. 1979). The combination of rolling topography and intense agricultural use creates a scenario in which runoff from fields, pastures, and barnyards is common, and nonpoint sources of agricultural runoff present the primary regional water quality problem (Wis. Dep. Nat. Resour. 1978*b*, Field 1986).

The two study areas within the Galena River watershed are described below. The techniques used to describe habitat characteristics and other physical parameters (Tables 1, 2, 3) are explained in the Methods section.

GALENA RIVER STUDY AREA

I sampled smallmouth bass populations in a 4.8-km stretch of the Galena River near Benton, Wisconsin (Fig. 2). The sampling area began at an old mill site south of Hwy 11 and ended at the bridge at Bean Street, just outside of Benton. This stretch included a surface area of 7.9 ha in which stream width averaged 14 m and ranged from 9-23 m. The substrate consisted primarily of coarse and cobble gravel and boulders. Silt deposits, often very thick, covered the rocky bottom in some pools, channel edges, and backwaters.

Riffles made up about 24% of the stream by length; the remaining habitat consisted of pools and runs. Maximum depth of pools along selected transects in midsummer 1981 ranged from 0.5-1.7 m and averaged 0.9 m. Outside of the transects, maximum depths were at least 2 m at low flow.

Stream gradients calculated from USGS topographic maps ranged from 1.4-3.0 m/km, and the average discharge over 45 years was 77.8 cfs at Highway 11 (J. Mason, Wis. Dep. Nat. Resour., unpubl. data; Holmstrom et al. 1984).

Habitat quality for smallmouth bass was high in the main stem of the Galena River (Table 1; Lyons et al. 1987), with gravel and boulder substrates predominating. Bank cover and deeper pools were located where the stream cut beside steep limestone bluffs.

The area covered by the creel census was 21 km long and 30 ha in surface area and included areas both upstream and downstream of the smallmouth bass sampling sites (Fig. 2).

TABLE 1. *Comparison of physical and biological characteristics of the study areas on the Galena River and Pats Creek.*

	Galena River	Pats Creek
Length of study area (km)	4.8*	2.8
Size of study area (ha)	7.9*	1.1
Subwatershed size (km^2)	210	26
Stream gradient (m/km)	1.4-3.0	2.6
Average (range) stream width (m)**	14(9-23)	4(2-8)
Average (range) maximum depth (m) of pools/runs**	0.9(0.5-1.7)	0.6(0.2-1.2)
Substrate		
% samples with coarse or larger gravel in pools/runs**	89	50
% samples with some boulders in pools/runs**	49	4
% samples with surface silt in pools/runs**	25	61
Percent pools/runs (by length)	76	63
Habitat suitability index (HSI)[a]	0.96	0.63-0.78

*Creel census area was 20.7 km and 30.0 ha.
**Determined from transects; see Methods section.
[a]Lyons et al. (1987), using HSI of Edwards et al. (1982). Maximum value possible is 1.0.

TABLE 2. *Comparison of annual mean, maximum, minimum, and total flow in the Galena River and Pats Creek.*

Water Year*	Stream Flow (cfs) Galena River**	Stream Flow (cfs) Pats Creek[a]
Oct 1980-Sep 1981		
Mean	37.5	2.6
Maximum	650 (22 Feb)	101 (22 Feb)
Minimum	20 (3 days, Feb)	1.3 (9 days, Feb)
Total	13,690	934
Oct 1981-Sep 1982		
Mean	68.9	4.9
Maximum	667 (13 Mar)	116 (16 Mar)
Minimum	28 (13 days, Feb)	1.7 (10 days, Feb)
Total	25,241	1,805

*As defined by USGS for summary purposes.
**Galena River flow at Highway 11 (see Fig. 2) based on 65% of flows (Mason, unpubl. data) reported for the Galena River at Buncombe (USGS 1982, Holmstrom et al. 1983).
[a](USGS 1982, Holmstrom et al. 1983).

TABLE 3. *Comparison of average maximum and minimum water temperatures in the Galena River and Pats Creek, 1982.*

	Average Water Temperature (C)					
	Galena River			Pats Creek		
Month	Max.	Min.	Difference	Max.	Min.	Difference
April*	17.2	6.7	10.5	18.0	2.0	16.0
May*	24.4	12.2	12.2	25.0	11.0	34.0
June	26.1	13.9	12.2	28.5	10.5	18.0
July	30.0	17.8	12.2	32.5	15.5	17.0
August	28.9	14.4	14.5	31.5	12.5	19.0

*13-30 April and 11-31 May; values for June, July, and August represent the entire month.

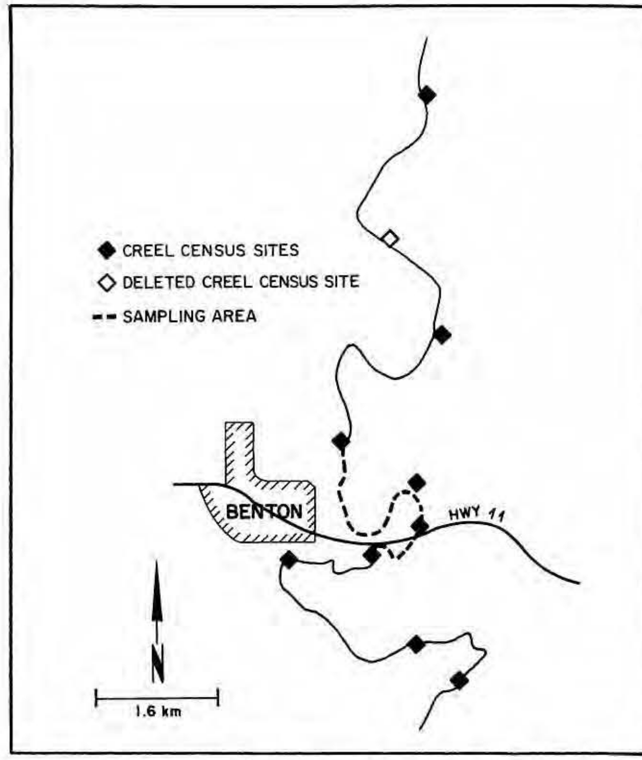

FIGURE 2. *Location of creel census and sampling sites on the Galena River.*

PATS CREEK STUDY AREA

I sampled smallmouth bass populations in a 2.8-km stretch or 1.1-ha area of Pats Creek, a tributary to the Galena River, Lafayette County (Fig. 1). This stretch was located between the bridges on Back Road and Highway 81. The stream averaged 4 m in width and ranged from 5-8.0 m. The substrate consisted of fine, coarse, and cobble gravels, but this substrate was often covered by a layer of silt up to 15 cm deep. Seemingly bottomless deposits of silt or silt and sand were common.

Riffles made up about 37% of the stream by length; the remaining habitat consisted of pools and runs. Maximum depth of pools along selected transects in midsummer 1981 ranged from 0.2-1.2 m and averaged 0.6 m. Banks in the upper reaches of the study zone were heavily grazed and damaged by cattle entering the stream; downstream reaches were less impacted and contained deeper pools and more suitable bank cover.

The stream gradient calculated from USGS topographic maps was 2.6 m/km. Flows were typically about 7% of those at the Galena River study site. Mean annual discharge during the study period was 3.8 cfs.

The Pats Creek study area provided good habitat for smallmouth bass (Table 1; Lyons et al. 1987). Compared to the Galena River study area, the Pats Creek area had less exposed gravel and boulder substrate, more bottom areas covered by silt, and more bank damage from cattle.

METHODS

ESTIMATION OF FISHERY CHARACTERISTICS

I sampled smallmouth bass populations with a 220v DC stream shocker at the Galena River study site in July 1981-83 and April 1982-84 and at the Pats Creek study site in July 1981, September 1982-83, and August 1984. Exact dates of each sampling period are shown in Tables 4, 5, and 7. All smallmouth bass captured were measured to the nearest millimeter (mm) for total length and were fin clipped (partial). Weights in grams (for biomass calculations) and scale samples (for age determinations) were taken from at least 5 fish in each 10-mm length group.

Chapman's modification of the Petersen estimate was used to estimate population size and density by age group (Ricker 1975). Because ages were determined for a subsample of fish in each 10-mm length group, I used proportions to estimate the number of marked (fin clipped) and unmarked fish of each age in each electrofishing run. The counts of marked and unmarked fish per 10-mm interval were allocated among the age groups according to the subsample proportions and were then summed over all size intervals for each age group. The variance associated with these estimates is probably underestimated due to the presence of only 5 fish in some of the 10-mm length groups.

Due to small sample sizes, data for fish ages 5 and older were combined into one cohort for population size and density calculations. Recaptures of age 1 smallmouth bass were usually too few to provide reliable estimates for the Galena River population.

Biomass estimates were calculated by multiplying the above population estimates by the average weight for fish in each age group for each sampling period. Growth increments were determined using actual lengths taken at the beginning or end of a growing season.

Total annual survival and mortality were estimated from the ratios of the population estimates of a single cohort at two time intervals (Everhart et al. 1975:113). Pats Creek estimates were calculated from late summer samples in 1982-84. July rather than April population estimates were used for the Galena River to minimize the effects of fish movement on the ratio of the estimates. Smallmouth bass appear to move little during the summer months (Larimore 1952) or within a single season (Munther 1970), but considerable movement of adults has been associated with spring spawning (Munther 1970, Montgomery et al. 1980) and perhaps with fall aggregation (Munther 1970, Coble 1975, Paragamian 1981).

ESTIMATION OF FISHING PRESSURE AND HARVEST

I conducted a sport fishery creel census for 40 hours per week from May through October 1982 and 1983. A monthly average of about 45% of the sampling effort occurred on weekends and 55% occurred during the 5-day week. Nine creel census sites covered all main fishing access points along the 21 km stream length (Fig. 2). A tenth site was eliminated early in the 1982 census because a landowner would not allow access to the stream; therefore, I assumed that fishing pressure was negligible at this location. Sampling hours and days were selected randomly in half and whole-day units, a day being defined as dawn to dusk.

The creel clerks made instantaneous vehicle counts at 3-hour intervals from dawn to dusk. One instantaneous count covering all 9 sites took less than 1/2 hour. Instantaneous counts began alternately at the upstream and downstream ends of the study area on each day. Time between instantaneous vehicle counts was used for angler interviews. I used standard DNR instantaneous count and angler interview forms (3600-106 and 3600-114).

Both monthly and yearly estimates of projected fishing pressure (total hours), catch rates (numbers of fish/hour), harvest rates (subset of catch not released), and projected harvest (total number and biomass of fish harvested) were calculated. Data were analyzed in part using DNR Bureau of Fisheries Management computer programs. However, I modified calculations of projected pressure and total harvest to correct for inaccuracies in the length (hours) of sampling days used by the Fisheries Management program. I also modified total harvest estimates to include separate catch rates for weekends and weekdays (M. Staggs, Wis. Dep. Nat. Resour., pers. comm., 1985).

The exploitation rate for Galena River smallmouth bass was calculated by dividing the projected annual harvest for the creel census study area by the April population estimate for the same area. The latter was determined by expanding the population estimate for the 7.9-ha population study area to the entire 30-ha creel census study area.

No anglers were seen on Pats Creek during a preliminary creel census conducted on four southwestern Wisconsin streams in 1981 (R. Kerr, unpubl. data). Thus I assumed that fishing pressure, catch, and harvest were nonexistent or negligible on this stream.

DETERMINATION OF HABITAT CHARACTERISTICS

Habitat characteristics were measured along the Galena River study area on 19 August 1981 and 13-14 May 1982 and on the upper 1.5 km of the Pats Creek area on 18 August 1981.

Using a 30-m fiberglass measuring tape, I measured the length of each pool, run, and riffle. Then 2-3 transects across each pool, run, and riffle were used to estimate stream width and maximum depth. Transects were located within the first quarter of the segment being measured, at the midsection, and within the last quarter. I determined substrate characteristics and depths at 1-m intervals across one of the transects in each pool, run, and riffle in the lower 2.1 km of the Galena River study area and the upper 1.5 km of the Pats Creek study area. Substrates were described as silt (< 0.2 mm), sand (0.2-1.9 mm), fine gravel (2.0-15.9 mm), coarse gravel (16.0-63.9 mm), cobble gravel (64-255.9 mm), boulder (256 mm-0.6 m), and bedrock (> 0.6 m) as defined by Paragamian (1981). I used these data to calculate total surface area by habitat type and to compare width, depth, and substrate characteristics between the two study areas.

MEASUREMENT OF TEMPERATURE AND FLOW

Average maximum and minimum monthly temperatures were calculated from April through August 1982. Temperatures were recorded by the creel clerk on the Galena River with a Taylor maximum-minimum thermometer mounted on a steel fence post and protected by a wire cage. Continuous temperature data were collected at a USGS monitoring station (15-minute increment temperature recorder) on Pats Creek about 2 km above the study area (Holmstrom et al. 1982, 1983).

Annual mean, maximum, minimum, and total discharge data were compiled for two years when data were available for both the Galena River and Pats Creek study areas. Daily flows for the Wisconsin portion of the Galena River watershed were measured at a permanent USGS monitoring station at the Galena River at Buncombe, Wisconsin, and were summarized annually (e.g., Holmstrom et al. 1983, 1984). Estimates of the corresponding flow at Highway 11 in the middle of the Galena River study area (Fig. 2) were based on 65% of the flows reported at Buncombe (J. Mason, unpubl. data). Data for Pats Creek came from the USGS station located about 2 km above the study area (Holmstrom et al. 1983, 1984).

RESULTS AND DISCUSSION

POPULATION DENSITY AND BIOMASS

Galena River

Considering spring and summer samples together, the density of smallmouth bass $\geq$2 years of age in the Galena River ranged from a low of 58 bass/ha in July 1981 to a high of 211 bass/ha in July 1982 and averaged 136 bass/ha. The corresponding biomass ranged from 23.6 kg/ha in July 1983 to 38.4 kg/ha in July 1982 and averaged 32.7 kg/ha (Tables 4, 5).

Biomass estimates for smallmouth bass (all ages combined) in the Galena River tended to be greater in spring samples, which preceded spawning, than in summer samples, which followed spawning (Tables 4, 5). This difference was probably due to the presence of many gravid females in spring. Females matured by the end of the third year in Iowa streams (Tate 1949, Cleary 1956) and were almost always mature between ages 3 and 5 (Coble 1975). Fish in the 3-5 year range were well represented in the spring samples in the Galena River (Table 5) and I observed many in spawning condition. However, the pattern of lower total biomass estimates did not hold for summer 1982 when large numbers of age 2 bass (1980 year class) contributed 21.8 kg/ha to the total 38.4 kg/ha.

The estimates of density and biomass for smallmouth bass in the Galena River compared favorably to similar estimates reported for other streams in Wisconsin and adjacent states (Table 6). Considering that the Galena River estimates would have been larger in 1982-84 if they had included age 1 fish, the Galena smallmouth bass population was clearly one of the largest in the region. This favorable comparison also holds when Galena River estimates are compared to other stream populations in North America (Paragamian and Coble 1975).

Comparisons of population size among smallmouth bass streams would be more meaningful if information on the substrate types of study areas were included in the literature (Paragamian and Coble 1975). Paragamian (1981) concluded that the percentage of substrate in coarse and cobble gravel would be an appropriate measure to use in comparing study sites. He reported that a segment of the Maquoketa River

TABLE 4. *Population, density, and biomass estimates by age group for smallmouth bass in the Galena (Fever) River in July 1981-83.*

Date and Age	Year Class	Popul. Est.	95% CI	Density No./km	Density No./ha	Biomass (kg/ha)
19-21 Jul 1981*						
1	80	940	(643-1,456)	448	303	16.5
2	79	87	(40-215)	41	28	6.2
3	78	4	(4-6)	2	1	0.7
4	77	62	(23-135)	30	20	12.0
≥5[a]		29	(11-38)	14	9	7.2
Total ≥1		1,122		535	361	42.6
Total ≥2		182		87	58	26.1
12-27 Jul 1982**						
2	80	1,443	(853-2,605)	301	183	21.8
3	79	82	(28-223)	17	10	3.0
4	78	24	(12-54)	5	3	2.4
≥5[b]		117	(49-300)	24	15	11.2
Total ≥2		1,666		347	211	38.4
18-20 Jul 1983**						
2	81	202	(119-364)	42	26	2.1
3	80	524	(378-749)	109	66	14.3
4	79	15	(11-40)	3	2	3.0
≥5[c]		42	(29-83)	9	5	4.2
Total ≥2		783		163	99	23.6

*In July 1981 only the downstream 2.1-km portion of the 4.8-km study area was sampled. The entire 4.8-km stretch was sampled on all other dates.
**There were few recaptures of age 1 fish in 1982-83; therefore no estimates were possible.
[a]Ages 5-6.
[b]Ages 5-7.
[c]Ages 5-8.

TABLE 5. *Population, density, and biomass estimates by age group for smallmouth bass in the Galena (Fever) River in April-May 1982-84.*

Date and Age*	Year Class	Popul. Est.	95% CI	Density No./km	Density No./ha	Biomass (kg/ha)
19-21 Apr 1982						
2	80	867	(623-1,244)	181	110	8.4
3	79	179	(130-254)	37	23	6.4
4	78	14	(9-31)	3	2	0.9
≥5**		188	(150-244)	39	24	17.5
Total ≥2		1,248		260	159	33.2
25-27 Apr 1983						
2	81	337	(92-433)	70	43	1.7
3	80	987	(697-1,490)	206	125	21.3
4	79	60	(23-126)	12	8	4.7
≥5**		89	(54-160)	18	11	10.4
Total ≥2		1,473		306	187	38.1
7-8 May 1984						
2	82	74	(33-167)	15	9	0.7
3	81	153	(87-296)	32	19	2.9
4	80	474	(331-708)	99	60	23.4
≥5**		86	(42-171)	18	11	9.7
Total ≥2		787		164	99	36.7

*There were few recaptures of age 1 fish, therefore no estimates were possible.
**Ages 5-8.

TABLE 6. *Smallmouth bass population and fishery parameters for the Galena River and Pats Creek compared to values reported for smallmouth bass streams in Wisconsin and states adjacent to southwest Wisconsin.**

Location	Population: Years of Study	Population: Density (No/ha)	Biomass (kg/ha)	Ages or Sizes	Fishing Pressure (hours/ha) and Months of Census	Total Harvest: Rate (No./100 hours)	Total Harvest: (No./ha)	Total Harvest: (kg/ha)	Reference
Galena River	1981-84**	361	29.2	1-8 (1981)	185-257	13-15	24-38	8.2	This study
		58-211	23.6-38.4	2-8 (1982-84)	(May-Oct)				
Pats Creek	1981-84	54-373	12.2-31.6	1-6	—	—	—	—	This study
		34-86	10.8-18.5	2-6					
Madden Branch (Lafayette Co., WI)	1979	217	—	150 mm	—	—	—	—	R. Kerr (unpubl. data)
Menominee River (Grant Co., WI)	1979	114	—	130 mm	—	—	—	—	R. Kerr (unpubl. data)
Livingston Branch (Iowa Co., WI)	1964-66	212-395	—	1-4	—	—	—	—	Forbes (1985)
Red Cedar River (Dunn Co., WI)	1973	132	15.1	1-8	318 (May-Sep)	—	21	5.1	Paragamian (1973) Paragamian and Coble (1975)
Plover River (Portage Co., WI)	1972	40-217[a]	3.7-29.2	1-9	—	—	—	—	Paragamian (1973) Paragamian and Coble (1975)
Little Wolf River	1981	68	12.9	1-8	—	—	—	—	
(Waupaca Co., WI)	1982	173	12.7	1-8	186 (May-Sep)	14	25	8.0	L. Meyers (unpubl. data)
Maquoketa River	1977-79[b]	2-28	0.1-3.0	< 200 mm					
(IA)		1-13	0.3-6.0	⩾ 200 mm	820-1,082[d] (Apr-Oct/Nov)	2-5	20-46	1.7-6.3	Paragamian (1984*a*)
	1977-79[c]	59-281	8.6-30.2	< 200 mm					
		13-25	7.0-19.5	⩾ 200 mm	628-1,047[d] (Apr-Oct/Nov)	4-8	24-72	6.3-20.0	Paragamian (1984*a*)
	1980-82[c]	62-94	2.8-3.4	< 200 mm					
		20-52	6.4-10.9	⩾ 200 mm	636-936[d] (Apr-Oct/Nov)	3-5	8-17	4.5-12.1	Paragamian (1984*b*)
Kankakee River (IL)	1978-79	—	—		143-228[e] (Mar-Dec)	13-14	19-33	5.5-7.8	Graham et al. (1984)

*Values given are ranges where the study covered more than one year. English units were converted to metric and other calculations were made by the author as necessary.
**Creel census in 1982-83.
[a]Range for 3 sites.
[b]Data for Area I only.
[c]Data for Area II only; 12-inch (305 mm) size limit imposed in 1980.
[d]Fishing and harvest data apply to both size groups in 1977-79 and only to fish greater than 12 inches (305 mm) in 1980-82.
[e]Smallmouth bass effort only; total effort was 1,471-2,399 hours/ha.

in Iowa with 22-25% coarse and cobble gravel substrate (Area I, Maquoketa River, Table 6) supported a lower density and standing stock of smallmouth bass than a reach of the same river with 65-95% coarse and cobble gravel (Area II, Maquoketa River, Table 6). In the Galena River study area, 89% of the substrate samples contained coarse or cobble gravel (Table 1), indicating that the river compared favorably to the Maquoketa River Area II in substrate composition, as well as in population density.

Pats Creek

The density and biomass of smallmouth bass ≥1 year old in Pats Creek ranged from a low of 54 bass/ha and 12.2 kg/ha in September 1983 to a high of 373 bass/ha and 31.6 kg/ha in July 1981 (Table 7). A young-of-the-year population estimate was possible only in the September 1983 sample when a population of 132 fingerlings, or 117/ha, was observed.

Density and biomass estimates for age 1 and older fish in Pats Creek compared favorably to estimates from other regional streams (Table 6). This comparison included the Galena River in July 1981 (the only Galena River sampling date to include age 1 fish in the estimate) when a density estimate of 361 bass/ha was matched by an estimate of 373 bass/ha in Pats Creek (Tables 4, 7). Corresponding biomass estimates were somewhat higher for the Galena River population (42.6 kg/ha) as compared to Pats Creek (31.6 kg/ha) due to the presence of more large fish in the Galena River and to the greater length and weight at age for fish from the Galena River in the July 1981 sample (Append. Tables 2, 3).

Estimates for the Pats Creek population ≥2 years old (Table 7) were also calculated for comparison to the Galena River estimates in all years (Tables 4, 5). Density of bass ≥ age 2 was lowest in Pats Creek in August 1984 (34 bass/ha) and highest in September 1982 (86 bass/ha). Biomass ranged from 10.8 kg/ha in August 1984 to 18.5 kg/ha in July 1981. The lowest and highest estimates of density and biomass for the Galena River population were roughly twice those for Pats Creek. Differences in population structure and habitat between the river and the stream that might help explain the lower estimates from Pats Creek will be discussed below.

Largemouth bass (*Micropterus salmoides*), which probably escaped from an upstream tributary impoundment, were observed in Pats Creek in 1983. I estimated density for both fingerling (76/ha) and adult (4/ha) largemouth bass (Table 8). However, any interaction between largemouth and smallmouth bass populations must have been transitory. No largemouth bass were captured in the 1984 sample, indicating that they either moved out of Pats Creek or were unable to survive in this small stream environment.

TABLE 7. *Population, density, and biomass estimates by age group for smallmouth bass in Pats Creek, 1981-1984.*

Date and Age*	Year Class	Popul. Est.	95% CI	Density No./km	Density No./ha	Biomass (kg/ha)
7-9 Jul 1981						
1	80	322	(206-532)	115	293	13.1
2	79	67	(45-129)	24	61	9.0
3	78	9	(5-13)	3	8	2.3
4	77	8	(6-19)	3	7	4.0
≥5*		5	(4-13)	2	4	3.2
Total ≥1		411		147	373	31.6
Total ≥2		89		32	80	18.5
14-15 Sep 1982						
1	81	42	(35-68)	15	38	2.0
2	80	95	(84-128)	34	86	15.2
3	79	0		0	0	0
4	78	0		0	0	0
≥5		0		0	0	0
Total ≥1		137		49	124	17.2
Total ≥2		95		34	86	15.2
12-14 Sep 1983**						
1	82	9	(8-19)	3	8	0.6
2	81	35	(22-83)	12	32	6.9
3	80	15	(13-37)	5	14	4.7
4	79	0		0	0	0
≥5		0		0	0	0
Total ≥1		59		20	54	12.2
Total ≥2		50		17	46	11.6
20-21 Aug 1984						
1	83	106	(78-166)	38	96	6.4
2	82	7	(6-16)	2	6	0.8
3	81	23	(20-49)	8	21	6.5
4	80	8	(6-21)	3	7	3.5
≥5		0		0	0	0
Total ≥1		144		51	130	17.2
Total ≥2		38		13	34	10.8

*Ages 5-6.

**Young-of-year (age 0) population estimate of 132 with 95% CI from 48-330, representing a density of 47/km or 117/ha.

TABLE 8. *Population and density estimates for young-of-year and adult largemouth bass* in Pats Creek, 12-14 September 1983.*

Size Group	No.	95% CI	Density No./km	Density No./ha
Young-of-the-year	86	54-143	30	76
Adults*	4	3-10	1	4
Total	90		31	80

*235-269 mm total length.

YEAR CLASS VARIABILITY

The 1977-82 year classes were represented in the density and biomass estimates for individual age groups in the Galena River (Tables 4, 5). The 1980 year class dominated the population estimates by number in every sampling period and was the only year class abundant enough to allow an estimate at age 1. This year class was larger than any other at ages 2, 3, and 4 (Tables 4, 5). The 1980 year class also dominated the population by weight, with biomass greater than any other year class in every sample except April 1982, when bass $\geq$ age 5 represented 17.5 kg/ha of the total 33.2 kg/ha. The importance of the 1980 year class was also clearly reflected in the length frequencies of a sample of smallmouth bass from each sampling period (Figs. 3, 4).

The 1978 year class was the smallest observed, with an estimated 3 or fewer bass/ha at ages 3 and 4. The 1983 Galena River year class appeared to be promising, although the study ended before estimates to quantify the abundance of this year class were possible. The length distribution of samples collected in May 1984 and July 1984 indicated the presence of a sizeable 1983 year class (Figs. 3, 4).

The representation of year classes in Pats Creek was similar to that of the Galena River for younger age classes ($\leq$ age 3), but not for older fish. As in the Galena River, the 1980 year class in Pats Creek had the greatest density and biomass at age 1 (1981) and age 2 (1982) (Table 7) and was well represented in the length-frequency diagram (Fig. 5). However, unlike the Galena River, the 1980 cohort did not dominate the population of Pats Creek at ages 3 and 4. The 1981 and 1983 year classes were also well represented in Pats Creek. The 1981 cohort was abundant at age 1 (38 bass/ha in 1982), age 2 (32 bass/ha in 1983), and age 3 (21 bass/ha in 1984); the 1983 cohort was abundant at age 0 (132 bass/ha in 1983) and age 1 (96 bass/ha in 1984). The 1978 and 1982 year classes were poorly represented, and the 1979 year class was absent at ages 3-5, although it had been present (61 bass/ha) at age 2.

The periodic dominance of a single year class, as observed for the 1980 cohort in this study, is an expected phenomenon in smallmouth bass populations in both streams and lakes. These variations in year class strength are often a regional phenomenon (Cleary 1956, Pfleiger 1975, Coble 1975) and have been related to regional trends in temperature and flow regimes during spawning and the first year of life (Swenson et al. 1982). Strong year classes are often 2, 3, or 4 years apart, but they can occur in consecutive years, as in the Livingston Branch (Iowa County, Wisconsin) in 1964 and 1965 (Brynildson and Truog, unpubl. data, summarized by Forbes 1985). The 1976 year class was extremely successful in southern Wisconsin and adjacent states (Paragamian 1984*a*, Forbes 1985). This year class may have been the strongest preceding the 1980 cohort in the Galena River, representing a 4-year time span between strong year classes.

POPULATION AGE STRUCTURE: TRIBUTARY VS. RIVER HABITAT

In Pats Creek the relatively large numbers of age 1 and 2 smallmouth bass in 1981-84 and the small numbers of fish age 3 or older (Table 7, Fig. 5) suggested that this tributary stream served as spawning and nursery habitat. Older fish may have moved downstream to more suitable habitat in the Galena River, where age 3 and older bass were well represented (Tables 4, 5; Figs. 3, 4). I do not know if this difference in age structure of smallmouth bass populations was as pronounced historically or if reduced water or habitat quality from human activities (Matthews 1984, Field 1986) encouraged older fish to migrate from Pats Creek. Older bass may have been selectively killed by transitory poor water quality in Pats Creek. However, it is highly unlikely that older fish were selectively removed by anglers. No anglers were observed on Pats Creek during a preliminary creel census in 1981 (R. Kerr, unpubl. data), and I have no records of anyone fishing there.

The hypothesis that differences in habitat quantity and quality encouraged older bass to move downstream was supported by a comparison of habitat characteristics in the tributary and river study areas (Tables 1, 2, 3) and by similar observations in the literature (Tate 1949, Schlosser 1982). The amount of habitat would, of course, be smaller in the tributary. However, a comparison of substrate characteristics and depths between the river and tributary indicated that the habitat in Pats Creek was less suitable to support a large population of adult bass. Pats Creek samples contained fewer boulders than Galena River samples, and Pats Creek was shallower than the Galena River, with smaller pool and run volumes. Thus, the quantity and quality of adult habitat in the tributary, in this case primarily cover, could not support many smallmouth bass above age 2 or 3.

Boulders were present in 49% of the substrate samples from the Galena River pools and in only 4% of the samples from Pats Creek pools (Table 1). Pool/run depths and widths (and therefore, volumes) were greater in the Galena River. Annual flows in Pats Creek were only 6-7% of those in the Galena River (Tables 1, 2). The importance of boulders and other cover types in providing suitable habitat for smallmouth bass has been reported by many investigators (e.g., Munther 1970, Coble 1975, Hubert 1981, Covington et al. 1983). The combination of cover and deep water for winter aggregation has also been documented (Munther 1970, Paragamian 1981).

The amount of gravel in substrate was also substantially different in Pats Creek as compared to the Galena River; 50% of the Pats Creek and 89% of the Galena River substrate samples contained at least some coarse or larger gravel, and 61% of the Pats Creek and 25% of the Galena River samples were covered by surface silt (Table 1). These differences indicated that the Galena River contained a greater proportion of suitable habitat as measured by substrate type. Many other investigators have reported the importance to smallmouth bass of gravel or rubble substrate in pools (e.g., Reynolds 1965, Munther 1970, Paragamian 1981, Rankin 1986).

More variable temperatures in Pats Creek as compared to the Galena River (Table 3) may also have determined the habitat selected by bass age 3 and older. The ranges between maximum and minimum monthly temperatures were wider for Pats Creek than for the Galena River, indicating that the tributary responded more rapidly to weather fluctuations and may have provided a more stressful environment for bass. Although these variable temperatures may have represented less than optimal conditions for young fish (e.g., for coho salmon; Thomas et al. 1986), the tendency for smallmouth bass to retreat from such conditions may be minimal until they reach an intermediate size (Funk 1955).

An overall measure of habitat suitability, the habitat suitability index (HSI) of Edwards et al. (1983), also confirmed that habitat quality in the Galena River exceeded that in Pats Creek (Table 1, Lyons et al. 1987). The HSI model incorporates 13 physical and chemical variables into an overall index that rates the suitability of streams for smallmouth bass. The variables include dominant substrate type in pools, average maximum depth of pools, and amounts of instream and bankside cover. An index value of 1.00 indicates optimum habitat. The HSI for the Galena River study area, 0.96, was close to the optimum; values for the two sections of the Pats Creek study area were 0.63 and 0.78, indicating the presence of good but not excel-

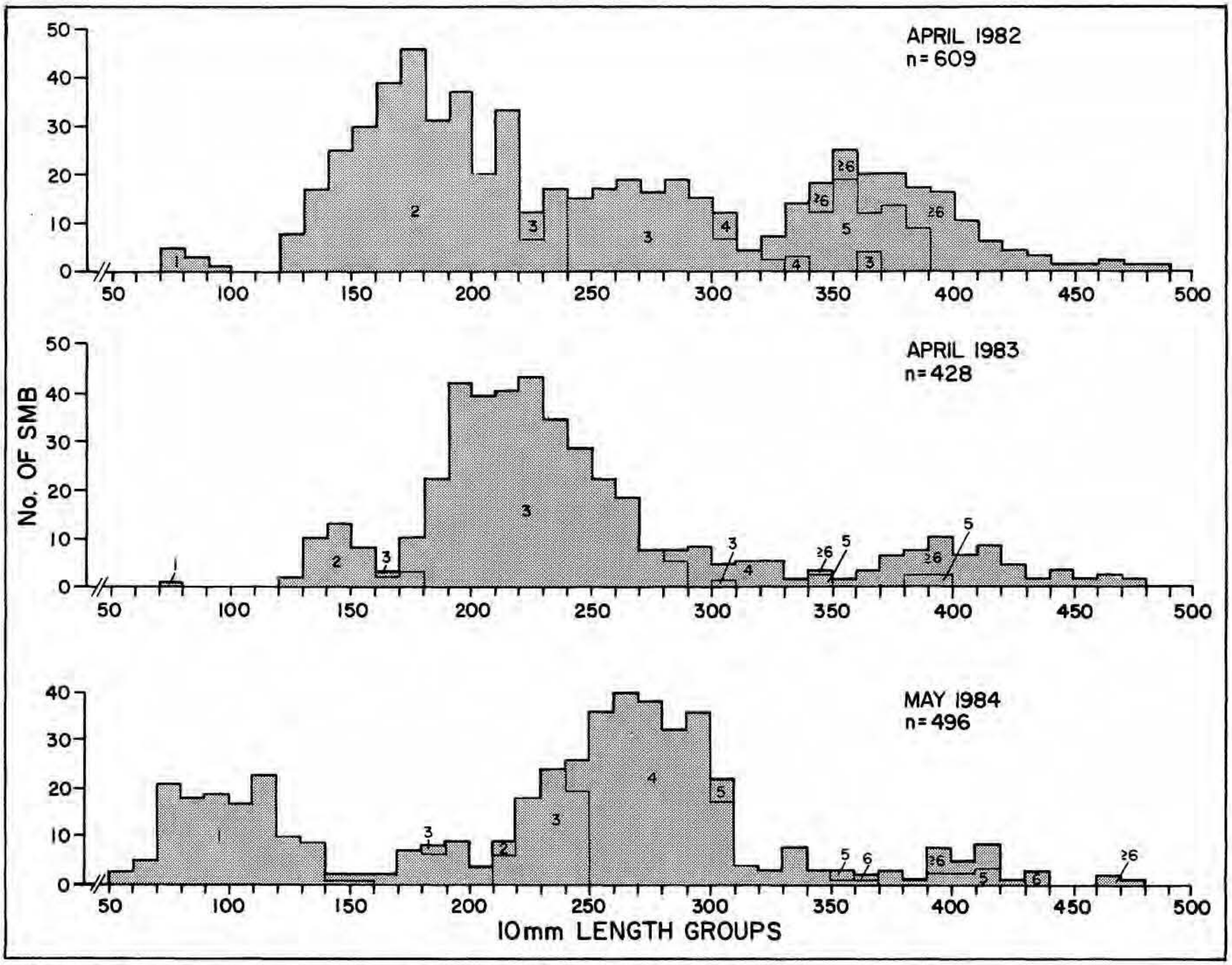

FIGURE 3. *Length frequency and age of a sample of smallmouth bass from the Galena (Fever) River in spring 1982-84.*

lent smallmouth bass habitat.

The concept of smallmouth bass moving downstream at about age 2 or 3 is supported by Funk's observation that intermediate-sized fish (210-330 mm) were the most mobile in Missouri streams (Funk 1955). Smallmouth bass from Pats Creek ranged from 166-304 mm in length near the end of the growing season at age 2 and from 260-337 mm in length at age 3 (Append. Table 3). Funk (1955) also believed that stream populations supported both a sedentary and a mobile component and that growing fish gradually moved from their place of hatching to search for suitable cover, food supplies, etc. Tate (1949) observed an absence of older fish in smaller Iowa streams and also believed that older and larger smallmouth bass moved to larger streams because of the shortage of suitable adult habitat in the upstream areas.

The use of tributaries or headwaters for spawning and juvenile habitat has been reported by other investigators. In a comprehensive analysis of seasonal and spatial shifts in age structure for all fish species including smallmouth bass in an Illinois stream, Schlosser (1982) reported that younger fish (ages 0 and 1) were found in shallow, temporally variable upstream or riffle habitats. He also reported that decreased discharges (reduced habitat volume) caused older fish, especially centrarchids, to move downstream toward deeper habitat or to pools. Schlosser also noted that movement between mid-river and headwater reaches usually involved fish $\geq$ age 3. The movement of adult smallmouth bass from rivers into tributaries to spawn has been observed by Cleary (1956) and Reynolds (1965); however, neither of these authors indicated how long the young remained in the tributary. Data from Pats Creek in this study showed that relatively few bass remained in the tributary after age 2 or 3. Since no spring samples of smallmouth bass were taken from Pats Creek, I do not know whether adults from the Galena River moved into Pats Creek to spawn or whether Pats Creek year classes were produced primarily by the small number of resident adults.

The relative importance to the Galena River fishery of spawning and nursery areas in the river vs. its tributaries is unknown. I have seen many gravid females in the Galena River in areas of excellent spawning habitat in spring and many fingerlings in fall, suggesting that successful reproduction has occurred in the river. In addition, yearling densities were equivalent in the Galena River and Pats Creek in July 1981 (Tables 4, 7) indicating that, at least for the 1980 year class, production of juvenile fish was the same per unit area in both the river and the stream.

GROWTH

Galena River smallmouth bass collected in spring just before the growing

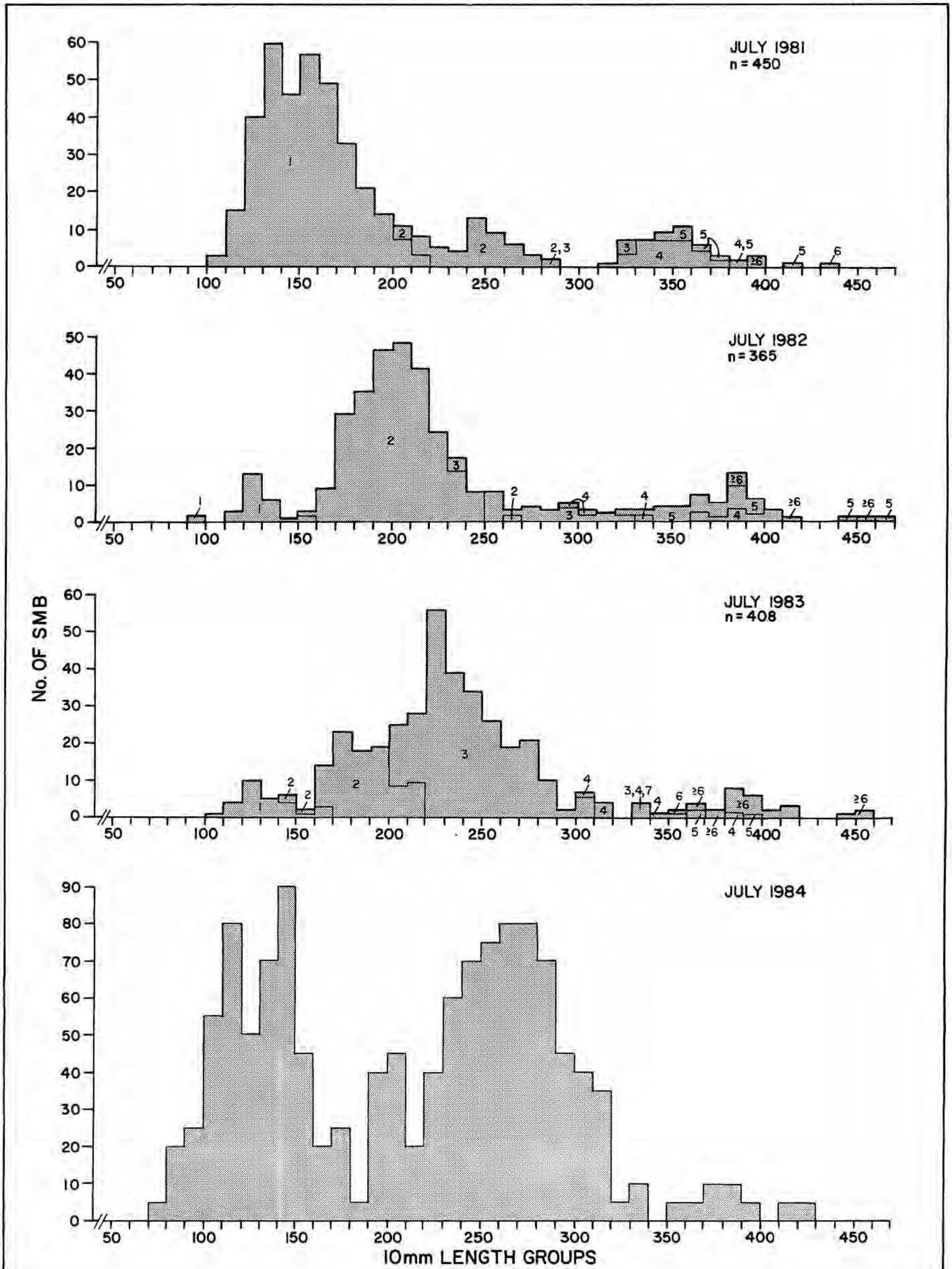

FIGURE 4. *Length frequency and age of a sample of smallmouth bass from the Galena (Fever) River in July 1981-83, and length frequency without age for a sample from July 1984.*

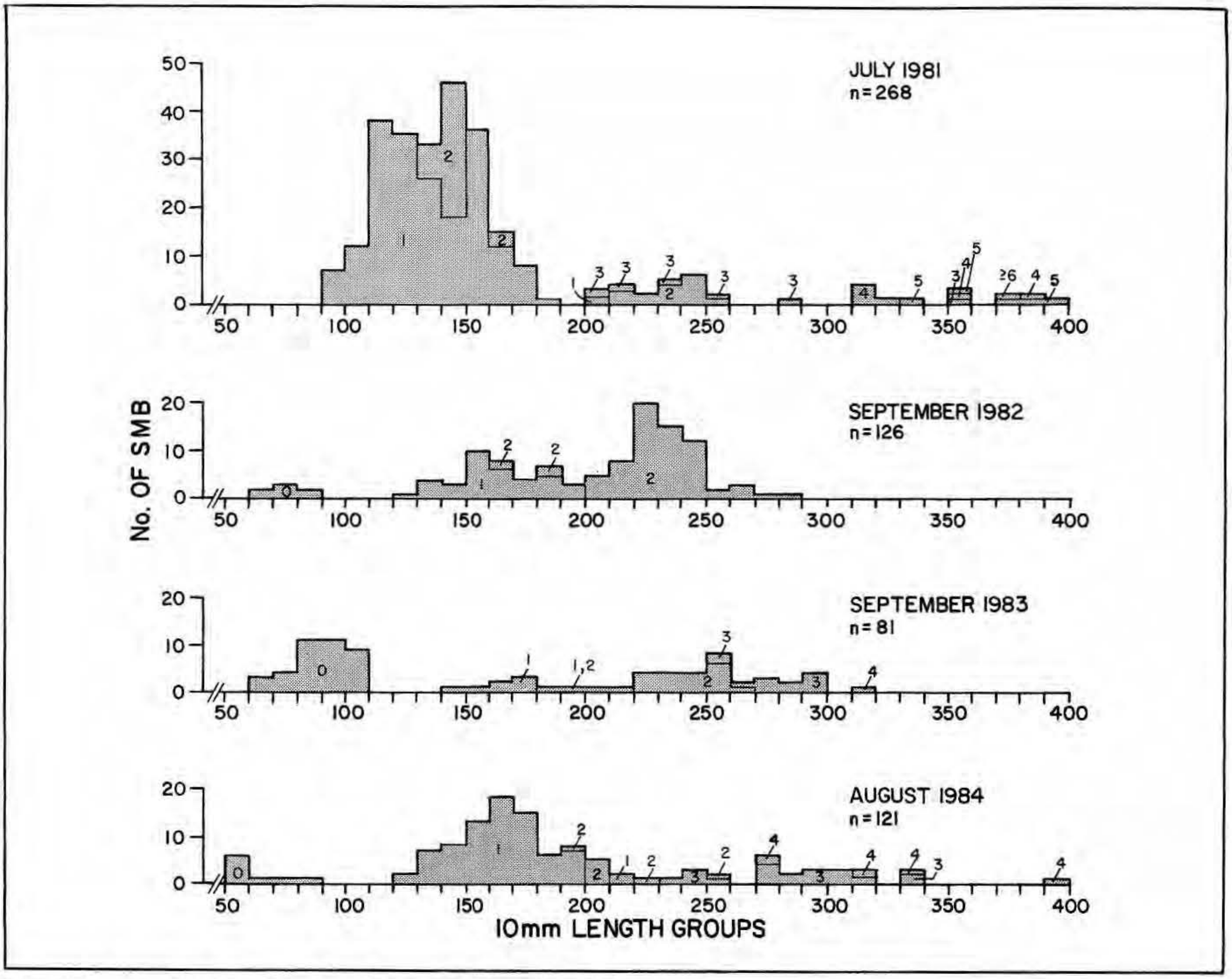

FIGURE 5. *Length frequency and age of a sample of smallmouth bass from Pats Creek in July 1981, September 1982 and 1983, and August 1984.*

season ranged from 173-445 mm total length at ages 2-8, respectively (Table 9, Append. Table 1). When I compared smallmouth bass size between streams in Wisconsin and Iowa, the length at age in the Galena River was considerably lower than the maximum observed from the Maquoketa River, Iowa. The length at age in the Galena River was higher than the minimum from the Upper Iowa River and was similar to the mean for all southern Wisconsin stream samples from 1954-82 (Table 9).

Annual growth increments for Galena River smallmouth bass ranged from 63-66 mm for ages 2-5 and declined to 21-30 mm for ages 5-8 (Table 9, Append. Table 1). Compared to the annual growth increments for populations from other streams in Wisconsin and eastern Iowa, this decline after age 5 appears abrupt, going from a plateau in the 60-mm range down to one in the 20-mm range. In other streams the pattern of decline in growth was more gradual with increasing fish age. Annual growth increments were highest (53-110 mm) between ages 1 and 3, were usually above 40 mm and often above 60 mm up to age 5, and usually fell well below 40 mm after age 5 (Table 9). In addition to examining annual growth increments from length-at-age differences averaged from single Galena River samples (Append. Tables 1, 2), I also calculated annual increments for individual year classes in 2 or 3 succeeding years. The resulting values (66, 49, 63, 34, 42, and 6 mm at ages 2-8) indicated that the two plateaus described above may be, at least in part, artifacts of averaging data from sample sizes and cohorts with different growth patterns.

Smallmouth bass collected near the end of the growing season in Pats Creek ranged from 84-330 mm in total length after their first through fifth growing seasons (Table 9, Append. Table 3). Annual growth increments were 81 and 71 mm during the second and third growing seasons, but decreased to 51 and 43 mm during the next two growing seasons (Table 9, Append. Table 3). This observation indicated that growth of Pats Creek smallmouth bass was excellent between ages 1 and 2 and between ages 2 and 3, but that those few fish that remained in the tributary after age 3 grew more slowly when compared to most other populations (Table 9). The reduced growth rate of bass ≥ age 3 supports the hypothesis discussed earlier that habitat quality for adult smallmouth bass was lower in Pats Creek than in the Galena River. Alternatively, the migration of smallmouth bass from Pats Creek might be size-dependent rather than age-dependent so that the slow-growing fish of each age group might remain in the tributary stream for a longer time.

GALENA RIVER FISHERY

Catch Composition

Smallmouth bass accounted for 70% and 74% of the catch by number and 63% and 60% of the harvest from the Galena River in 1982 and 1983, respectively. White suckers (*Catostomus commersoni*) constituted 6-9% of the catch and 10% of the harvest; bullheads (*Ictalurus* spp.) made up 12-15% of the catch and 22-26% of the harvest. Species rarely caught included chubs (*Semotilus atromaculatus* and *Nocomis biguttatus*), sunfish (*Lepomis* spp.), common carp (*Cyprinus carpio*), redhorse (*Moxostoma* spp.), rock bass (*Ambloplites rupestris*), gar (*Lepisosteus* sp.), channel catfish (*Ictalurus punctatus*), walleye (*Stizostedion vitreum vitreum*), and sauger (*S. canadense*).

Fishing Pressure, Catch, and Harvest

Estimates of total fishing effort for the Galena River were 257 hours/ha in 1982 and 185 hours/ha in 1983 (Table 10). Although fishing effort was relatively high in May of both years, catch and harvest rates for smallmouth bass were relatively low. Fishing pressure and catch and harvest rates increased in June of each year and remained high through August. Interestingly, catch and especially harvest rates were higher in September and October than they were in May, even though fishing pressure was comparatively low. The differences between spring and fall may indicate that many spring anglers were attracted by the season opening and spring weather when bass were not actively feeding, and that fall anglers, while fewer, were more effective. Paragamian (1973) also found that fishing pressure for smallmouth bass on the Red Cedar River, Iowa, was highest in May and lowest in October. The highest catch rates he observed were during August and September when water temperature was at its annual maximum.

When compared to other streams in the upper midwest, the Galena River received a moderate amount of fishing pressure (Table 6). Estimated total fishing effort for smallmouth bass was similar to the pressure on the Little Wolf River in Wisconsin and the Kankakee River in Illinois, but was lower than fishing pressure in the Maquoketa River, Iowa. Of five Missouri streams included in a previous review (Paragamian and Coble 1975), fishing pressure on the Galena River was lower than that of two streams, higher than that of two other streams and comparable to one stream.

Estimated harvest rates for smallmouth bass were similar for the Galena River (13-15 bass/100 hours) and for the Wolf and Kankakee rivers (14 and 13-14 bass/100 hours, respectively) (Table 6). Values reported for the Ma-

TABLE 9. *Calculated or actual length (mm) at age and growth increments for smallmouth bass from the Galena River and Pats Creek compared to values reported for some Wisconsin and Iowa streams. Increments are shown in parentheses.*

Location	Age 1	2	3	4	5	6	7	8	9	10
Galena River (this study)		173	239	302	368	394	424	445		
			(66)	(63)	(66)	(26)	(30)	(21)		
Pats Creek (this study)*	84	165	236	287	330					
		(81)	(71)	(51)	(43)					
Wisconsin** (southern counties)	86	178	246	304	350	394	430	462		
		(92)	(68)	(58)	(46)	(44)	(36)	(32)		
Wisconsin[a] (northern counties	96	173	244	312	368	404	432	450	475	
		(77)	(71)	(68)	(56)	(36)	(28)	(18)	(25)	
Maquoketa River (IA)[b]	102	180	259	325	389	428	470	490	488	510
		(78)	(79)	(66)	(64)	(39)	(42)	(20)	(18)	(22)
Upper Iowa River[b]	98	166	219	278	318	342	412	430		
		(68)	(53)	(59)	(40)	(24)	(70)	(18)		
Five Iowa streams (average)	102	175	249	312	363	401	434	460	490	510
		(73)	(74)	(63)	(51)	(38)	(33)	(26)	(30)	(20)
Des Moines River (IA)[c]	119	229	297	340	389	411				
		(110)	(68)	(43)	(49)	(22)				

*One year added to values in Appendix Table 3, assuming that the growing season was completed.
**Mean for 22 samples on 13 streams 1954-82; from Forbes (1985).
[a]Mean for 3 streams 1972-79; from Forbes (1985).
[b]Paragamian (1984*a*).
[c]Reynolds (1965).

TABLE 10. *Monthly and annual fishing pressure, catch and harvest rates, and total harvest estimated for Galena (Fever) River smallmouth bass, 1982-1983.*

Year	Month	Fishing Pressure (hours/ha)	Catch Rate* (SMB/100 hours)	Harvest Rate* (SMB/100 hours)	Total Harvest (No./ha)	Total Harvest (kg/ha)**
1982	May	48	18	8	3.8	0.8
	June	81	45	10	7.7	1.7
	July	37	32	17	6.5	1.4
	August	66	56	24	15.8	3.4
	September	17	43	19	3.2	0.7
	October	8	23	13	1.0	0.2
	Total	257	—	—	38.0	8.2
	Mean	—	36	15	—	—
1983	May	46	13	3	2.1	0.7
	June	52	33	12	6.3	2.2
	July	43	50	21	9.7	3.3
	August	30	42	12	3.6	1.2
	September	8	18	14	1.4	0.5
	October	6	15	15	1.0	0.3
	Total	185	—	—	24.1	8.2
	Mean	—	28	13	—	—

*Catch refers to the total number of bass caught; harvest indicates the subset of the catch that was not released.
**Based on an average weight of harvested smallmouth bass of 0.218 kg in 1982 (n = 139) and 0.344 kg in 1982 (n = 108).

quoketa River, Iowa were lower (2-8 bass/100 hours) than for the Galena River, and those reported for the Kankakee River, Illinois, were considerably higher (19-33 bass/100 hours).

The total estimated number of smallmouth bass harvested in the Galena River was 38.0 bass/ha in 1982 and 24.1 bass/ha in 1983, with the largest numbers harvested in June, July, and August of each year; total biomass harvested was 8.2 kg/ha in both years (Table 10). The numbers of bass harvested from the Galena River were similar to the numbers reported for the Red Cedar and Little Wolf rivers, Wisconsin, and the Kankakee River, Illinois (Table 6). However, the maximum numbers reported for these four streams (38, 21, 25, and 33 bass/ha, respectively) were considerably below the maximum reported for the Maquoketa River, Iowa, (46-72 bass/ha) before the establishment of a 12-inch length limit (Table 6, Paragamian 1984*a*). Minimum estimates of annual harvest were similar in all of the above studies; the smallest observation (8-17 bass/ha) occurred after the length limit effectively reduced the smallmouth bass harvest from the Maquoketa River in 1980 (Table 6, Paragamian 1984*b*).

Angler Characteristics

The Galena River fishery was especially popular among local residents during the years of this study. Ninety-four percent of the 833 anglers interviewed during the 1982 census were Wisconsin residents, as were 92% of the 737 anglers interviewed during the 1983 census. Most of the anglers, 89% in 1982 and 85% in 1983, traveled less than 25 miles to reach the study area. Fewer anglers, 2% in 1982 and 6% in 1983, came from distances of 26-50 miles away and only 8% came farther than 50 miles from home in both years.

MORTALITY AND EXPLOITATION

Total annual mortality rates including any immigration or emigration for the smallmouth bass population in the Galena River were estimated at 52% and 65% (Table 11). These values were similar to those reported in the literature for smallmouth bass stream populations in Wisconsin and Missouri (range 55-66%) (Paragamian and Coble 1975), but were not as wide in range as those from five Iowa streams (range 42-84%) (Paragamian 1984*a*).

Estimates of total annual mortality in Pats Creek were more variable than estimates for the Galena River and were more similar in range to those observed in the five Iowa streams (Paragamian 1984*a*). Maximum values were 64-84% between September 1982 and September 1983 and minimum values were 36-38% between September 1983 and August 1984 (Table 11). I can only speculate about the reasons for this wider range for annual mortality estimates in Pats Creek. Part of the estimated mortality in Pats Creek may be due to the movement of fish older than age 2 or 3 to downstream habitats, as discussed earlier. Variability in the timing or magnitude of this movement, if known, might help explain the variability in total annual mortality. The time period of the higher mortality estimates included the growing season when largemouth bass were present in the stream (Table 8). Competition between the two predator species (largemouth and smallmouth bass) for food or space might have negatively influenced the survival of smallmouth bass. However, many factors such as temperature and flow regimes, food availability, water quality, gear selectivity, migratory behavior, etc. may directly or indirectly determine the magnitude of annual mortality. Variability in these factors may have more pronounced biological effects in a small tributary, such as Pats Creek, than in a larger river.

Exploitation rates for the smallmouth bass fishery in the Galena River were higher in 1982 (24% for fish ≥ age 2 and 28% for fish ≥ age 3) than in 1983 (16% for fish ≥ age 2 and 15% for fish ≥ age 3). The portion of the total annual mortality attributed to angler harvest was 34% in 1982-83 (ratio of average exploitation and average total annual mortality); the remaining 66% of total annual mortality was due to natural causes.

The 1980 year class constituted a substantial portion of the harvest—65% in 1982 and 56% in 1983 (Table 12). The average size of harvested bass increased from 256 to 287 mm in length and from 0.218 to 0.344 kg in weight from 1982 to 1983.

TABLE 11. *Estimated total annual mortality and survival for smallmouth bass populations in the Galena River and Pats Creek.*

Stream (Time 2/Time 1)	Annual Mortality	Survival
Galena River		
Jul 1982/Jul 1981*	0.52	0.48
Jul 1983/Jul 1982*	0.65	0.35
Pats Creek		
Sep 1983/Sep 1982*	0.84	0.16
Aug 1984/Sep 1983*	0.38	0.62
Sep 1983/Sep 1982**	0.64	0.36
Aug 1984/Sep 1983**	0.36	0.64

*Estimates based on ratio of population estimates of all bass ⩾ age 3 at Time 2 to all bass ⩾ age 2 at Time 1.

**Estimates based on ratio of population estimates of all bass ⩾ age 2 at Time 2 to all bass ⩾ age 1 at Time 1.

TABLE 12. *Number of smallmouth bass by age group in a sample of bass harvested from the creel census.*

Age Group	Census Year 1982 (%)	1983 (%)
1	1(1)	0(0)
2	89(65)	6(6)
3	30(22)	61(56)
4	2(1)	15(14)
5	10(7)	2(2)
6	3(2)	11(10)
7	1(1)	13(12)
Sample size	136	108

SUMMARY AND MANAGEMENT IMPLICATIONS

STATUS OF SMALLMOUTH BASS POPULATIONS

The smallmouth bass fishery of the Galena River is of high quality, with population density and biomass estimates comparable to or exceeding those of other smallmouth bass stream fisheries in the region. Pats Creek, a tributary to the Galena River, provides variable, but potentially important spawning and juvenile habitat for smallmouth bass.

Recent Bureau of Fisheries Management surveys have provided a broader picture of the status of smallmouth bass streams in southwestern Wisconsin (R. Kerr, unpubl. data). Other than the Galena River, the only stream known to support a quality smallmouth bass population is the Little Platte River, Wisconsin. Some streams that have had smallmouth bass fisheries in the past still have good habitat conditions. The most notable of these streams is Rattlesnake Creek, which had a habitat suitability index (HSI) for smallmouth bass comparable to the Galena River (0.94 for Rattlesnake Creek and 0.96 for the Galena River). Rattlesnake Creek had few smallmouth bass (catch in one electrofishing run of 4 bass/ha in Rattlesnake Creek as compared to 41 bass/ha in the Galena River) (Lyons et al. 1987).

The absence of a historical regional assessment of the population status of smallmouth bass has limited the development of management strategies. Results of this study indicate what can be expected from driftless area streams with excellent (Galena River) and good (Pats Creek) habitat for smallmouth bass. These results also illustrate the importance of observing the density and age or length structure of a smallmouth bass population for several years to allow the observation of strong, medium, and weak year classes. As managers develop programs to protect, enhance, or rehabilitate smallmouth bass stream populations in southwestern Wisconsin, they should conduct regular population assessments in streams, including the Galena River and Pats Creek, using standardized methods to estimate population size and length/age structure.

DOCUMENTATION OF A FISH KILL

We suspect that fish kills on southwestern Wisconsin streams have extensively affected smallmouth bass and other stream biota (Matthews 1984; Wis. Dep. Nat. Resour., unpubl. memo reps.). However, establishing the causes and magnitude of the effects of fish kills has usually not been possible. These events are transitory and sporadic and vary in location and possible causes. We do not know how often fish kills affect fish acutely, causing immediate death, or sublethally, causing chronic stress that reduces longer-term fitness or reproduction. Moreover, most fish kills are reported long after the kill conditions have passed, making information gathering difficult.

Data for this study were gathered through May 1984; however, a fish kill of unknown origin affected the Galena River study area on 9-10 June 1984. A follow-up population estimate by the fish manager on 2-6 July 1984 enabled us to document, for the first time on a southwestern Wisconsin stream, a decline in smallmouth bass population density following a fish kill (R. Kerr, unpubl. data). Although the smallmouth bass population was not decimated, the estimated density of 30/ha after the kill was the lowest observed in four years and was slightly less than half the next lowest density of 65/ha observed in April 1982 (Table 13). Although dead smallmouth bass were observed, we do not know how many fish died and how many may have moved away to avoid the poor conditions. In addition to smallmouth bass, dead redhorse, white suckers, stonecats (*Noturus flavus*), and minnows (*Cyprinidae*) were observed (R. Kerr, unpubl. data).

One month after the kill, population size structure was not dramatically different than it had been a month before the kill. A comparison of the length frequency before the event in May 1984 (Fig. 3) and afterward in July 1984 (Fig. 4) revealed similar proportions of fish within the spectrum of length groups. No bass larger than 430 mm were observed in July, whereas 12 fish of this size had been caught in May. I do not know if this difference was caused by the fish kill. All other samples from the study period, except for July 1981 (Fig. 4), included fish larger than 430 mm (Figs. 3, 4).

While the area affected by the kill covered only 6-8 km of the approximately 35 km used by anglers, follow-up assessments should be continued to determine population recovery and status. This recommendation echoes the one made earlier that a regular program be designed and implemented to document smallmouth bass population status in selected streams. In addition,

TABLE 13. *Population and density estimates for smallmouth bass ⩾ 200 mm total length on six sampling dates before and one sampling date after a known fish kill on the Galena (Fever) River.**

Sampling Date	Population Estimate	95% CI	Density No./km	Density No./ha
July 1981**	265	(138-559)	126	85
April 1982	515	(428-620)	107	65
July 1982	819	(516-1,365)	171	104
April 1983	838	(610-1,188)	175	106
July 1983	608	(462-820)	127	77
May 1984	796	(601-1,082)	166	101
Fish kill June 1984				
July 1984	234	(169-333)	49	30

*Fish caught in the July 1984 samples were not aged. The estimates for July 1981 through May 1984 were re-calculated for the ⩾ 200 mm length group for comparison to the July 1984 samples.

**Only the downstream 2.1-km portion of 4.8-km study area was sampled in July 1981.

further DNR research studies are now underway (J. Mason, pers. comm.) to determine causes and effects of runoff from agricultural watersheds to smallmouth bass streams. Both research and monitoring aspects of this work should be implemented as part of an effort to actively manage—not just monitor—the quality of smallmouth bass streams in southwestern Wisconsin.

SIGNIFICANCE AND PROTECTION OF THE GALENA RIVER AND ITS TRIBUTARY NETWORK

The Galena River system is a unique resource for the anglers of southwestern Wisconsin. At a time when other streams in the region no longer support smallmouth bass fisheries (R. Kerr, unpubl. data), the Galena River continues to provide a quality fishery within the 21-km creel census study area. My observations, plus those of the area fish manager and local residents, indicate that the area actively used by anglers extends another 3 km above and 11 km below (to the Wisconsin-Illinois border) the creel census study area.

The tributaries to the main stream of the Galena River also support smallmouth bass populations. Data from this study indicate that Pats Creek may serve as a spawning, nursery, and juvenile habitat. Management surveys of other tributaries have documented the presence of smallmouth bass in the Shullsburg Branch, Kelsey Branch, Madden Branch, tributaries to the Madden Branch, and the upper portions of the Galena River (Fago 1985; Forbes 1985; R. Kerr, unpubl. data).

I do not know if anglers use the tributary streams. However, the condition of the tributary smallmouth bass populations is important to the management of the Galena River fishery. First, in addition to whatever role each stream might play as spawning, nursery, and juvenile habitat, the tributary populations may also serve as population reservoirs that could recolonize portions of the Galena River system after acute fish kills or other types of population declines. Fish kills have been documented in the Galena River stream system in Pats Creek (July 1982), the Madden Branch (July 1981 and April 1984), the upper reaches of the Galena River (September 1985), and the study area of the Galena River (June 1984) (R. Kerr, unpubl. data).

Second, the water and habitat quality of the Galena River fishery depends on the water and habitat quality of its upstream tributaries, which in turn depend on land use in the watershed. Nonpoint source discharges impact the water quality of Pats Creek and several other tributaries (Field 1986). Steps to reduce nonpoint impacts have been taken. For example, the Galena River watershed was designated by the DNR Bureau of Water Quality Management as a priority area for nonpoint source improvement practices (Konrad et al. 1985). In addition, cost-sharing incentives to improve land use practices were implemented in subwatersheds of the Galena River where streams had poor or very poor water quality (Wis. Dep. Nat. Resour. 1979). Certainly these efforts to improve water quality in degraded areas form one important cornerstone for smallmouth bass management in the Galena stream system, and they should continue to receive public support. However, long-term protection of habitat and water quality in the Galena River fishery requires more than attention to the headwaters areas. Incentives for improved land-use practices should be encouraged, not only in the area eligible for the existing nonpoint source program, but throughout the watershed if long-term protection of habitat and water quality is to be secure. Recent efforts by the local DNR fish manager to obtain easements along the stream are a positive step. This purchase of easements should continue, and steps should be taken to improve bank and riparian conditions along these stream reaches.

The maintenance or improvement of habitat and water quality in streams of the Galena River watershed is of highest priority. However, the development of effective management strategies will ultimately require knowledge of the seasonal habitat requirements and movements of smallmouth bass in the Galena River stream system and how these characteristics vary according to the age or size of smallmouth bass. Research projects addressing these questions will be essential to the future wise management of smallmouth bass in southwestern Wisconsin streams.

POTENTIAL NEED FOR NEW FISHING REGULATIONS

The results of this study indicate that, at present, new regulations to restrict the harvest of smallmouth bass from the Galena River are unnecessary to protect population size. Current statewide regulations provide a closed season from 1 March until the first Saturday in May and a daily bag limit of 5 smallmouth bass. Total annual mortality in the Galena River during 1982-83 was estimated at 65%, and 34% of this total mortality was due to fishing. Exploitation estimates averaged 20% for fish age 2 and older and 22% for those age 3 and older.

The amount of harvest associated with the smallmouth bass fishery of the Galena River should be watched. Fishing pressure on the Galena River (185-257 hours/ha) was substantially lower than that reported for the Maquoketa River in northeast Iowa (628-1,082 hours/ha), where a 12-inch minimum length limit was recently imposed (Table 6) (Paragamian 1984*a*, 1984*b*). In the Maquoketa River fishery, total annual mortality was 71%, 50% of which was due to fishing, before the minimum length limit took effect (Paragamian 1984*a*). If fishing pressure on the Galena River should substantially increase and if estimates of fishing mortality and exploitation of smallmouth bass should also rise, future length limits may be needed. One factor that might contribute to increased fishing pressure and harvest would be an increase in the number of anglers that travel great distances to fish the Galena River (85-89% of the anglers interviewed in this study were within 25 miles of home).

While additional harvest regulations are unnecessary to protect total population size, current estimates of exploitation are large enough to significantly reshape population structure. In the future, managers could choose to examine size-specific exploitation rates and potential effects of length limits to improve the size structure of the harvest.

APPENDIX

APPENDIX TABLE 1. *Mean length and weight at age for smallmouth bass collected in the Galena (Fever) River in April-May 1982-84.*

Date	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
Mean length (mm)							
19-21 Apr 82	178 (122-239)* (41)**	280 (230-361) (17)	320 (304-335) (2)	354 (327-384) (17)	390 (344-435) (12)	416 (366-464) (4)	472 (462-483) (2)
25-27 Apr 83	148 (129-179) (21)	231 (161-305) (62)	312 (289-335) (18)	373 (347-400) (5)	385 (345-425) (20)	419 (370-470) (16)	439 (424-447) (3)
7-8 May 84	185 (144-219) (24)	227 (190-248) (19)	297 (247-369) (47)	385 (310-416) (14)	410 (364-435) (13)	449 (395-472) (4)	409 (−) (1)
Mean length (weighted)	173	239	302	368	394	424	445
Increment	66	63	66	26	30	21	
Mean weight (g)							
19-21 Apr 82	76 (30-150) (35)	282 (135-490) (10)	495 (−) (1)	606 (440-900) (15)	741 (500-910) (7)	1,022 (620-1,361) (4)	1,452 (−) (1)
25-27 Apr 83	40 (20-65) (21)	171 (60-355) (60)	419 (300-530) (18)	741 (540-920) (5)	823 (595-1,179) (20)	1,058 (655-1,452) (16)	1,185 (880-1,361) (3)
7-8 May 84	80 (30-140) (21)	149 (85-205) (18)	391 (210-860) (46)	839 (400-1,100) (13)	961 (623-1,140) (11)	870 (−) (1)	890 (−) (1)
Mean weight (weighted)	67	179	400	718	848	1,042	1,179
Increment	112	221	318	130	194	137	

*Range.
**Sample size.

APPENDIX TABLE 2. *Mean length and weight at age for smallmouth bass collected in the Galena (Fever) River in July 1981-84.*

Date	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
Mean length (mm)								
16-23 Jul 81	159 (101-215)* (58)**	248 (207-299) (36)	312 (283-328) (3)	347 (302-398) (26)	374 (349-414) (12)	427 (393-453) (3)		
12, 27 Jul 82	130 (116-142) (10)	206 (164-263) (44)	279 (236-321) (15)	361 (303-400) (6)	374 (322-462) (17)	445 (−) (1)	383 (−) (1)	
18-20 Jul 83	136 (115-162) (10)	184 (144-219) (27)	257 (206-335) (48)	337 (308-390) (8)	373 (362-392) (3)	390 (360-456) (11)	388 (335-418) (8)	420 (390-455) (3)
Mean length (weighted)	150	213	264	348	374	401	388	420
Increment	63	51	84	26	27	−13	32	
Mean weight (g)								
16-23 Jul 81	54 (10-135) (57)	220 (120-365) (31)	517 (480-590) (3)	600 (470-953) (22)	673 (610-820) (10)	1,093 (920-1,225) (3)		
12, 27 Jul 82	28 (15-45) (10)	119 (55-240) (40)	292 (160-460) (15)	774 (685-880) (4)	753 (500-1,361) (17)		750 (−) (1)	
18-20 Jul 83	39 (19-62) (9)	81 (40-120) (6)	216 (110-396) (46)	562 (438-780) (6)	741 (680-820) (3)	804 (600-1,020) (10)	842 (760-925) (2)	840 (−) (1)
Mean weight (weighted)	49	158	240	615	725	871	811	840
Increment	109	82	375	110	146	−60	29	

*Range.
**Sample size.

APPENDIX TABLE 3. *Mean length and weight at age for smallmouth bass collected in Pats Creek 1981-84.*

Date	Age 0	1	2	3	4	5	6
Mean length (mm)							
7-9 Jul 81	— (0)	137 (100-203)* (37)**	211 (133-256) (20)	259 (210-351) (6)	336 (313-385) (6)	369(335-396) (5)	373 (—) (1)
21 Oct 81[a]	106 (—) (1)	168 (120-218) (14)	280 (262-304) (4)	— (0)	352 (—) (1)		
14-15 Sep 82[a]	73 (61-84) (7)	159 (121-190) (25)	233 (166-290) (42)				
12-14 Sep 83[a]	91 (64-110) (38)	168 (149-177) (7)	240 (200-265) (17)	286 (260-301) (11)			
20-21 Aug 84[a]	52 (53-83) (9)	168 (128-218) (38)	215 (192-252) (6)	288 (236-337) (16)	320 (227-400) (6)		
Mean length (weighted)[b]	84	165	236	287	330		
Increment	81	71	51	43			
Mean weight (g)							
7-9 Jul 81	—	45 (5-125) (37)	147 (43-245) (20)	282 (125-610) (6)	551 (420-860) (6)	676 (460-810) (5)	860 (—) (1)
21 Oct 81	15 (—) (1)	73 (20-145) (14)	335 (260-410) (4)				
14-15 Sep 82	—	52 (25-95) (24)	176 (55-320) (42)				
12-14 Sep 83	—	72 (43-95) (7)	216 (150-310) (16)	348 (235-400) (10)			
20-21 Aug 84	—	66 (25-140) (38)	124 (80-190) (6)	315 (160-460) (14)	490 (277-400) (6)		
Mean weight (weighted)[b]	64	190	329	490			
Increment	126	139	161				

*Range.
**Sample size.
[a]Since these samples were taken near the end of the growing season, they were used as indicators of a full year's growth in Table 5.
[b]Excluding July 1981.