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# The Life History of the Flame Chub, *Hemitremia flammea* (Jordan and Gilbert), in Pond Creek, Loudon County, Tennessee

Marcia K. Sossamon
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To the Graduate Council:

I am submitting herewith a thesis written by Marcia K. Sossamon entitled "The Life History of the Flame Chub, *Hemitremia flammea* (Jordan and Gilbert), in Pond Creek, Loudon County, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

David A. Etnier, Stephen Moore

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Date November 28, 1990

# THE LIFE HISTORY OF THE FLAME CHUB,

# HEMITREMIA FLAMMMEA (JORDAN AND GILBERT),

# IN POND CREEK,

# LOUDON COUNTY, TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Marcia K. Sossamon

December 1990

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# ABSTRACT

Life history data were obtained from 243 preserved specimens of the flame chub, Hemitremia flammea, collected from June 1989 to June 1990 at Pond Creek in Loudon County, Tennessee. Flame chubs had a life expectancy of 1.5 years, and some individuals reached 2 years. Length-weight relationships showed that as the length of the flame chubs increased, their weight did not increase as much as most other fish. During the spawning season, females averaged larger than males and outnumbered them. Flame chubs spawned between January and June, peaking in March. Fecundity generally increased as the total length of the female increased. The stomachs of Hemitremia specimens most frequently contained dipteran larvae. Other food items included flatworms, aquatic earthworms, crustaceans, aquatic insects, snails, seeds, and detritus. Flame chubs were associated with aquatic vegetation consisting most often of swamp smartweed and small pondweed.

The Abrams Creek population in Cades Cove in the Great Smoky Mountains National Park was very small, and appeared to be declining. The population there should be monitored, and other suitable habitat in the area should be sampled in hopes of locating other populations in the system, and in the National Park.

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# CHAPTER I

## INTRODUCTION

The flame chub, Hemitremia flammea (Jordan and Gilbert) is the only member of its genus, and like many other members of the family Cyprinidae, little is known about its life history. The name Hemitremia is derived from the Greek words hemi, meaning half, and trema, meaning aperture (Jordan 1876). This refers to the incomplete lateral line of the fish. The word flammea, meaning flaming, describes the bright orange coloration which develops during spawning season.

Hemitremia flammea is distributed throughout parts of the Eastern Highlands (Mayden 1987). Populations of Hemitremia can be found in Tennessee, Georgia, and Alabama (Figure 1). Flame chubs are relatively more abundant in Middle Tennessee than in East Tennessee, probably due to the presence of more suitable habitat in the lower sections of the Tennessee River. Specimens were collected in Kentucky before 1900 by David Starr Jordan and associates. However, the flame chub is considered to have been extirpated in Kentucky since no other collections have been reported. Habitat destruction or modification may have led to this disappearance. Hemitremia is widespread in the western portion of the Caney Fork River system of the Cumberland

Figure 1. Distribution map of Hemitremia flammea (after Boschung 1980; Etnier and Starnes in Litt.)

River drainage, and also occurs in Bledsoe Creek, a northern tributary to the Cumberland River in Sumner County (Etnier and Starnes, unpubl. manus. in Litt.). It is known from one locality in the Coosa River system of the Mobile Bay Basin. It is distributed throughout the Tennessee River system from the Knoxville area downstream to the Pickwick Reservoir area, and in the Upper and middle Duck River system. Specimens of Hemitremia have been collected in some tributaries of the Elk River and Sequatchie River systems. Only two populations have been reported to exist in the Little Tennessee River system, one in Abrams Creek, and one in Anthony Creek, a tributary to Abrams Creek (Ross 1962). What was reported as Anthony Creek may have actually been in Abrams Creek proper. The Abrams Creek population, along with a population in Pond Creek of the Tennessee River drainage, were the sources of information for this study.

Two age classes appeared in some collections of Hemitremia flammea (Starnes and Etnier 1980). Speculation has been that the spawning season occurs between late December and early June (Boschung 1980). During the spawning season, they display bright orange coloration below the lateral stripe, from the pectoral fins to the caudal fin. Information regarding food habits of the flame chub indicates that they feed mostly on terrestrial and aquatic insects (Boschung 1980).

Life history data on Hemitremia have been very limited in the past.

Hemitremia flammea occupies a relatively well-defined habitat. It is an upland species associated with clear, cold springs and spring-fed streams and is generally found in areas with abundant aquatic vegetation and firm substrate covered with organic matter (Burr and Warren 1986). The streams are primarily pastoral in nature, flowing through patchy, forested areas and farm land.

Because most Hemitremia populations are very restricted, they are vulnerable to modifications in or destruction of their habitat. In Tennessee, they are considered to be a species of "special concern" by the Tennessee Heritage Program and American Fisheries Society, and a species deemed "in need of management" by the Tennessee Wildlife Resources Agency (Starnes and Etnier 1980; Williams et al. 1989). Much of the known Hemitremia habitat has suffered from siltation due to agricultural development and removal of vegetation along the banks of the springs and streams (Armstrong & Williams 1971). Their habitat may also be threatened by fertilizer and pesticide runoff from cultivated fields, and by waste from livestock. Other southeastern spring fishes, which occupy the same type of habitat as the

flame chub, have suffered as a result of habitat degradation. For example, the spring pygmy sunfish, Elassoma sp., which inhabits limestone springs, has also suffered due to habitat alteration, siltation, and pesticide runoff (Ono et al. 1983). Removal of aquatic vegetation from a spring pool resulted in the destruction of a population of watercress darters, Etheostoma nuchale. High levels of nitrogen and coliform bacteria in a spring, probably due to contamination from surface water or fecal material, caused gas bubble disease in another population of watercress darters (Ono et al. 1983). These same factors which contributed to the population depletion of species associated with spring habitats could have caused destruction of flame chub populations in the past, and may appear as problems in the future.

Since little is known regarding the life history of Hemitremia flammea, the first objective of this research was to obtain information concerning age and growth data, reproduction, and food habits. A description of the stream characteristics, water quality, and associated flora and fauna was also included.

The second objective was to obtain a population estimate of the Hemitremia flammea population located in Abrams Creek in Cades Cove of the Great Smoky Mountains National Park and to characterize the habitat there.

Then, management recommendations to maintain the population at Abrams Creek could be developed, if possible. Because this is one of the only two recorded populations of _Hemitremia_ in the Great Smoky Mountains National Park and the Little Tennessee River drainage, it is important to maintain this population.

# CHAPTER II

## STUDY AREAS

The study site for this life history research was located in Loudon County, Tennessee and can be found on the Pattie Gap quadrangle USGS 7.5-minute topographic map. A 200-m stream reach running through a dairy cattle field owned by Mr. Morgan Gray was used to collect fish and water quality data. The stream originates at Richardson Spring and flows into Pond Creek, a tributary of the Tennessee River (Figure 2).

The stream flowed through a culvert at the upstream end of the study site. Above the culvert, the stream was choked with aquatic vegetation, making sampling extremely difficult. Below the site, the stream had little aquatic vegetation, but the riparian vegetation was dense. Since these areas were strikingly different from the 200-m reach, and few specimens of _Hemitremia flammea_ were collected in them, they provided natural boundaries to the study site. The cold spring water remained at a relatively constant temperature year round. The stream banks were generally steep, except in a portion of the pool at the head of the reach. Cattle caused considerable erosion of the stream bank by walking in and out of the stream. Thus, the substrate was characterized by predominantly silt and organic matter, with some small

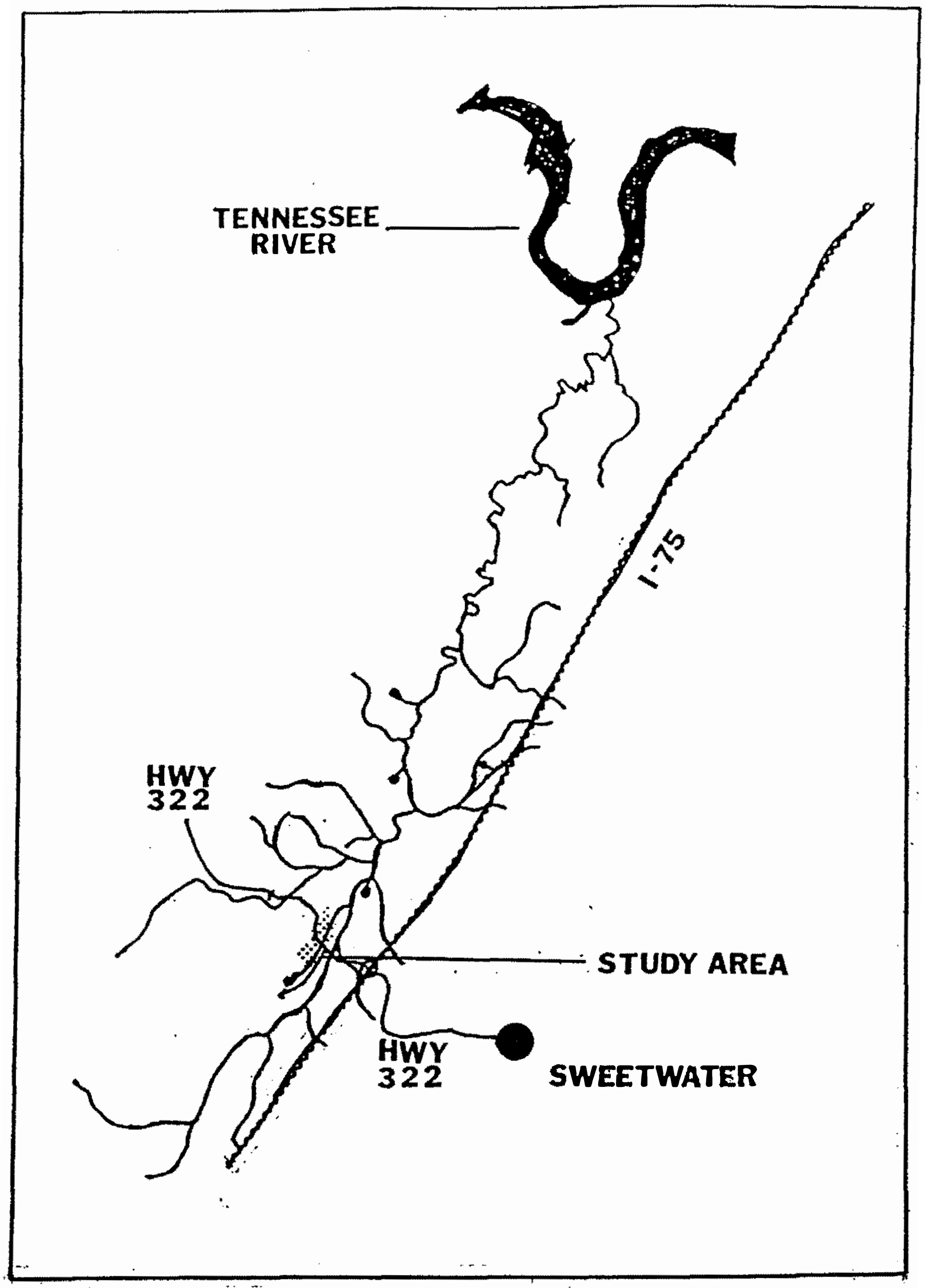


Figure 2. Map of the Pond Creek system in Monroe Co., Loudon Co., and McMinn Co., Tennessee

gravel. No riparian vegetation was present on the stream banks of the study site. However, aquatic vegetation was abundant, including smartweed (Polygonum coccineum), small pondweed (Potamogeton pusillus), watercress (Nasturtium officionale), cattail (Typha latifolia), water starwort (Callitriche heterophylla), and soft rush (Juncus effusus).

The second study site was located at Abrams Creek in Cades Cove of the Great Smoky Mountains National Park in Blount County, Tennessee. This location can be found on the Cades Cove quadrangle USGS 7.5-topographic map. Six spring seep areas where the water percolates up through the ground were the source of collections for the population estimates and habitat description. These seeps flow directly into Abrams Creek which in turn flows into the Little Tennessee River (Figure 3).

The study area was a shaded, boggy area near Abrams Creek, surrounded by fields utilized by cattle and horses and where hay was, and continues to be grown. One location occupied by Hemitremia flammea consisted of two stagnant pools which were evidently a part of the spring seep system running to the creek, but which were cut off by low water. The water flowing from the spring seeps was clear and cold. The substrate in these areas ranged from sand to silt to leafy organic matter. Woody debris

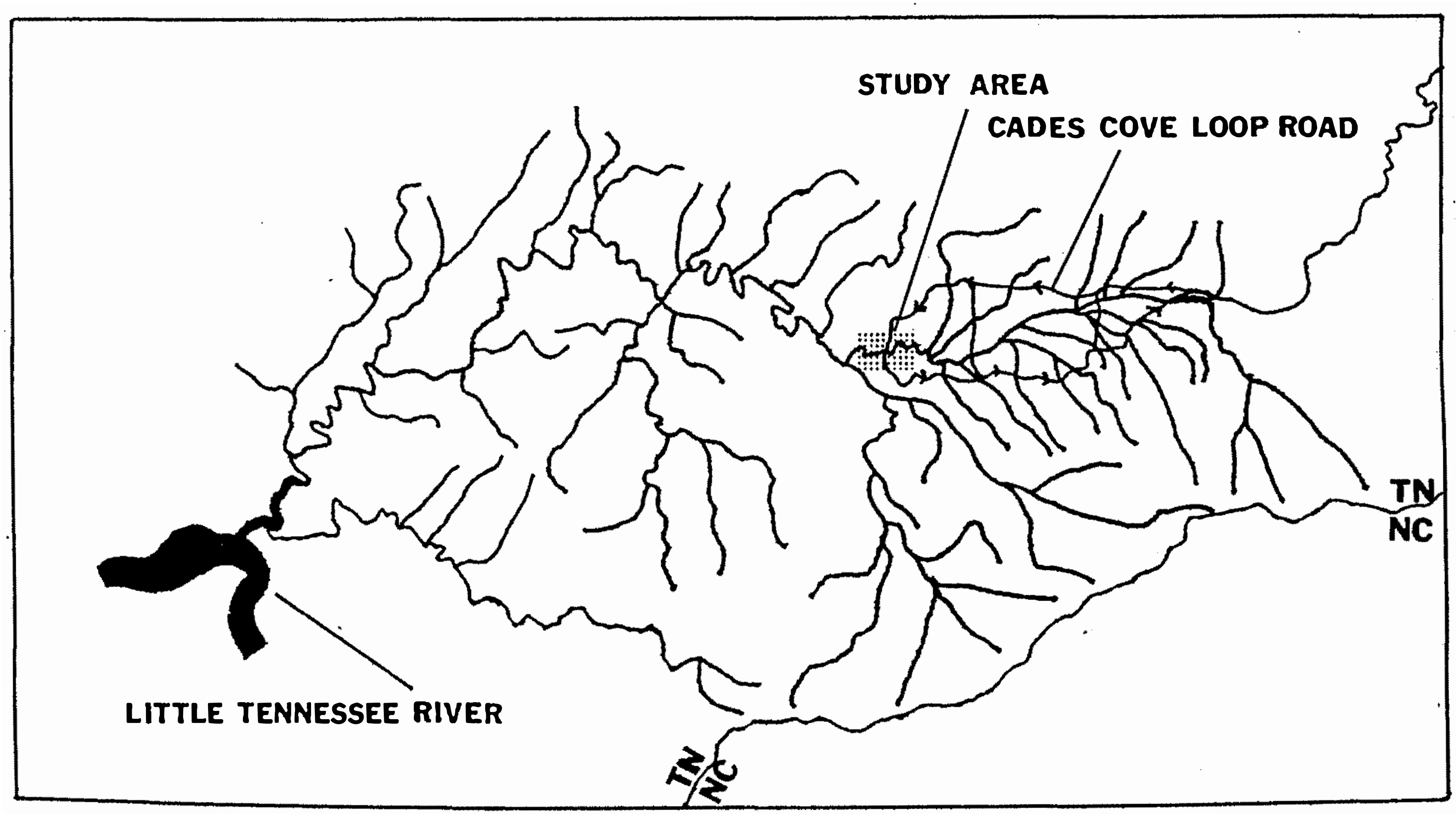


Figure 3. Map of the Abrams Creek system in Blount Co., Tennessee

was common in some areas in the stream. Riparian vegetation was present in all areas and was moderately dense. Aquatic vegetation was present, but not abundant, and consisted primarily of watercress. Some grasses were partially submerged on the periphery of one of the pools.

# CHAPTER III

## METHODS

In February 1989, the search began for a population of *Hemitremia flammea* large enough to study. Records of previous collections and locations were obtained from the University of Tennessee Research Collection of Fishes, Knoxville, and the Tennessee Heritage Program. Pond Creek of Loudon, Monroe, and McMinn counties was the targeted stream system, based upon previous collections and travel distance. Several springs were seined, but only very few specimens of *Hemitremia* were collected. After another failed attempt to find a substantial population in Pond Creek, efforts were made to locate one in Hickory Creek of Coffee county, and only a few specimens were collected. After communications with Bob Wallus of the Tennessee Valley Authority, a large population of *Hemitremia*, which was previously overlooked, was found in the Pond Creek System.

Life history data were collected from June 1989 to June 1990 on a monthly basis at the Pond Creek location; monthly intervals were used to avoid population depletion. The collection of 20 fish was the set goal for each monthly collection. A total of 243 flame chubs was collected using a 2.5 m long, 5 mm mesh seine throughout the course of the study. Immediately upon

capture, all of these specimens were preserved in 10% formalin and later stored in 40% isopropanol. These fish were weighed to the nearest 0.01 gram using a Scientific American electronic balance, and total lengths were measured to the nearest millimeter.

Age and Growth

Scale analysis verified by a length-frequency distribution was used to distinguish age groups. Scales from 183 flame chubs were removed from a point above the lateral line and below the dorsal fin. The scales from each fish were then placed on a glass slide for viewing. Scale analysis was accomplished by projection at 80X magnification on a Eberbach 2700 scale projector. The relationship between scale growth and body growth was assumed to be proportional. Therefore, the length at the time when each annulus was formed could be determined by back-calculation using the formula $L_a = (LS_a)/S$, where $L_a$ = fish length at age a, L = fish length, $S_a$ = length to annulus a, and S = scale length. Average length at the time each annulus was formed could then be calculated. Mean length at each age was also determined, using empirical data from those fish which were aged by scale analysis, to obtain an overall growth rate (Cragg-Hine and Jones 1969). In November, 99 fish were collected, and all were released except 20 which were

sacrificed for the monthly collection. Their total lengths were measured to obtain data for a length-frequency distribution; no weights were taken on those fish released. The age, determined by scale analysis, of each specimen collected in November was compared to the length-frequency distributions.

Length-weight relationships were determined by employing regression analysis. Mean lengths for each monthly collection were calculated and plotted for both sexes. Sex ratios for each month were determined and compared.

Reproduction

The gonads were excised from each fish to determine its sex. A binocular dissecting microscope and a compound microscope were used when the gonads were not mature. The gonads from each specimen were weighed to the nearest 0.0001 gram using a Mettler H35AR analytical balance. A gonadosomatic index (GSI) [(gonad weight/body weight) X 100] was calculated for each fish to determine maturation (Anderson and Gutreuter 1985). Changes in mean GSI values for each sex over time were used to estimate spawning season length and peak. Fecundity of the flame chub was determined by direct count. The number of ova in both ovaries of maturing females collected from February to June was counted, using a

gridded petri dish, a binocular dissecting microscope, and a hand counter. Regression analysis was performed to determine any relationship between body length of females and egg number. The presence of tubercles was monitored in males, and their pattern was described. Details of breeding coloration were noted in both sexes, as indicators of spawning season.

In March 1990, when brightly colored Hemitremia were collected at the study site, and females with developed eggs were found, 8 males and 9 females, were taken to the lab and placed in a 400-l tank with a viewing window. This living stream was set up in the lab to simulate the Pond Creek habitat and encourage spawning in captivity. A coolerator was used to maintain a constant water temperature comparable to the actual stream. A daylight fluorescent lamp was placed above the tank, and all other light was blocked out by black plastic sheets suspended from the ceiling. A timer was used on the illumination source to keep the light period as close to the actual day length as possible. Small gravel and sand were used as substrate, and Potamogeton, Nasturtium, and Polygonum were transported from the stream and planted in the substrate. The water was recirculated, flowing up through the coolerator, through the tank, and under the false bottom to the coolerator again. The fish were fed

frozen bloodworms and freeze-dried tubifex worms daily. The fish were fed as much as they could eat in 5 minutes, and no more. Records were kept of the day length, water temperature, and notes concerning their behavior. The fish were kept until the end of May and were then released at the study site. The study area was visited weekly in April and May in search of Hemitremia larvae.

## Food Habits

Data on the food habits study were gathered from 10 Hemitremia specimens from each monthly collection. Those fish with empty digestive tracts were discarded. The stomach and intestines of each fish were removed, cut open, and rinsed with a fine stream of 40% isopropanol into a petri dish. The contents were examined under a binocular dissecting microscope and a compound microscope. Dietary habits were studied by qualitative analysis of gut contents. Prey items were identified to their order when possible with assistance from Pennak (1978) and Needham and Needham (1938). The percent frequency of occurrence of each food item was calculated by dividing the total number of flame chubs in which the food item was present by the total number of digestive tracts (Lagler 1956; Windell 1968).

Habitat

Even though the nature of the area was spring like and little fluctuation in water level would be expected, average width and depth were measured every three months to determine if any seasonal changes in the water level occurred at the study area. Water quality data were collected on each sampling date. These measurements consisted of water temperature, pH, dissolved oxygen, acidity, alkalinity, carbon dioxide, and hardness. All of these characteristics were measured by a Hach Water Test Kit, except for temperature which was measured with an armored thermometer.

Samples of aquatic vegetation in the area were collected and identified. The composition of vegetation types was monitored throughout the study and changes noted. Other species of fish associated with Hemitremia flammea in the study area were also identified and monitored. Occasional samples of invertebrates were collected by sweeping through the aquatic vegetation and substrate with a fine mesh hand net.

Abrams Creek Population Study

A population estimate for each site in the Abrams Creek study area was performed once in March 1989 and once in December 1989. In those areas a three-pass depletion estimate was performed with a backpack

electroshocker to obtain data for a population estimate. The number of flame chub adults and juveniles was counted, and the fish were then released. To avoid any possible mortality caused by excess handling, no other measurements were taken for the Hemitremia specimens, due to the apparently low population size. In March, other species collected were counted to obtain estimates of their populations. Population estimates were obtained using a Microfish 3.0 computer program (Van Deventer and Platts 1989).

Each site in the Abrams Creek study area was measured to obtain the length and an average width and depth. In March, water quality measurements including temperature, pH, and dissolved oxygen were taken. Vegetation types and abundance were noted. These conditions were compared to those at the Pond Creek location to determine if anything could be done to improve the quality of the population in Abrams Creek.

# CHAPTER IV

## RESULTS AND DISCUSSION

### Age and Growth

Based on analysis of scales and length frequency distributions, the life expectancy for most *Hemitremia flammea* was determined to be between 1-1.5 years with a few 2 year olds. Scale examination was difficult since annuli were generally not distinct. Growth rings were relatively evenly spaced, but a slight reduction in spacing, along with broken, branching, or irregular rings on all scales examined indicated location of annuli. The even spacing was probably a result of constant water temperatures year round. *Percina tanasi* scales were also difficult to read due to temperature uniformity (Starnes 1977). Scale analysis of 183 specimens revealed that three age classes were present in the collections. Age 0 fish accounted for 59% of those examined, age 1 fish made up 39%, and 2% were age 2. These 2-year old fish may have been those which hatched very late in the spawning season and did not mature soon enough to contribute to the following reproductive season. They then lived through the next year to spawn as 2 year olds.

Body lengths for each age were determined from back-calculations using the relationship between scale growth and body growth assuming isometric growth. The mean

length at the time the first annulus appeared was 37 mm, and 48 mm for the second annulus. The mean length for age 0 was 40 mm, for age 1 was 52 mm, and was 56 mm for age 2. Actual lengths at each age obtained from actual fish measurements exceeded those determined from back-calculation. This discrepancy is apparently common among other fish, and results when the fish has grown before the scales are developed (Everhart and Young 1981).

A length-frequency distribution (Figure 4) obtained from 99 flame chubs collected in November, containing all three age groups, was used for comparison. Of those included in the distribution, 20 were taken for scale analysis. Overlapping in lengths of age groups was observed; age 0 fish up to 48 mm were found, and age 1 individuals ranged from 46 to 57 mm, but the age 2 fish were only 54 and 59 mm. Age groups 0 and 1 were well-defined, but age group 2 had only 2 representatives. This is usually the case when a subsample is taken to determine age of each individual (MacDonald 1987).

Young-of-the-year fish appeared in all collections with the exception of June 1989 and 1990, and accounted for most of the individuals from August 1989 to January 1990. It was evident when looking at the age composition and mean length for each month, that most adults were absent from the collections during this time. Young-of-the-year apparently formed their annuli sometime in

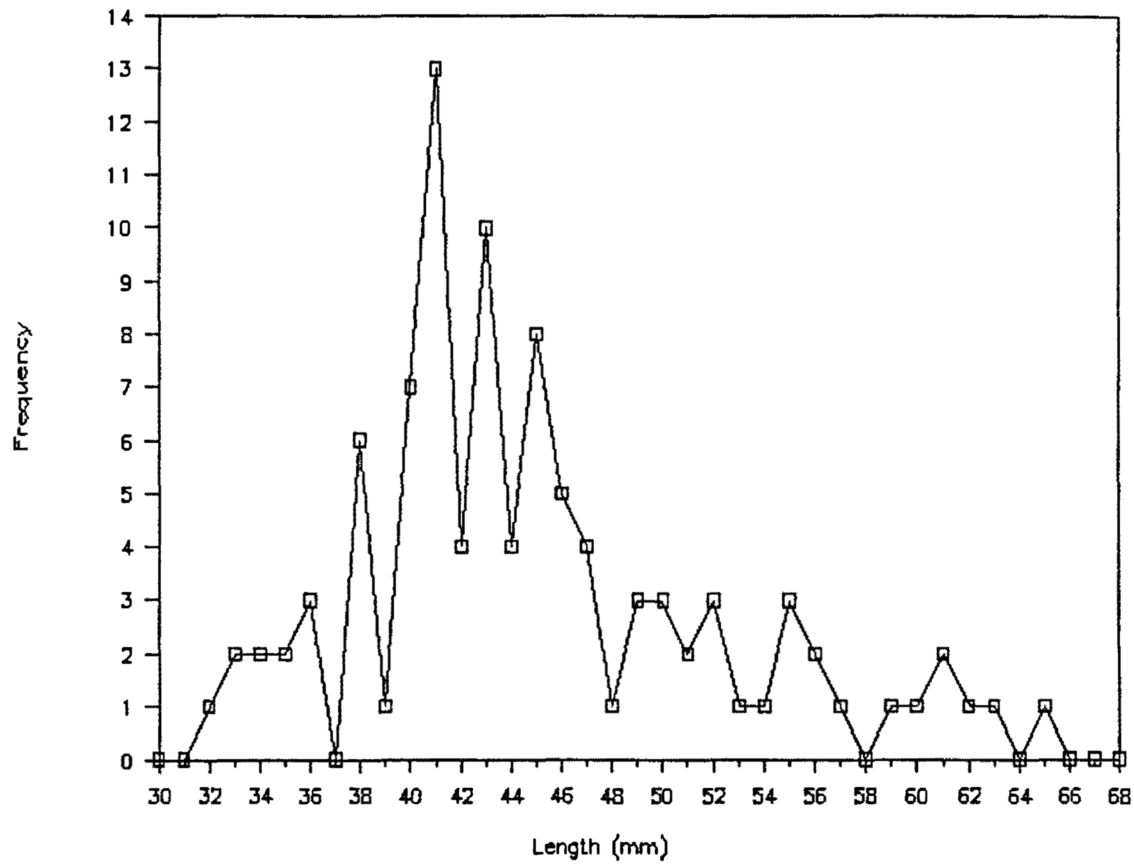


Figure 4. Length-frequency distribution of 99 specimens of Hemitremia flammea collected at Pond Creek in November 1989

February, possibly coinciding with maturity. Monthly changes in size composition were most likely caused by recruitment of young-of-the-year and mortality of adults. A decrease in mean length (Figure 5) from June to August suggested post-spawning mortality. Age and growth of a population of Notropis longirostris examined by Heins and Clemmer (1976) was close to that of the flame chub. Many other cyprinids including Phoxinus eos, Hybopsis aestivalis, H. amblops, and H. dissimilis have life expectancies similar to the Hemitremia found in this study (Carlander 1969). Small species such as these generally have a short life expectancy, and therefore usually mature at an early age.

The length-weight relationship is commonly expressed by the formula: $W = aL^b$, where W = weight, L = length, and a and b are constants determined from regression (Anderson and Gutreuter 1983). Normally for most fishes, the weight is the length cubed. However, the parameter b was estimated at 2.0 for Hemitremia, which indicates that as their lenght increases, there weight does not increase as much as normal (Anderson and Gutreuter 1983). The a and b values calculated here were generally lower than those of other cyprinids surveyed by Carlander (1969). For this study, length-weight relationships were calculated separately for each sex.

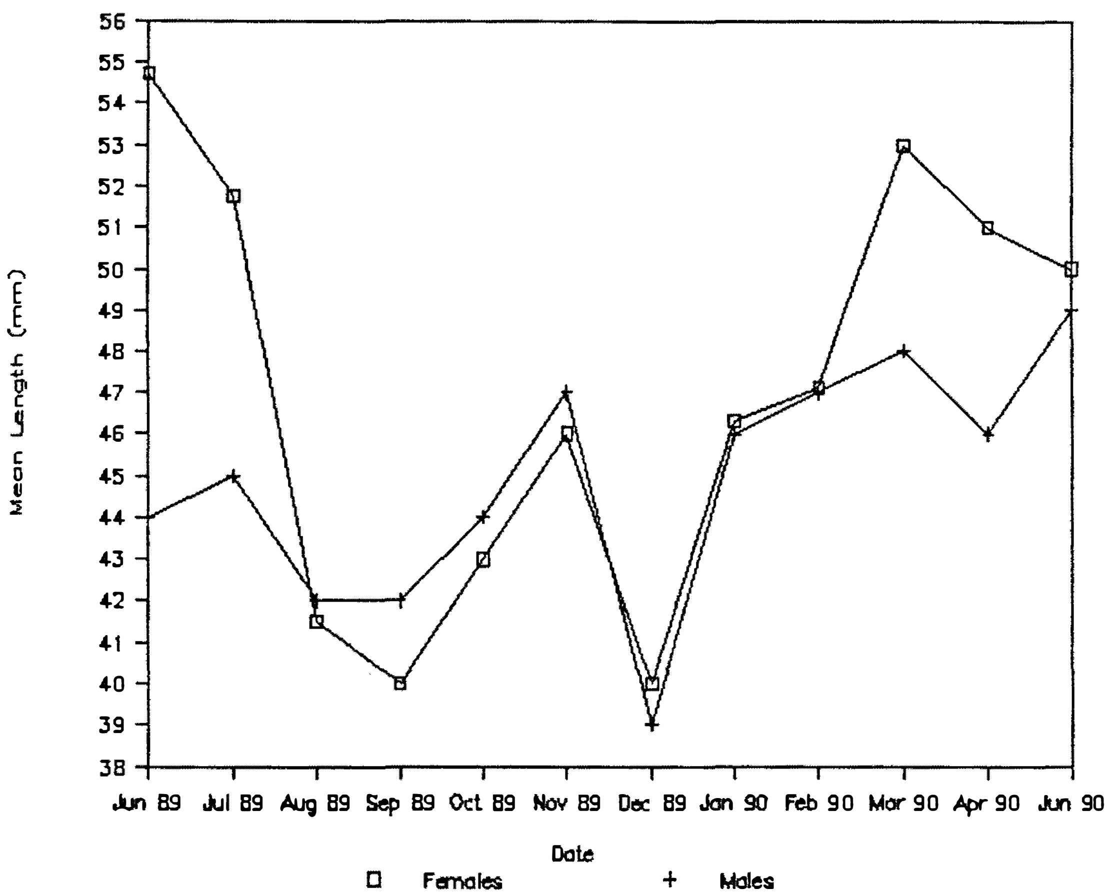


Figure 5. Mean lengths of male and female Hemitremia flammea in monthly samples collected at Pond Creek (N = 243)

The equations for these relationships are listed in Table 1. It might be expected that the length-weight relationship would be different between sexes, due to egg production of the females during spawing season. However, this was not the case; the relationships were virtually the same. This could have been a result of increased musculature in the males during the same period, which occurred (Burkhead 1980) in *Campostoma anomalum*.

*Hemitremia flammea* ranging from 27 to 68 mm TL were collected throughout the study. The largest female measured 68 mm TL and the largest male was 55 mm TL. Males and females appeared to grow in length at the same rate throughout most of the year, with the exception of the spawning season. During this time, females generally accelerated in growth and surpassed males in length (Figure 5). Other authors have observed growth patterns similar to that of the flame chub in other cyprinids. In *Notropis blennius* and *N. cummingsae* spawning females had a larger average size than males, and the largest specimens of *N. bifrenatus* were females even though there were no sexual differences in growth (Carlander 1969).

Overall, the sex ratio of those fish collected at Pond Creek was 1 male to 1.4 females. Sex ratios changed during the year, slightly favoring the males in late summer and fall samples, and greatly favoring the females

Table 1. Length-weight equations for each sex of *Hemitremia flammea* collected at Pond Creek.

| Sex | Equation |
|---|---|
| Females | $W = .0006\ L^{2.0}$ |
| Males | $W = .0005\ L^{2.0}$ |

in part of the breeding season samples (Table 2). Unequal sex ratios have been reported for other cyprinids such as Notropis maculatus which favored females (Cowell and Barnett 1974) and Rhinichthys atratulus which was skewed toward males (Tarter 1969). A possible explanation for the presence of more males in the months following the spawning season could involve higher mortality of females after the reproductive season. The faster rate of growth exhibited in females during that time may have resulted in a shorter life span. The appearance of more females than males could have been because of sampling bias during spawning season. For instance, in Campostoma anomalum, sexual segregation of adults during the spawning season caused a shift in the sex ratios toward females and in turn biased the sampling (Burkhead 1980). A greater number of females could also serve to enhance reproductive success.

## Reproduction

The mean gonadosomatic index (GSI) of male and female Hemitremia flammea specimens was calculated for each monthly sample and these were then plotted against time to illustrate gonadal development and the length and peak of the spawning season (Figure 6). The ovarian weight of one female collected in April comprised over

Table 2. Sex ratios of males to females for each monthly collection of *Hemitremia flammea* at Pond Creek

| Date | Males | # Females | Sex Ratio(M:F) |
|---|---|---|---|
| JUN | 1 | 19 | 1:19 |
| JUL | 8 | 13 | 1:1.6 |
| AUG | 11 | 6 | 1.8:1 |
| SEP | 12 | 9 | 1.3:1 |
| OCT | 12 | 8 | 1.5:1 |
| NOV | 8 | 13 | 1:1.62 |
| DEC | 9 | 11 | 1:1.2 |
| JAN | 10 | 10 | 1:1 |
| FEB | 4 | 18 | 1:4.5 |
| MAR | 5 | 14 | 1:2.8 |
| APR | 9 | 11 | 1:1.2 |
| JUN | 10 | 10 | 1:1 |

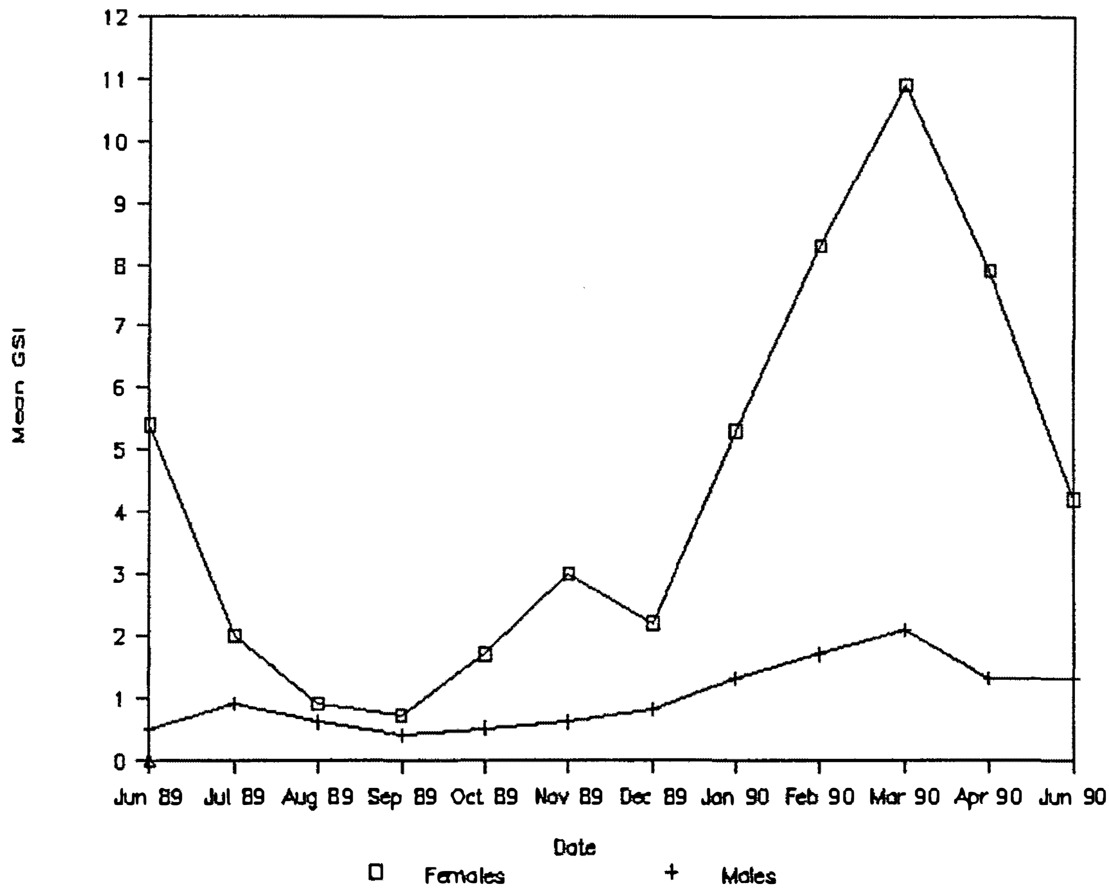


Figure 6. Mean gonadosomatic indices (GSI) for male and female <u>Hemitremia</u> <u>flammea</u> in monthly samples collected at Pond Creek (N = 243)

26% of the total body weight. Females with GSI values higher than 8.0 were considered to be mature, due to the presence of mature ova in these fish. An accelerated increase in ovarian weights began in late January and was interpreted as the onset of the reproductive season. Because mature and immature fish were considered together, the mean gonadosomatic index was not as high as the value for mature females, but two individuals had GSI values of 8.9 and 11.6. Ovarian weights increased rapidly until March when they reached a maximum, indicating the peak in the spawing season. Mean gonadosomatic indices decreased steadily following the peak in March. Also, females with only a few eggs left in the ovaries, some of which were in the state of reabsorption, were present in June collections of both years. In the previous year, GSI values declined until they reached their minimum in September. The presence of spent females and reduced ovarian weights indicated the completion of spawning.

Individual GSI values for males ranged from 0.2 to 2.5 and did not vary as greatly as those for females. Gonadosomatic indices decreased slightly from July to September when they reached their minimum. Values began to increase slowly in October, accelerated slightly in January, and steadily increased until maximum values were reached in March. A small decline occurred in April and

then values stabilized. The males in this population followed the same trends as the females throughout their reproductive cycles, but on a much smaller scale.

Based on the monthly changes in the relationship between gonad weight and body weight of females and males, it was concluded that the spawning season of Hemitremia flammea in Pond Creek began in January, peaked in March, and ceased in July. The occurrence of multiple spawning in one reproductive season by individuals was not determined in this study.

Sexually mature specimens of both sexes were taken in June 1989, and in all collections between January and June 1990. Data showed that Hemitremia became sexually mature in their first year of life. The sexes did not necessarily mature at the same size and age. Males were found to mature at an earlier age and smaller size than females. The smallest mature male was age 0 and 40 mm TL. The smallest mature female was age 1 and measured 47 mm TL. Females were generally larger than males in June and July of 1989. The mean lengths for females exceeded the mean lengths for males from February to June 1990 (Figure 5). These sexual differences in lengths appeared to coincide with the spawning season.

Sexual dimorphism commonly occurs among the cyprinids. Hemitremia males and females exhibited some

differences throughout most of the study period. Nuptial males developed breeding tubercles beginning in October; during the spawning season, the majority of all males captured had tubercles. Large tubercles in a single row of 4-6 were occasionally found on the dorsal margin of the eye, but were absent elsewhere on the head. Small tubercles were scattered across the operculum and were present in a single row on the outer margin of the operculum and interoperculum. Also, the suboperculum was surrounded by a single row of small tubercles. The margins of the brachiostegal rays, except the innermost ray, were also lined with small tubercles. All body scales had 8-15 small tubercles on the scale margins, except the breast and belly scales from the pectoral fins to the anal fin. Scales on the nape from the head to the dorsal fin had no tubercles on their margins either. Large tubercles were present on the pectoral fins, beginning in a single row at the base of each ray, and increasing to 2-3 tubercles in a row toward the edge of the fin on the most anterior rays; tubercles became less prominent on the posterior rays. No tubercles were present on the leading ray of the pectoral fin or posterior to the seventh ray. Tubercles were not found on the pelvic, anal, caudal, or dorsal fins.

Both sexes displayed varied color intensities under the lateral stripe from the pectoral fins to the caudal

fin, ranging from no color to brilliant orange. Males were usually much brighter than females, and generally exhibited some coloration, although varied, throughout the year. Brightly colored males appeared only during the spawning season. Brightly colored females which had already spawned were observed in June 1989 and 1990, but were most often colored light orange from November to June.

Fecundity of individual females could depend on a number of factors including age, size, and condition. Because of obvious gross changes in ovaries, ova in mature females collected from February to June were counted to obtain fecundity data. Two types of eggs were found in all females examined; some were small and transparent, and others were larger and opaque. Egg numbers varied from 346 in a 54-mm specimen to 2165 in a 68-mm specimen. The mean number of eggs in females during the spawning season was 794. The total length and number of ova are listed in Table 3. Fecundity of these females was higher than that of some other cyprinids of similar size and life expectancy, such as *Notropis maculatus* and *N. longirostris* (Cowell and Barnett 1974; Heins and Clemmer 1976).

Fecundity is generally related to the length of the female fish (Bagenal and Braum 1968). Usually the

Table 3. Total lengths and ova numbers of 25 mature *Hemitremia flammea* females collected from February to June 1990 at Pond Creek

| Date | Total Length | Ova number |
|---|---|---|
| 02-27-90 | 54 | 778 |
| 02-27-90 | 51 | 702 |
| 02-27-90 | 56 | 880 |
| 02-27-90 | 53 | 674 |
| 02-27-90 | 47 | 594 |
| 02-27-90 | 60 | 897 |
| 02-27-90 | 50 | 606 |
| 02-27-90 | 58 | 874 |
| 02-27-90 | 60 | 805 |
| 03-28-90 | 50 | 607 |
| 03-28-90 | 55 | 507 |
| 03-28-90 | 68 | 2165 |
| 03-28-90 | 55 | 775 |
| 03-28-90 | 68 | 1222 |
| 03-28-90 | 53 | 561 |
| 03-28-90 | 53 | 733 |
| 03-28-90 | 55 | 892 |
| 03-28-90 | 57 | 638 |
| 04-27-90 | 49 | 614 |
| 04-27-90 | 57 | 807 |
| 04-27-90 | 60 | 860 |
| 04-27-90 | 55 | 519 |
| 04-27-90 | 59 | 1179 |
| 06-09-90 | 54 | 346 |
| 06-09-90 | 51 | 617 |

relationship between fecundity and length is found to be linear, as in females of *Rhinichthys atratulus* (see Tarter 1969) and *Notropis baileyi* (Mathur and Ramsey 1974). However, the relationship between the number of eggs and total length of *Hemitremia* females was not determined to be linear. The following equation was derived ($R^2$ = .71):

$$N = 483 + 80e^{[0.13(L-47)]}$$

where N = number of eggs, and L = body length. Although the relationship was not linear, a relative increase in the number of ova occurred as the total length increased, and fecundity therefore depended on size of the female.

During the spawning season flame chubs began to be much more abundant in the study area. Beginning in March, large aggregations of flame chubs appeared in the study area. They generally swam in large groups in open water but when disturbed, they would scatter and dart to cover or swim in the opposite direction of the disturbance. This behavior was also observed to some extent in the living stream.

Eggs were found on some of the vegetation in the living stream and at the study site, but these eggs were not those of flame chubs. The study area was visited weekly during the middle part of the spawning season, but no recently hatched larvae were observed.

A survey of literature pertaining to reproduction in

fishes indicated that photoperiod and temperature are the most important factors regulating gonadal development and the onset of reproduction. The water temperature at the study site varied little during the spawning season of *Hemitremia flammea*, ranging from 11 C to 17 C. Therefore, due to thermal constancy, it was suspected that photoperiod played a more important role. Other external factors may have also affected the reproductive cycle, but were not determined in this study.

## Food Habits

Qualitative analysis of the dietary habits of *Hemitremia* revealed that they utilized a varied range of food items (Figure 7). Dipteran larvae and pupae were the dominant food item, appearing in 77% of all digestive tracts examined. From June to August 1989 and from December to June of the following year, dipterans were found in 70-100% of the digestive tracts of all specimens analyzed. Only from September through November did the percentage of flame chub stomachs containing dipterans fall below 50%. Other species in the family Cyprinidae have similar food habits (Carlander 1969; Cowell and Barnett 1974). Detritus consisting of organic matter, macerated plant material, and bottom ooze appeared in 17% of the fish. Sand also appeared frequently among the other food items, but in small

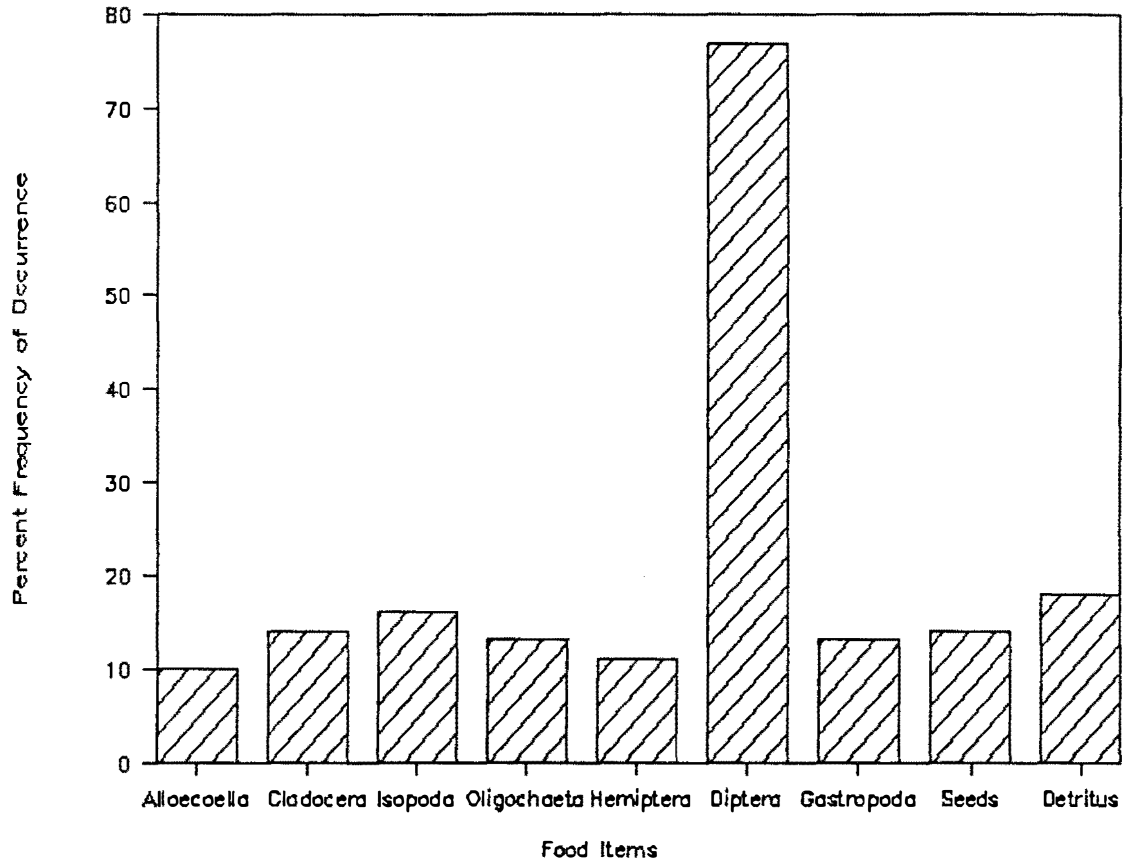


Figure 7. Percent frequency of occurrence of food items found in the digestive tracts of 120 <u>Hemitremia flammea</u> collected at Pond Creek

amounts. The presence of detritus and sand indicated some feeding activity on or near the bottom in fish such as Notropis maculatus and N. longirotris (Cowell and Barnett 1974; Heins and Clemmer 1975). On many occasions flame chubs were observed pecking on the bottom in the living stream and were also seen nipping at the plants. Seeds which appeared to be from pondweed plants were occasionally found in digestive tracts from September through April, and occurred frequently in October (40%) and March (50%). Seeds of various sedges appeared in a food study of Notropis longirostris (see Heins and Clemmer 1975). Listed in decreasing order of abundance, other food items included isopods, cladocerans, gastropods, hemipterans, and aquatic oligochaetes. Flatworms occurred in some of the digestive tracts and were only identified to the Class Alloecoella. The number of digestive tracts in which each food item occurred in the monthly collections appears in Table 4.

Food selection was not included in this study since samples of potential food items were not taken in the monthly collections. However, invertebrates were collected occasionally in the vegetation and substrate and are discussed in the habitat section. Dipterans were abundant as well as isopods and gastropods at times. Availability may have been an important factor in

Table 4. Frequency of occurrence of food items in digestive tracts of 10 *Hemitremia flammea* from each monthly collection at Pond Creek

| | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | JUN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alloecoella | 1 | 2 | - | 1 | - | - | - | 1 | 2 | 3 | 1 | 1 |
| Oligochaeta | 3 | - | - | 4 | 4 | 1 | 1 | - | 1 | - | 1 | - |
| Cladocera | 6 | 3 | 1 | 1 | 1 | 3 | 1 | - | - | - | - | 1 |
| Isopoda | 2 | 7 | 3 | 1 | - | 4 | 1 | 1 | - | - | - | - |
| Hemiptera | 2 | 2 | 3 | 4 | - | - | - | - | - | - | - | 2 |
| Diptera | 9 | 10 | 7 | 2 | 3 | 5 | 9 | 9 | 10 | 8 | 10 | 10 |
| Gastropoda | 3 | 1 | 4 | - | 1 | 1 | 1 | 1 | - | 2 | - | 2 |
| Seeds | - | - | - | 1 | 4 | 1 | 3 | - | 2 | 5 | 1 | - |
| Detritis | 5 | 3 | 2 | 2 | - | 4 | 1 | 1 | 1 | 1 | 1 | 1 |

determining the diet of the flame chub. Also, larger individuals were more likely to be better able to prey upon larger food items than smaller fish (Heins and Clemmer 1975).

Habitat

The Pond Creek study site had an average width of 5.1 m. Water levels decreased throughout the study period. Average depth dropped from 42.2 cm in June 1989 to 24.3 in March 1990, and average stream width decreased from 6.2 m to 4.9 m. Water levels at the study site remained low during periods of heavy rain and flooding, possibly indicating a drop in the water table.

The water remained clear throughout most of the study period, but became increasingly turbid in the spring of 1990. Cattle watered in the stream, adding organic matter and soil to the water, and causing further turbidity. One characteristic of the study site was the relatively constant water temperature, due to the proximity to the spring. The water temperatures at the study site averaged 15 C, and ranged from 11 C in January to 17 C in April. The stream was well-oxygenated, with an average dissolved oxygen content of 8 mg/l. The dissolved oxygen was highest in February at 10 mg/l and lowest in June at 4 mg/l. The pH, approximately neutral throughout the year, was 7.5 every month, with the

exception of July when it was neutral (7.0). Other parameters describing water quality are listed in Table 5.

Extensive masses of aquatic vegetation furnished ideal shelter for Hemitremia flammea and other fish in the study area. Large clumps of completely or partially submerged swamp smartweed (Polygonum coccineum) provided cover throughout the year. Other relatively large areas were covered by small pondweed (Potamogeton pusillus) during the spring and summer. Pondweed grew upstream and separate from the smartweed, but both were utilized by the fish. During the fall and winter months when the pondweed disappeared, flame chubs moved downstream to seek cover in the smartweed. Watercress (Nasturtium officionale) was scattered throughout patches of both pondweed and smartweed and was abundant most of the year. Waterstarwort (Callitriche heterophylla) appeared occasionally during the spring and summer months. Cattail (Typha latifolia) and soft rush (Juncus effusus) were sparse but occurred through all seasons. Aquatic plant life obviously played an important role in the life of the flame chub, as it provided shelter for the fish, as well as the invertebrates which the fish preyed upon. Six other commonly occurring species made up the fish community at the study site. The mosquitofish, Gambusia affinis, was abundant throughout most of the year at the

Table 5. Water quality data collected each month of the study period at Pond Creek

| Date | Temp.(C) | D.O. (mg/l) | Hard. (mg/l) | CO2 (mg/l) | pH | Acid. (mg/l) | Alkal. (mg/l) |
|---|---|---|---|---|---|---|---|
| JUN | 16 | 9 | 181 | 30 | 7.5 | 0 | 181 |
| JUL | 15 | 7 | 181 | 30 | 7.0 | 0 | 170 |
| AUG | 15 | 7 | 181 | 25 | 7.5 | 0 | 181 |
| SEP | 15 | 7 | 170 | 10 | 7.5 | 0 | 198 |
| OCT | 16 | 9 | 181 | 30 | 7.5 | 0 | 198 |
| NOV | 16 | 7 | 181 | 15 | 7.5 | 0 | 181 |
| DEC | 12 | 9 | 181 | 20 | 7.5 | 0 | 181 |
| JAN | 11 | 8 | 119 | 15 | 7.5 | 0 | 136 |
| FEB | 14 | 10 | 119 | 20 | 7.5 | 0 | 102 |
| MAR | 15 | - | 153 | 15 | 7.5 | 0 | 153 |
| APR | 17 | 9 | 181 | 20 | 7.5 | 0 | 170 |
| JUN | 16 | 4 | 198 | 25 | 7.5 | 0 | 170 |

study site. They were closely associated with the flame chub by utilizing the same habitat. *Gambusia affinis* were generally gregarious in open water, seeking cover in the vegetation when disturbed, behaving much like flame chubs. The bigeye chub, *Hybopsis amblops*, and blacknose dace, *Rhinichthys atratulus*, as well as fry of green sunfish, *Lepomis cyanellus*, and largemouth bass, *Micropterus salmoides*, were frequently collected in the vegetation. The banded sculpin, *Cottus carolinae*, were abundant throughout the year on the stream bottom and occassionally in the vegetation. Species such as the golden shiner, *Notemigonus crysoleucus*, and fathead minnow, *Pimephales promelas*, were each present on one occasion at the study site. In the spring, *Hemitremia* was the most abundant species in the study area.

Aquatic invertebrates were found in the vegetation and substrate including aquatic oligochaetes, amphipods, and odonate nymphs. Other invertebrates such as isopods, gastropods, dipteran larvae and pupae, and hemipterans were abundant. These invertebrates, with the exception of the odonate nymphs, were preyed upon by flame chubs, and were of great importance in their diet.

## Abrams Creek Population Study

In late 1988, six spring areas in Abrams Creek in Cades Cove of the Great Smoky Mountains National Park

were sampled, and approximately 20 specimens of Hemitremia flammea were collected. In March and April of 1989, the area was resampled so that population estimates could be made for the flame chub and associated species. Flame chubs were present in only two of the previously sampled locations. A three-pass depletion using a backpack electroshocker was performed in each of these areas. Only 7 flame chubs were collected in site 1, and the population estimate generated by Microfish 3.0 (Van Deventer and Platts 1989) was 8, with a lower 95% confidence interval of 7, and an upper confidence interval of 15. All flame chubs collected at this site were juveniles. Other species inhabiting this area were white sucker, Catostomus commersoni; blacknose dace, Rhinichthys atratulus; stoneroller, Campostoma anomalum; creek chub, Semotilus atromaculatus; and Tennessee snubnose darter, Etheostoma simoterum. Population estimates for each species are listed in Table 6. Flame chubs were the only species found in site 2. This area consisted of two small pools adjacent to each other. In the first pool, the flame chub population size was estimated to be 11 with lower and upper 95% confidence intervals of 7 and 35, respectively; the actual number of flame chubs collected was 7. In the second pool, only 3 flame chubs were present, and the population size was

Table 6. Population estimates and 95 % confidence intervals (CI) for five species collected in March 1989 at site 1 of the Abrams Creek study area

| Species | Population Estimate | Lower CI | Upper CI |
|---|---|---|---|
| Flame Chub | 8 | 7 | 15 |
| White Sucker | 35 | 32 | 42 |
| Blacknose Dace | 146 | 139 | 154 |
| Stoneroller | 27 | 25 | 32 |
| Creek Chub | 103 | 78 | 134 |

estimated to be the same, with lower and upper 95% confidence intervals of 3 and 4, respectively. All specimens appeared to be adults, and some were displaying breeding coloration. No other species of fish were found in these pools. The study area was visited again in December 1989 to monitor the population size. Only 2 flame chubs were found in the area; one adult was in the large pool at site 1 and another adult with breeding coloration was found at site 2.

Site 1 of the Abrams Creek study area originated where water percolated up through the ground into a large pool which averaged 19.7 m long, 20.4 m wide, and had an average depth of 8.6 cm. A small side spring, 11 m long and 2 m wide, flowed into the large pool and had an average depth of 21.1 cm. The water then flowed through a 28 m long channel and into Abrams Creek. The average width was 6 m wide, and the average depth was 16.5 cm. The mouth of the channel was the boundary to the site. Site 2 consited of two small pools, which had no water flowing through them on either collection date. This was probably due to low water levels at the time. The first pool was 5.7 m long, 1.6 m wide, and averaged 13.2 cm deep. The second pool was 5.6 m long, 2.3 m wide, and averaged 9.2 cm deep.

The water was clear and cold at site 1, ranging from 14 to 15 C during the sampling period. Dissolved oxygen

levels ranged from 6 to 8 mg/l. The pH was nearly neutral, with values ranging from 7.0 to 7.8. The water quality was not as good at site 2, since the pools had no water flowing through them. The water temperature at site 2 was only slightly warmer (16 C) than site 1. However, the dissolved oxygen content was quite low at 3 mg/l; the pH was slightly acidic at 6.5.

When the study area was first sampled, watercress was abundant at site 1. At the time of the first population estimate in March, it was much less abundant and only in a few clumps throughout the site. In December watercress was scarce, probably due to the cold temperatures. No aquatic vegetation was present at site 2 on either occasion.

A population was found in Anthony Creek in 1962, but flame chubs have not been collected in the area recently. It is possible that this population is actually the same population as the one studied here. What Ross considered Anthony Creek may actually been part of Abrams Creek proper. Since this population and the study population are the only two reported in the Little Tennessee River system and the Great Smoky Mountains National Park, a continued survey of potential habitat in the Abrams Creek system might be beneficial in locating any other flame chub populations if any are present.

Since the *Hemitremia* population at the study area is so small and appears to be declining, it should be monitored on an annual basis. Due to National Park regulations, habitat management is not feasible. However, protection of the flame chub from surrounding agricultural practices is possible, and amelioration of recent habitat degradation caused by grazing may be feasible.

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