NATURAL HISTORY AND CHARACTERISTICS OF *PIMEPHALES VIGILAX* (BAIRD AND GIRARD)

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1939

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1952

Submitted to the faculty of the Graduate School of
Oklahoma State University in partial
fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
August, 1962

NATURAL HISTORY AND CHARACTERISTICS OF PIMEPHALES VIGILAX

(BAIRD AND GIRARD)

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ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. W. H. Irwin, Oklahoma State University, under whose guidance the study was carried out, for his understanding and wise council and his example of high standards in research. To Drs. Roy W. Jones, George A. Moore, L. Herbert Bruneau, of the Zoology Department; Dr. Robert D. Morrison, Statistician, who furnished valuable advice and criticism; and to Dr. William A. Drew, Entomologist, who assisted in classifying the Arthropoda in the stomach contents of fish, the author is indeed grateful.

Appreciation is also expressed to my wife, Genevieve, and our three children, whose moral and spiritual support was a continuous inspiration.

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CHAPTER I

INTRODUCTION

The material included in this thesis concerns *Pimephales vigilax* (Baird and Girard). Particular studies were made concerning the description from a population segment distribution, food used, feeding habits, general behavior, breeding habits, scale profile, and characteristics usable for identification. Embryological stages were not studied. Studies were made in the laboratory and in a small pond five miles north of Oklahoma State University campus during 1960 and 1961.

Pimephales vigilax is a member of the fish family Cyprinidae. Individuals of the family constitute a large portion of the food of commercial and game fishes. The bullhead minnow, *P. vigilax,* is important commercially as a bait species. No literature dealing specifically with the breeding habits, growth, food, behavior or general life history of the species was found.

Studies of the feeding habits of minnows were initiated in the United States by Forbes (1883) through his work in Illinois. Subsequently, such investigators as Pearse (1915, 1918, 1921), Kraatz (1928), Harrington (1948), and Ewers (1933, 1935) made significant contributions in the field.

An objective of the study was to learn the types of food eaten and the proportional amounts taken by the minnow.

Research on life histories of fishes often utilizes a method of interpreting the age of fishes through evidences provided by growth rings upon the scales. The scales sometimes form annual rings which can be counted to determine the age of a fish. Since the diameter of the scale increases proportionately with the length of the fish, the calculation of growth for each year of its life is possible. With this in mind, a study was made to reveal the scale-body relationships, age, and growth of the bullhead minnow.

The history of synonymy shows that difficulty has been experienced in finding characters that clearly describe each species. The purpose, herein, was to test the characters to learn which could be used to present a good word picture of _P_. _vigilax._ The literature was searched for characters that might help. Characters which epitomize _P_. _vigilax_ were applied to an available population, the sampled data were gathered, and analyzed to see if the measured characters changed with different samples.

CHAPTER II

REVIEW OF LITERATURE

The species, _Pimephales vigilax_ is much discussed taxonomically. The common names have also been numerous, but most generally _P. vigilax_ is called the bullhead or parrot minnow. The synonymy and the early history of collections have been reviewed efficiently by Hubbs and Black (1947).

Descriptions from Literature

The types, _Ceratichthys vigilax_ (Baird and Girard), collected by Capt. R. B. Marcy and Lieut. G. B. McCellan were described by Baird and Girard (1853) as follows:

> Body fusiform compressed; specimens before us two inches long, probably immature. The head forms the fifth of the length. The eyes are rather small. The dorsal fin is longer than high; its anterior margin situated almost at the same distance from the snout and the base of the caudal fin. Caudal fin forked, anal back of the dorsal. Base of ventrals behind the anterior margin of the dorsal; tip not reaching the anal fin. Pectorals not reaching the base of ventrals. The pectorals, ventrals and anals are proportionally small compared to the dorsal D9, A8, C3, 18.8, I3, V8, P14.
>
> Scales large; lateral line running through the middle of the sides, slightly bent downwards on the abdomen. Black brownish yellow, a greenish gray stripe down each side covering the lateral line.

The genus _Pimephales_ was described by Rafinesque in 1899 as follows:

> Body oblong, thick and scaley, vent posterior near the tail. Head scaleless, fleshy all over, even over the gill covers, rounded, convex above and short. Mouth terminal,

> small, toothless, with hard cartilaginous lips. Opercle double, three branchial rays. Nostrils simple. Dorsal fin opposite the abdominals, with the first ray simple and cartilaginous. Abdominal fins with eight rays.
>
> A singular new genus, which differs from *Catostomus* by the terminal mouth, hard lips, soft head, simple dorsal ray and caudal. The name is abbreviated from Pimelecephales which means fat-head.

The bullhead minnow or parrot minnow, known as *Ceratichthys perspicuus* (Girard) since publication of the *Ceratichthys* monograph by Hubbs and Black (1947), has had names such as *Ceratichthys vigilax perspicuus*, *C. perspicuus*, *C. taurocephalus*, *Pimephales vigilax perspicuus*, *Pimephales vigilax*, and *Hyborhynchus* sp. Cross (1953) used the name *Pimephales vigilax perspicuus* as presented by Bailey (1951) in which he synonymized *Ceratichthys* under *Pimephales* after Hubbs (1951) had established the subspecific status.

Hay (1888) considered *Hyborhynchus* synonymous with *Pimephales*, as did other authors at that time, and called attention to the similarity and frequent taxonomic confusion of *Pimephales (Hyborhynchus) notatus* and *Cliola (Ceratichthys) vigilax*.

Bailey (1951) contended that the fishes of the Pimephalinae (*Ceratichthys*, *Pimephales*, and *Hyborhynchus*) are sufficiently allied to be grouped into a single genus and referred all of the forms (including *C. perspicuus*) to *Pimephales* in a list of fishes of Iowa.

Characteristics and phylogeny of the Pimephalinae were presented by Hubbs and Black (1947). The members of the sub-family differ from other cyprinids in two primary respects. First, the second (rudimentary) ray of the dorsal fin is typically enlarged, blunt, and separated from the third ray by a membrane. In other American cyprinids the second ray has the form of a thin splint appressed to the third ray.

Second, the nuptial tubercles of breeding males are limited in number and arrangement to one, two, or three definite transverse rows on the snout. In other minnows the tubercles are either much more numerous or scattered, or occur in decidedly different patterns.

Designation of P. perspicuus as a subspecies of P. vigilax was incidentally accomplished by Hubbs (1951) who retained the generic name Ceratichthys.

Hubbs and Black (1947) applied the name perspicuus to the form in which the breeding males bear nuptial tubercles in a 5-4 arrangement, restricting vigilax to the southwestern form in which the tubercles are confined to a single row of 5-0. The authors found only slight variation in the number of tubercles developed by each form. Largely on this basis they accorded full specific status to both forms, although it was indicated that intergrading populations might eventually be discovered.

I examined more than fifty breeding males of Pimephales vigilax perspicuus from one farm pond; the tubercle arrangement was 5-2 in 46, 5-0 in 3, and 7-1 in 1. The 5-2 arrangement is in agreement with that of Cross (1953). Cross stated that E. W. Bonn, of the Texas Game and Fish Commission, had informed him that he has taken Ceratichthys with a second row of tubercles from Lake Texoma, also within the distributional range of P. vigilax as indicated by Hubbs and Black (1947).

In my fifty or more specimens the digestive canal reached to the posterior end of the coelom, looped, returned to the anterior end of the coelom, looped again and continued posteriorly straight to the anus. The first longitudinal portion was the stomach, the canal bent and led forward along the left side of the coelom, proceeded to the anterior end where it turned backward and traversed the right side on the way to the anus.

Pimephales v. *vigilax* is characterized by breeding tubercles on the adult male, arranged in a single row. *Pimephales v. perspicuus* has a second row of two tubercles between the nostrils and one tubercle behind each nostril. (Hampton, 1954).

The body of *P. v. perspicuus* is robustly rounded to very slender, never compressed. The origin of the dorsal fin is over the insertion of the pelvics. The anal fin is short, usually with 7 rays. The peritoneum is silvery. The mouth is horizontal or nearly so and is quite terminal. The jaws of breeding males are cornified and broadened to form a parrot-like beak. A lateral dark band is usually present and often ends in a conspicuous caudal spot. The anterior dorsal rays regularly have a dark spot. The pharyngeal teeth are always 4-4, with or without hooks. (Hampton, 1954).

Where the ranges of *P. v. perspicuus* and *P. v. vigilax* overlap, the two forms have intergraded (Cross 1953). In the Wichita Valley (Kansas) area the minnows of the *P. vigilax* type are almost completely mixed (Hampton 1954).

Range and Distribution

The general range of *P. vigilax* describes an elipse in the center of the United States, including parts of 29 states some of which are east and some west of the Mississippi River.

The range includes southeastern Minnesota, southern Wisconsin, southern Michigan, Iowa, Illinois, Indiana, Ohio, Kentucky, Tennessee, Arkansas, Missouri, southwestern Pennsylvania (rare), western West Virginia, western Virginia, western North and South Carolina, northwestern

Georgia, west Florida, Alabama, Mississippi, Louisiana, all of Texas except the western tip, northeastern Mexico, eastern New Mexico, eastern Colorado, Oklahoma, Kansas, Nebraska except the northwestern counties and southeastern South Dakota. The fish is found most consistently in large, silty streams and bayous.

Distribution of *Pimephales vigilax* (Baird & Girard) in Oklahoma

Pimephales vigilax occurs over a large part of Oklahoma, being recorded from 34 of the 77 counties (Appendix A). It seems likely that the species occurs much more widely than the recorded collections indicate since collections have been made on all large rivers in the state or one of their upper branches (Figure 1).

Records of collections were found at only two institutions in the State, Oklahoma State University and Oklahoma University. There were 2831 *P. vigilax* specimens recorded by collectors from the two universities. These included 186 collections made between the years 1926 and 1961.

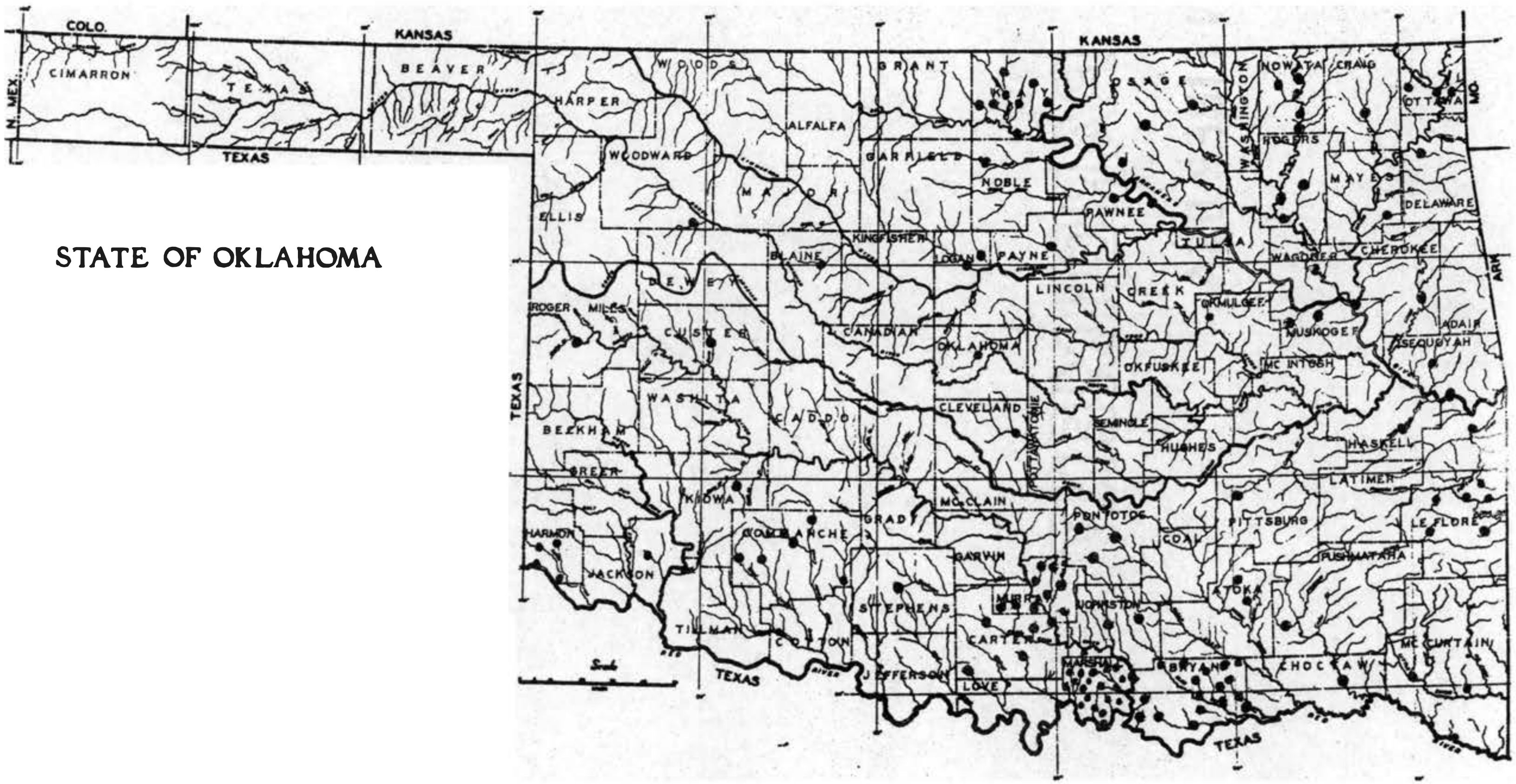

Figure 1. Oklahoma map showing the known distribution of *Pimephales vigilax.* A dot represents a location from which specimens were collected.

CHAPTER III

MATERIALS AND PROCEDURES

Specimens of *P. vigilax* were collected with fish-mesh seine from Lake Texoma and transported to the Oklahoma State University, Aquatic Biology Laboratory. At the Laboratory, they were placed in metal aquaria and treated with terramycin and acriflavine to prevent bacterial infections.

Thirty-five specimens were selected for observation and placed in special aquaria. Four hundred were placed in a farm pond (Figure 2), five miles north of the laboratory where conditions were such that good growth and reproduction seemed probable.

Laboratory Care of Fish

Six aquaria with the 35 specimens were placed on a table in the laboratory where they were available for frequent observations. The aquaria had the following specifications: No. 1, fifteen inches deep, thirteen inches wide and thirty inches long; No. 2, thirteen inches deep, fourteen inches wide and thirty-seven inches long; No. 3, two-aquaria, 10 inches deep, eight and one-half inches wide, and fifteen inches long; No. 4, two-aquaria seven and one-half inches deep, six and one-half inches wide and eighteen inches long. Sand and rock were placed in tank No. 1, aquatic plants and small gravel were placed in aquarium tank No. 2, and the other tanks remained free of obstructions.

Figure 2. Farm Pond Stocked with Pimephales vigilax

Snails (Helisoma) were kept in all the aquaria to aid in removal of excess organic matter. The aquaria were provided with the following fish; Nos. 1 and 2, 6 males and 7 females each at the beginning for behavior studies (later, the fish were removed and one male and two females replaced) and, Nos. 3 and 4, one male and one female each. Thereafter, when a fish was removed from an aquarium for any reason, (illness or death) it was replaced with one from the farm pond. The tanks were aerated liberally.

Food

White worms were cultured in covered containers and used as one of the foods for the minnows.

Microworms (small nematodes), used as food for the young fish, were reared as described by Emmons, 1953.

Ground shrimp, cultured Daphnia, a poultry food (laying mash), a stock food (fifty percent protein meal), chopped and whole earthworms, June bug larvae and mosquito larvae, were also used.

Stomach Analysis

Forty specimens to be used for stomach-analysis and to measure the recognition characters for use in a description of P. vigilax were collected from the pond. The specimens were collected in four sample groups of ten each with collection dates designed to sample food from different seasons. Sample collections were made Aug. 6, 1960; Nov. 6, 1960; Jan. 6, 1961; and April 6, 1961.

Immediately after collection the specimens were fixed in 10 percent formalin. The digestive tracts were removed, wrapped separately in cheese cloth, numbered individually for identification and replaced in 10 percent formalin for future analyses.

The fixed viscera were washed in water to rid them of excess quantities of formalin before analyzing the stomach contents. The contents of the alimentary tract were removed by washing and scraping the food materials into petri dishes. From 15 to 30 ml of water, depending on the amount of food found, were placed in the petri dishes and the stomach contents thoroughly separated.

Identification and enumeration of the stomach contents were executed by means of a microscope and a Sedgewich-Rafter counting cell. The cell was completely filled with the stomach contents and water. A compound microscope with a 40 mm objective and a 10X ocular and a 45X dissecting microscope were used for making observations. The fragmented and partially digested condition of most food materials permitted only a rough identification of stomach contents. The organisms from each stomach were counted. Individual cell counts were used for algae and other plants while animals were enumerated as single units. When fragments representing different structures of cladocerans, copepods, etc. were present, estimations were made of the number of organisms involved.

No attempt was made to compensate for the differences in size between plant and animal foods. The estimated percentages were based upon the numbers of individuals.

The volumes were determined by a method similar to that used by Leonard (1950). The food from each stomach was placed in a graduated centrifuge tube (3 ml cerebrospinal protein centrifuge tube, graduated in 0.004 ml) and the volume read in hundredths of a cubic centimeter, after centrifuging for two minutes at 3000 rpm.

Records were made of the fish specimens, recording the collection data (place, time of day) and total length in millimeters. Apparent conditions of the water were noted as clear, turbid, warm, and cool. Each specimen was weighed in grams be means of a chainomatic torsion balance.

Measurements of Characters of *Pimephales vigilax*

The use of structural measurements in fish taxonomy has been greatly acclaimed by most workers, but I have found no references to statistical analyses pertaining to *P. vigilax*. A statistical study was undertaken to determine whether or not variations in appropriate characters of *P. vigilax* were statistically significant.

A list of all the structures, measurements, patterns, and colors that were found in use in species descriptions (for various kind of fishes) were assembled from the literature and from this list 33 variable characters that seemed to be related to *P. vigilax* were selected. Forty specimens of *P. vigilax* consisting of four sample groups of ten specimens each were examined, measured, and the findings recorded for each of the 33 characters. Correlation coefficients among all 33 variables were computed within each of the four sample groups. The four groups were combined into one large group to obtain the correlation coefficients among the variables. Appendix E exhibits all these values. The data were analyzed to study the differences among the sample groups for each of the variables. Each of 20 of the more important variables and the food volumes were analysed as a completely randomized experiment which contained 10 fish in each sample group. The analyses of variance on the 20 variables are assembled in Tables VI, VII, VIII, and IX. The tables show the variations in the named characteristics from the first time of collection in August, 1960 to the last date of collection in April, 1961. Later some of the characters which proved statistically significant were used to aid in a description.

The following analyses were made on each of the variables (characters).

1) The arithmetic means for each of the sample groups and all groups combined.
2) The standard deviation of each characteristic was computed in order to show the degrees of variation among the individuals in each sample group.
3) Correlations among all the variables within each sample group (10 specimens) were computed to give a measure of relationships among the variables.
4) All forty observations were combined as one group and the correlations among the variables were computed. This denoted the relationships among the many variables where age of fish, season of year and other neutral sources of variation were ignored.
5) Analyses of variances were made to test the differences among means of the single groups for each of the characters.
6) Coefficients of variations were obtained in order to relate the uncontrolled variation in the present study with the variation that is found in other biological data.

CHAPTER IV

CONTRIBUTIONS TO THE NATURAL HISTORY OF *PIMEPHALES VIGILAX*

Ecological Relationships

Higher aquatic plants were entirely missing from the farm pond in which *P. vigilax* was held. Algal forms that become established rapidly were the dominant plant group present. In the spring, *Cladophora* was a conspicuous member but was succeeded in the summer by *Spirogyra* and *Chara.* Small filamentous green blue-green algae and diatoms were found encrusting and penetrating the weathering surface of exposed bedrock, or on the mud of the pond bottom. Small phytoplankters were rare, the algae were composed largely of attached adventitious forms.

The animal forms were also restricted. Zooplankters were extremely rare. With the exception of the snail *Physa* sp., Mollusca were not common. Large crustacea, such as *Ascellus* and *Gammarus,* were found on exposed roots and detritus, but were not abundant. The most common invertebrate forms present were the insects including Ephemeroptera, Trichoptera, Odonata and some aquatic Coleoptera, Hemiptera and Diptera. Notable numerous among Diptera were Chironomidae, Heptageniidae and Psychodidae. Amphibian larvae were the only other permanent vertebrate inhabitants.

Pimephales vigilax is an inhabitant of sluggish waters of large inland streams, connected backwaters, silty streams, ditches, creeks and bayous. They are found on sandy and muddy bottoms in eddies behind debris of logs and mats of floating vegetation. The waters of their more northern range are usually clear and cool while those of their southern range, where the fish are more numerous, are warm and often turbid. They are found in lakes and impoundments as well as in large rivers. In recent years, the natural range may have been extended and made more continuous by incidental stocking and by the advent of impoundment construction.

At the present time, the bullhead minnow is well distributed and rather abundant in Lake Texoma. From the museum records it was the most abundant species in the net collections from Lake Texoma by Dr. G. A. Moore, Professor of Zoology at Oklahoma State University, and his students during several consecutive years.

The fish seems to avoid strong currents and to be highly tolerant of turbid and silty situations.

General Behavior

Pimephales vigilax usually inhabits shallow, slowly moving waters. When observed in the wild they spent most of their time lying on the bottom under the protection of rocks and aquatic vegetation. In the laboratory they were inactive and remained on the bottom of the aquarium most of the time, resting sometimes on the pelvic and anal fins. Locomotion was a few inches at a time and in the form of short gliding movements, accomplished by a vibration of the caudal fin.

The fish quite readily adapted themselves to life in aquaria. Most individuals took food fifteen or twenty minutes after being brought to the laboratory. After the first few days, *P. vigilax* overcame fright and would remain in the open when the aquaria were approached. When food was placed in the aquaria the fish swam to meet the stream of food as it fell through the water and began eating as soon as the food came within reach. The fish would never rise to the surface to meet the food in the water but would wait until the food fell to their level. Frequently the food reached the bottom of the tank or the sand before it was eaten. Usually the fish remained in a school and watched the food being placed in the aquaria. Sometimes they would leave the school seemingly happy to receive the food. If they did not catch the food while it was falling, they secured it from the bottom by tilting the body slightly so that the long axis of the body formed a 35 to 40° angle with the tank bottom. Ground shrimp, apparently preferred to other foods, was usually caught as it fell through the water. The fish frequently would move higher for the shrimp than for other kinds of food. The fish captured *Daphnia* by rapid pursuit. Prepared dry foods or other nonmotile foods were readily taken if no live foods were in the aquaria but were refused sometimes when live foods were available. Similar behaviors were reported by Fahy (1954) in *Etheostoma blennioides* Rafinesque and Petravicz (1936) in *Microperca punctulata* Putnam (=*E. microperca* Jordan & Gilbert).

An often observed but still little understood phenomenon in the social behavior of fishes is the school. Schooling may be caused by grouping of individuals brought into a given locality by some factor or factors not concerned with relationships between individuals or there may be a closely knit cohesive group with a definite centripetal influence existing between two individuals.

Parr (1927) was the first of modern investigators to attempt an analysis of schooling behavior in fishes. Previous to 1927, a period of fifty years passed without the publication of new information about schooling. Newman (1876) quoted Kent's report that schools of herring in aquaria dispersed at night but reformed with daylight. Pimephales vigilax also schooled in the daytime and dispersed at night. There was no feeding at night as was once suspected. Night time was a definite period of rest for P. vigilax.

A main factor in the formation and maintenance of schools of P. vigilax was vision. This has been amply demonstrated for other fish by Bowen (1931-1932), Breder (1929, 1942), Parr (1921, 1931), Shaw (1962) and others. The formation of a school depends upon the attraction which other fish exert upon an individual. Pimephales vigilax remained parallel to and at a given distance from their companions. The above authors believe the maintenance of this distance to be the result of visual stimuli from each side. A fish located between two others makes no adjustment of distance as long as it perceives its companions with equal intensity. A fish on the outside of a group is unable to balance its visual stimuli correctly and pushes constantly toward the center. This aids in preserving the integrity of the school. A minimal distance is always maintained between the fish, close approach gives antagonistic stimuli or somehow weakens the tendency to approach, so that a balance is attained. It appears that approach of the fish to each other in schools was made only at that distance at which an object became clearly visible. There is a tendency for the fish to maintain a certain "comfortable" retinal reaction status, which is reached by close approach to objects of small size and a more distant approach to objects of large size.

"Mills" (a circular movement of the individuals within a school) were formed in the aquaria while the school as a whole remained relatively stationery. Pimephales vigilax began to form mills when the school made a sharp turn of 180^{o} or more. Parr (1927) explained a similar reaction in Clupeidae and Scombridae, by assuming that the fish passing near each other in opposite directions exert stronger visual stimuli than do their companions traveling in the same direction, since the perception of the latter are with respect to a given individual nearly stationary. The fish on the inside of the mill tend to incline toward each other. Their companions on the outside, in order to preserve the visual pattern, follow them and soon the whole school is circling. (Parr 1927).

A peculiarity of the school lies in the ability of all members to orientate in the same direction. Size as well as form seemed to have an attracting or repelling influence on P. vigilax. Often individuals were separated from the school, but when the aquarium was approached or a noise (air or water vibration) was made the fish would hasten to the school. Schooling seemed to be a part of "fear", a reaction that has been recognized in many species of fishes. The reaction may have been the result of the members of a dispersed group fleeing to the safest spot, or to the place best suited for defense.

Sex attraction tended to break the uniformity of the school. There was a lack of attraction or even a repulsion and fighting among members of the same sex, and, correspondingly, a stronger attraction among members of opposite sexes. To obtain such differential attractions there seems to be a kind of sexual dimorphism recognizable by the fish. When sexual attraction fades, schooling behavior may become more pronounced. In the forms which survive, this mechanism must change from ambosexual to nonsexual orientation, resulting in an attraction for all individuals of a species for each other, regardless of sex. In this manner, the sex complex may be substituted for the schooling complex. Schooling in P. vigilax was not accompanied by conspicuous sexual differences. There are fish that exhibit the most perfect of schools, show complete lack of external sex differences and spawn in indiscriminate schools, without apparent heterosexual orientation (i.e. Clupeidae & Scombridae). In P. vigilax the appearance of dimorphous sex characters during the breeding periods is accompanied by the disintegration of schools. The schools are reformed following the cessation of breeding.

The habit of schooling during periods of sexual inactivity is apparent in P. vigilax. Actual schooling probably depends upon the promoting or suppressing influence of externally perceptable sex differentiation.

Food and Feeding

Laboratory Specimens. The feeding of P. vigilax was not a difficult problem. When first brought into the laboratory the fish were offered a dry food mixture of poultry laying mash and fifty percent protein meal. Some specimens appeared to take the food.

Chopped earthworms and June-bug larvae were used as food immediately after the beginning of the experiment and were eaten by the fish until live animal foods were made available. Small earthworms and dwarf white worms were readily eaten by all the fish; mosquito larvae were preferred. When both white worms and mosquito larvae were available to the fish the worms were ignored. Cladocerans and copepods were readily accepted by some fish while others seemed to ignore them.

Although the fish ate laying mash, 50 percent protein meal and shredded shrimp vigorously, they preferred living foods. Live foods comprised the greater part of their diet.

Stomach Analysis of Pond Fish. The analysis of the stomach contents of *P. vigilax* showed it to be an omnivorous feeder. *Pimephales vigilax,* because of its small size, is restricted to small organisms or fragments of organisms for food. The specimens examined were collected from the farm pond and were restricted to foods that were available there. A variety of kinds of food including algae, fungi, water mites, rotifers, crustaceans, annelids, insects, molluscs, and debris was found in the digestive tracts (Table I).

Some difficulty was encountered in identifying the particles. Sometimes fragments of organisms were difficult to separate from organic matter. A greenish color would indicate only that chlorophyll was present.

Animal materials (except chitin) seemed to be more quickly and fully digested than plant materials. Animal food was found in all of the stomachs examined and consisted of many small aquatic insect larvae and adults. Chironomidae and Psychodidae larvae were the families most frequently found. Small crustaceans comprised the greatest single dietary group and were found in most stomachs. Cladocera were most abundant, being found in the largest number of specimens. Adult diptera were found in only two stomachs. Aquatic Hemiptera and Coleoptera larvae were observed in many cases, but small adult Coleoptera were encountered in twenty-one stomachs. Trichoptera larvae were recognized in six stomachs. Nematodes were recognized in four cases. In approximately half the cases, the animals were intact, but the rest could be recognized only from the antennae and other pieces of shell. The total volume of plant food was small, and the total volume of animal food was large, precentagewise.

Seasonal variations in the volume of the food of the sample groups showed an increase in the amount of mud and debris when there was a reduction in animal and plant food. Mud was generally found in stomachs containing some particular animal and probably should be considered as incidentally taken, (Appendix C).

The green and blue-green algae were easily recognizable when intact. Many times filamentous green-algae occurred in fragments. Marssonella, Nostoc, Oscillatoria and Spirulina were the only blue-green algae forms found in the stomachs; their occurrence, though sporadic, at times comprised a large percentage of the food. Diatoms were numerous in many stomachs, usually associated with mud and debris. Their total volume was never more than about 5 percent of the content of any one stomach. Fragmentary remains of higher plants were recognized in the specimens containing large amounts of debris.

TABLE I

FOOD ORGANISMS OF 40 *PIMEPHALES VIGILAX*

BACILLARIEAE -	*Achnanthidium, Navicula*
HETEROKONTAE -	*Bumillaria*
CHLOROPHYCEAE -	*Closterium, Cosmarium, Genicularia, Characium, Draparnaldia, Mougeotia, Odogonium, Pediastrum, Rhizoclonium, Spirogyra, Ulothrix*
MYXOPHYCEAE -	*Marssoniella, Nostoc, Oscillatoria, Spirulina*
EUGLENOPHYCEAE -	*Phacus, Euglena*
FUNGI - IMPERFECTI -	*Spongiimpropecti, Alternaria*
ROTIFERA -	*Euchlanis, Diglena*
ANNELIDA -	Bristleworm
MOLLUSCA -	*Physa, Planorbis*
CRUSTACEA -	*Bosmina, Chydorus, Daphnia, Pleuroxus, Simocephalus*
HYDRACARINA -	(Water mites)
HEXAPODA -	Odonata, Chironomidae, Heptugeniidae, Notonectidae, Psychodidae, Salidae, Culicidae (larvae)

Breeding Activities

Sex Characters. The secondary sex characters were first noted in males in the fall collection September 6, 1960. Three other collections were made during the year and no other sex characters were noted until May 2, 1961. The characters noted were pearl organs or nuptial tubercles on the snout and had a number of 5-2. On May 20, 1961, a v-shaped pre-dorsal rugose skin pad was formed above the scales on the nape. The pad became prominent soon after the males began caring for the nest and seemed to be used advantageously in keeping the nest clean. The pad, formed by a thickening of the epidermis overlying the scales, is very striking in shape and color. The pectoral fins appeared white rather than the usual dark color they had possessed previously. The first one-half ray of the dorsal fin was white. In one case, the fish had burrowed a small opening under a stone and began to move from one side of the nest to the other as though he was scratching his back on the stone. On June 9, 1961, there appeared more evidence of color changes. A golden orange band, as wide as the dorsal fin base was long, extended on each side from the dorsal fin to the belly. Two white narrow bands were formed on the ventral edge of both sides starting from the proximity of the opercle, extending latero-ventrally to the end of the caudal penduncle and continuing up both sides of the caudal penduncle to join at the middorsal line.

Nest. It was evident that the male chose the location of the nest because he was often seen burrowing and digging materials away from objects in the aquarium. Large openings were excavated in the soil by a large male that guarded the opening and kept other fish from entering.

The eggs of the bullhead minnow usually were found on the under side of objects that lie horizontal to the surface of the water. In some cases where there was no normally suitable site available in the pond or aquarium, a nest site was selected that was not horizontal to the surface of the water.

The nests may be found under boards, rocks, stones, tree trunks or limbs, concrete, metal, pipes, or tile if the male can dig or burrow an opening underneath the object large enough to perform his activities.

> Henry C. Markus (1934) speaking of P. promelas stated "The under surfaces of pieces of broken or whole tile seems to offer admirable places for them to deposit eggs and makes it easy to transport the nests for experimental study."

Prespawning activities. Pimephales vigilax appeared to become more fearless as the spawning time appraches. The males always seemed to be more aggressive than the females and when attempts were made to catch them with a dip net, they would swim under, over and around the net, but would refuse to be frightened away from the nest permanently. The protective instinct seems to be highly developed in the males. They were pugnacious, attacking intruding males with great speed and vigor.

While the males were developing the sexual characters, the females became distended with eggs. At times, females would go in and out of the nest while the male was there. At other times, a female would remain outside of the nest opening for hours without moving away. Several females were found distended with eggs in September of 1960.

Because of the small size of the fishes, the utilization of the lower surface of some object for the reception of the eggs may be regarded as being a choice of location best suited for their protection as well as a means of removing the eggs from any danger of "drowning" in the silt. This illustrates a retention and a modification of characters found in the genus, such as, the nesting instinct and the adhesive nature of the eggs. The adhesion of the eggs to a surface seems to be a technique of Pimephales which is unusual among the members of its family.

Spawning act. One male observed on July 22, selected a nest 26 days before a female located herself in front of it. Here she remained most of the time, day and night. She moved away from the opening only during the feeding periods and soon after feeding, returned.

Several days later, the female was observed to enter the nest where she remained for a short period and returned to her former position. Occasionally the male would come out and the female would enter. When she came out, he re-entered. The exchange of positions occurred several times and finally the male took his former position in the nest and began to move from side to side. Both fish swam in a circular manner when entering, or leaving the nest and while moving about the aquarium during the spawning activities. The circular motion was always in a clockwise direction. The spawning activities lasted about ten minutes. Then the female joined the other fish in the aquarium. Another spawning activity, involving one male and two females in the same aquarium, was observed. The females proceeded as above with the male following each as it entered the nest. Each fish remained in the nest for a short time.

It was impossible to see the release of the eggs and sperm because of their minute size. In spite of diligent observation the fish were never seen to turn, even partly, toward a position of placing eggs on the roof. It is postulated that the bouyant and adhesive eggs when released rise in the water and stick to the upper surface of the nest.

The sperm released fertilize the eggs while floating in the water or attached to the roof. When the brick was removed from the water, eggs were firmly attached to the portion which formed the roof. The brick was carefully replaced and the male resumed his usual nesting activities.

A search was made for small fry for several days but none was found. Since the aquarium water had become quite turbid, it was replaced with clean water. While emptying the last container of water, many minute fry were found adhering to the sides and bottom.

Male activities. The male cares for the eggs during the incubation period, protecting them from animals small enough to enter the nest opening and eat or destroy the eggs. The protector of a nest can usually defeat in battle, while he is defending a nest, any fish that is twice his size. In no case was a fish observed to be driven from the nest while making preparation for the eggs or while the eggs were being incubated. The constant movement of the male beneath the eggs kept the water agitated. Agitation may be an important factor which aids in the development of the eggs. The male by his constant movements brushed the eggs with the rugose pad and kept the nest free from sediment, minute water animals, and plants that might attach themselves. The movements of the male underneath tend to keep the eggs free from such undesirable materials. Brushing and agitation may be necessary since the bullhead minnows are "at home" in turbid water. One collection of 15 freshly laid eggs was brought from the farm pond and agitated with air in the laboratory in an attempt to hatch them. Three hatched, seven were attacked by some kind of fungus and the embryos died and five failed to form embryos. A second collection of twenty or more eggs were transferred from the farm pond to a regulated, air-conditioned box. The eggs hatched without a male being present.

Eggs. Two hundred thirty-three eggs were taken from the farm pond soon after the spawning act. The eggs were scattered on the under side and attached firmly to a stone. In the sunlight, they reflected purple, blue, red and greenish colors, (Figure 4). The freshly laid eggs were spherical and from 1 to 1.5 mm in diameter. All the eggs examined carefully appeared to be in the one-celled stage. The incubation period of the eggs was determined after the eggs had been carefully scraped from the rock, placed in a small jar of water and transferred to the laboratory. The eggs hatched in four and one-half to six days in water with a temperature of 79 to 83° F. This would appear to indicate that eggs were laid at different times. The water temperature on the date of collection was 78° F.

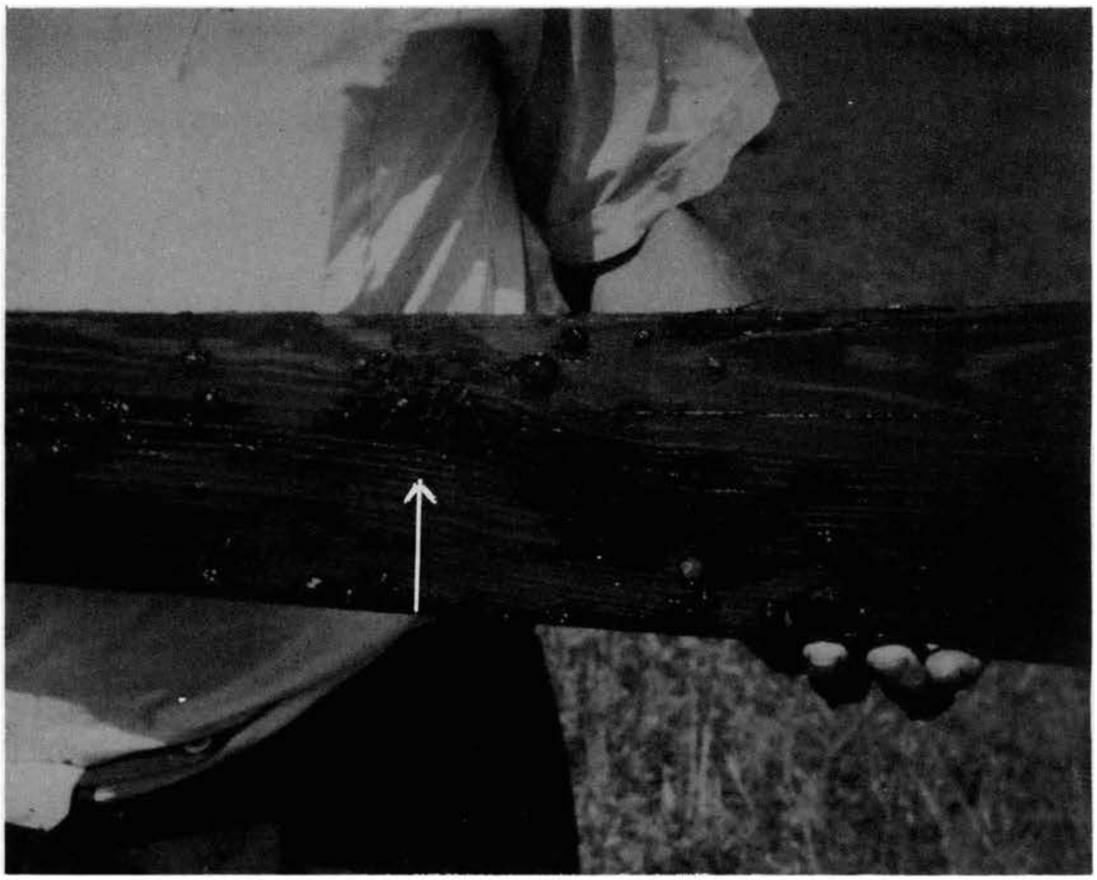

Figure 3. Eggs of Pimephales Vigilax

CHAPTER V

THE CHARACTERS, FOOD VOLUMES, AND STATISTICAL ANALYSIS OF MEASUREMENTS

Scale Characteristics

The scales (cycloid) of P. vigilax were collected from each fish by removing them from the integument above the lateral line just below the dorsal fin. The scales of the bullhead minnow are not favorable for age determination as are those of whitefishes, bass, sunfishes and many other fresh water species. Primary and secondary radii are present and interspersed. The radii exist on the posterior part of the scale between the posterior margin and the focus. Circuli were readily distinguishable, but winter rings or annuli were indistinguishable and none was found. There was no crowding of circuli on the scales examined with extremely similar characters showing on the scales from all individuals regardless of size, age, sex, or length of fish. The circuli were widely spaced except at the scale margins where they seemed more closely aligned. The scales of the females were smaller than those of the males of the same presumed age, but no other difference was found. There was no basis upon which to calculate the age of the fish from the growth of their scales (Figure 3).

A search was made for all possible characters and their values, external or internal, that applied to Pimephales vigilax. One hundred ten characters were selected for descriptions and measurements. From

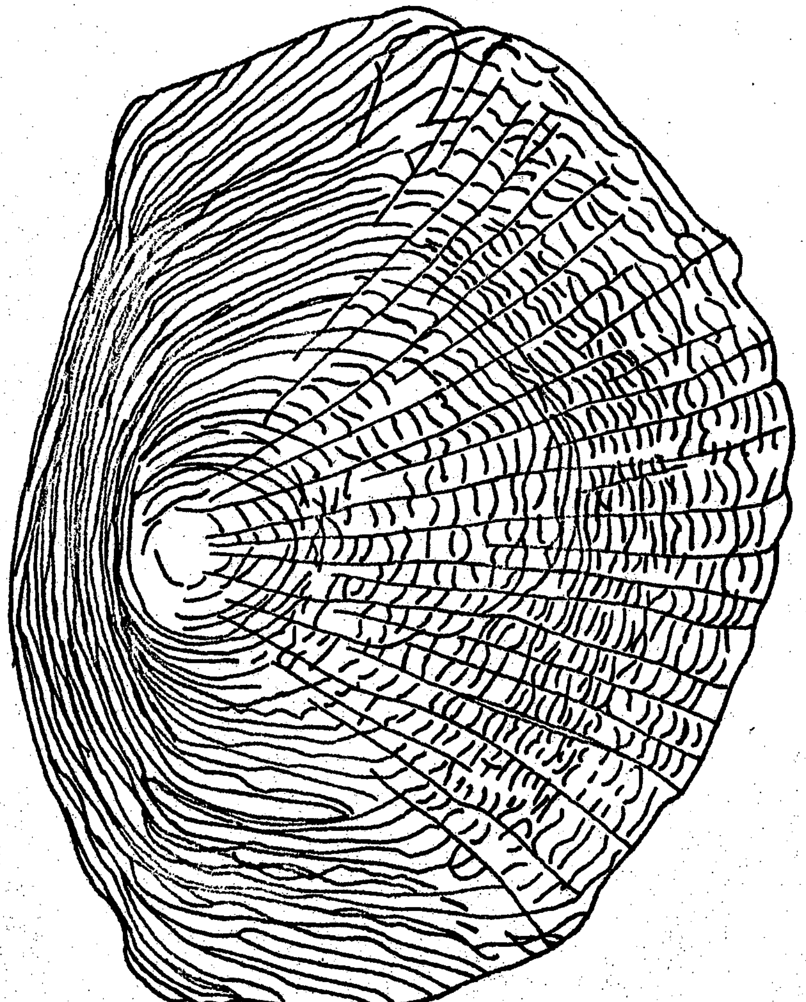

Figure 4. Scale of Pimephales vigilax

this number, eighty-two characters were used in making measurements and counts. Later, when the material was prepared for statistical analysis, only 33 of these characters were thought practical. The remainder were rejected because variations were lacking or the characters did not apply to P. vigilax. The 33 selected were used as statistical variables. The 33 characters were: total length, standard length, head length, head width, head depth, snout length, snout length into head length, postorbital length of head, interorbital width, orbital length, diameter of orbit, length of upper jaw, length of mandible, diameter of eye, gape width, body depth, nape, predorsal length, caudal peduncle width, caudal peduncle depth, caudal peduncle length, length of paired fins, dorsal fin height, dorsal fin base length, anal fin height, anal soft ray length (longest), height of pectoral, anal base length, caudal fin formula, least depth of caudal peduncle, mid-dorsal line scales, lateral line scales and weight of fish.

After the analysis had been calculated, selected characters were placed into four groups and food volumes were added to group No. 1. The groups were as follows: one; total length, head width, head depth, body depth, weight and food volume in stomaches: two; total length, head length, length of upper jaw, diameter of eye, gape width, nape length, predorsal length, and caudal peduncle length: three; caudal peduncle width, caudal peduncle depth, and caudal peduncle length: four; length of paired fins, dorsal fin height, fin base length (dorsal), anal fin height, and height of pectoral.

The coefficients of correlation, coefficients of variation, over-all means, and standard deviations from the calculations were used to determine the validity of the characters. There were many other calculations available that were not thought applicable for a proper characterization of *P. vigilax.*

Analyses of Variances

There were differences among sample groups with respect to total length, head width, head depth, body depth, and weight. The differences were significant even at the one percent probability level. There was no significant difference existing among the sample groups with respect to the amount of food found in the stomach. The analyses of variances for total length, head width, head depth, body depth, weight, and food are shown in Table II. The coefficient of variation for the amount of food was 90 percent, very high and above normal. This seems to be large in comparison with coefficients of variation on general biological data. The total length, head width, head depth, and body depth have a coefficient of variation range from 11.51 to 37.45 percent.

There were differences among the sample groups with respect to the head length, length of upper jaw, diameter of eye, gape width, nape length, predorsal length, and caudal peduncle. The differences were all significant at the one percent probability level with one exception, the diamter of the eye, which shows no significant difference. The coefficients of variation for head length, length of upper jaw, diameter of eye, gape width, nape length, predorsal length, and caudal peduncle length were normal for other biological data.

TABLE II

MEAN SQUARES OF THE SAMPLE GROUPS AND WITHIN THE SAMPLE GROUPS; THE COEFFICIENTS OF VARIATION; THE OVER-ALL MEAN, AND STANDARD DEVIATIONS FROM AN ANALYSIS OF CERTAIN APPARENTLY RELATED SIZE MEASUREMENTS AND FOOD VOLUME.

Source	df	Total Length	Head Width	Head Depth	Body Depth	Weight	Food Volume
Sample Group	3	772.83**	20.57**	59.47**	48.83**	25.6437**	0.002279
Within Sample Group	36	64.26	1.54	2.31	3.90	2.0042	0.004652
Coefficients of Variation		11.51%	14.29%	15.01%	16.76%	37.43%	90.00%
Over-All Mean		69.48	8.85	10.10	11.78	3.7774	0.07485
Standard Deviation (Pooled)		8.01	1.240	1.51	1.97	1.41421	0.067

**Significant at 1% level
df = degrees of freedom

The coefficients of variation for these measurements ranged from 13.47 to 19.56. This is in agreement with coefficients of variation that are obtained for general biological data. All of the values are shown in Table III.

TABLE III

MEAN SQUARES OF THE SAMPLE GROUPS AND WITHIN THE SAMPLE GROUPS; THE COEFFICIENTS OF VARIATION; THE OVER-ALL MEAN; AND STANDARD DEVIATIONS FROM AN ANALYSIS OF CERTAIN, APPARENTLY RELATED, SIZE MEASUREMENTS.

Source	df	Head Length	Length of Upper Jaw	Diameter of Eye	Gape Width	Nape Length	Predorsal Length	Caudal Peduncle Length
Sample Group	3	27.83**	11.47**	0.33	10.89**	57.77**	128.09**	40.29**
Within Sample Group	36	3.63	0.56	0.26	0.61	5.07	13.99	4.41
Coefficient of Variation		13.47	19.56	18.21	15.84	13.64	13.54	14.55
Over-All Mean		14.28	3.80	2.80	4.93	16.55	27.53	14.43
Standard Deviation (Pooled)		1.90	0.74	0.50	0.78	2.25	3.74	2.10

**Significant at 1% level
df = degrees of freedom

There were differences among the sample groups with respect to caudal peduncle width, caudal peduncle depth, and caudal peduncle length. These differences were significant at the one precent probability level. The coefficient of variation for the caudal peduncle width was above normal while the coefficients of variation for the caudal peduncle depth and caudal peduncle length were below normal All of the values are shown in Table IV.

TABLE IV

MEAN SQUARES OF THE SAMPLE GROUPS AND WITHIN THE SAMPLE GROUPS; THE COEFFICIENTS OF VARIATION; THE OVER-ALL MEAN; AND STANDARD DEVIATIONS FROM AN ANALYSIS OF CERTAIN, APPARENTLY RELATED, SIZE MEASUREMENTS.

Source	df	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length
Sample Group	3	4.17**	9.20**	40.29**
Within Sample Group	36	0.52	1.24	4.41
Coefficient of Variation		25.30	16.39	14.55
Over-All Mean		2.85	6.80	14.43
Standard Deviation (Pooled)		0.72	1.11	2.10

**Significant at 1% level
df = degrees of freedom

There were differences among the sample groups with respect to the length of paired fins, dorsal fin height, fin base length (dorsal), anal fin height, and height of pectoral fin. The differences of the length of paired fins, dorsal fin height, and height of pectoral fin were significant at the five percent probability level. Fin base length and anal fin height were significant at the one percent probability level. The coefficients of variation for length of paired fins, fin base length, and height of pectoral fin, were normal for other biological data. The coefficients of variation for dorsal fin height and anal fin height were slightly above normal. All of the values are shown in Table V.

Correlation Coefficients

Correlations among total length, head width, head depth, body weight, and food are shown in Table VI. All the correlation coefficients may be considered good with the exception of the food correlations. In general, when the sample groups of the fish are ignored, the correlation coefficients are lower than the respective correlation coefficients for any one sample group.

Correlation coefficients among total length, head length, length of upper jaw, diameter of eye, gape width, nape length, predorsal length, and caudal peduncle length are shown in Table VII. Correlation coefficients for length of upper jaw with the other variables were found to be lower in all fish of the second sample group except that diameter of the eye was the lowest in the first sample group. The correlation was negative. All other correlation coefficients in the table were positive except the gape width correlation with the length of upper jaw for the first group of fish.

TABLE V

MEAN SQUARES OF THE SAMPLE GROUPS AND WITHIN THE SAMPLE GROUPS; THE COEFFICIENTS OF VARIATION; THE OVER-ALL MEAN; AND STANDARD DEVIATIONS FROM AN ANALYSIS OF CERTAIN, APPARENTLY RELATED, SIZE MEASUREMENTS.

Source	df	Length of Paired Fins	Dorsal Fin Height	Dorsal Fin Base Length	Anal Fin Height	Height of Pectoral Fin
Sample Group	3	12.10**	78.89**	10.69**	18.33**	7.43*
Within Sample Group	36	1.82	4.92	1.90	1.64	2.49
Coefficient of Variation		15.87	23.47	15.50	21.08	16.59
Over-All Means		8.45	9.43	8.80	6.00	9.53
Standard Deviation (Pooled)		1.34	2.21	1.37	1.28	1.57

*Significant at 5% level
**Significant at 1% level
df = degrees of freedom

TABLE VI

CORRELATION COEFFICIENTS OF SELECTED GROUP 1 VARIABLES FOR THE DIFFERENT SAMPLE GROUPS.

		Head Width	Head Depth	Body Depth	Weight	Food
Total Length	Lowest	0.836	0.618	0.840	0.905	0.266
	Highest	0.929	0.972	0.921	0.992	0.806
	All Combined	0.933	0.908	0.920	0.966	0.314
Head Width	Lowest		0.733	0.752	0.793	0.444
	Highest		0.962	0.912	0.965	0.830
	All Combined		0.929	0.920	0.956	0.392
Head Depth	Lowest			0.338	0.646	0.329
	Highest			0.926	0.946	0.804
	All Combined			0.879	0.927	0.289
Body Depth	Lowest				0.816	0.037
	Highest				0.958	0.830
	All Combined				0.936	0.239
Weight	Lowest					0.187
	Highest					0.862
	All Combined					0.310

TABLE VII

CORRELATION COEFFICIENTS OF SELECTED GROUP 2 VARIABLES FOR THE DIFFERENT SAMPLE GROUPS.

		Head Length	Length of Upper Jaw	Diameter of Eye	Gape Width	Nape Length	Predorsal Length	Caudal Peduncle Length
Total Length	Lowest	0.838	0.046	0.317	0.792	0.861	0.910	0.869
	Highest	0.961	0.915	0.896	0.930	0.978	0.978	0.916
	All Combined	0.941	0.786	0.532	0.906	0.943	0.969	0.935
Head Length	Lowest		0.176	0.230	0.614	0.820	0.768	0.705
	Highest		0.896	0.844	0.896	0.922	0.938	0.883
	All Combined		0.734	0.555	0.811	0.891	0.923	0.868
Length of Upper Jaw	Lowest			0.113-	0.302-	0.028	0.066	0.085
	Highest			0.745	1.000	0.809	0.912	0.763
	All Combined			0.395	0.832	0.736	0.724	0.749
Diameter of Eye	Lowest				0.075	0.309	0.344	0.330
	Highest				0.958	0.910	0.886	0.787
	All Combined				0.478	0.549	0.554	0.582
Gape Width	Lowest					0.740	0.721	0.731
	Highest					0.911	0.926	0.848
	All Combined					0.886	0.864	0.858
Nape Length	Lowest						0.853	0.699
	Highest						0.972	0.876
	All Combined						0.947	0.864
Predorsal Length	Lowest							0.729
	Highest							0.926
	All Combined							0.903

Correlation coefficients among the characters, caudal peduncle width, caudal peduncle depth, and caudal peduncle length are shown in Table VIII. Other than the first sample group, high positive correlation coefficients were found among all the characters. Correlation coefficients between caudal peduncle width and the other two measurements were found to be zero in the first sample group of fish. The zero readings happened because all the measurements for caudal peduncle width in the sample group were the same.

TABLE VIII

CORRELATION COEFFICIENTS OF SELECTED GROUP 3 VARIABLES FOR THE DIFFERENT SAMPLE GROUPS.

		Caudal Peduncle Depth	Caudal Peduncle Length
Caudal Peduncle Width	Lowest	0.000	0.000
	Highest	0.879	0.788
	All Combined	0.733	0.756
Caudal Peduncle Depth	Lowest		0.794
	Highest		0.881
	All Combined		0.881

Correlation coefficients among length of paired fins, dorsal fin height, fin base length (dorsal), anal fin height, and height of pectoral fin are shown in Table IX. All the correlation coefficients in group 4 are good with one exception. The lengths of paired fins and anal fin heights produced a negative correlation coefficient.

TABLE IX

CORRELATION COEFFICIENTS OF SELECTED GROUP 4 VARIABLES FOR THE DIFFERENT SAMPLE GROUPS.

		Dorsal Fin Height	Fin Base Length (Dorsal)	Anal Fin Height	Height of Pectoral Fin
Length of Paired Fins	Lowest	0.496	0.766	0.100-	0.499
	Highest	0.920	0.895	0.867	0.773
	All Combined	0.864	0.833	0.761	0.726
Dorsal Fin Height	Lowest		0.460	0.432	0.654
	Highest		0.953	0.914	0.768
	All Combined		0.859	0.870	0.730
Fin Base Length (Dorsal)	Lowest			0.074	0.504
	Highest			0.908	0.842
	All Combined			0.748	0.685
Anal Fin Height	Lowest				0.526
	Highest				0.867
	All Combined				0.726

Low Correlations

In general snout length into head length, orbital length, diameter of the orbit, length of mandible, eye length, diameter of eye, mid-dorsal line scales, lateral line scales and food volumes have poor correlations, less than 0.50, with one another and all the other variables in the study. The low correlations can be caused by several conditions. If the standard deviation of a variable is high, one might expect that variable to have a low correlation with another variable which has a high standard deviation. Another cause for a low correlation of two variables could be attributed to one of the variables having no variation. Such a case is readily seen in the correlation of the caudal fin formula with all the other variables. In this case the number of fin rays had practically no variation. Although the variable gives very little information about the other variables it could be a good identifying character, since there is practically no variation in the fin formula. The correlations of food volumes with all the other variables are low. This could be due to its high standard deviation.

High standard deviations of two variables do not necessarily mean that one will find low correlations. It is possible to have a high correlation between two variables and at the same time coefficients of variations (C.V.) which may be high. This is exhibited by the weight and total length of the fish. The C.V.'s for these two variables are 37.4 and 11.5 respectively. The first of these two C.V.'s is very high while the second is in the neighborhood of those values generally found in biological observations. The correlation between the two characteristics is 0.96. These examples show that correlation coefficients may be of great assistance in studying relationships among several characteristics. However, one should observe the variances of the variables along with their respective means.

High Correlations

Total length, standard length, head width, gape width, body depth, nape and pre-dorsal length, in general, were highly correlated with one another. These correlation values were found to be approximately 0.80 or higher. The high correlation values indicate that it would not be necessary for one to measure all the variables to describe this species.

Reasons for Statistical Treatment

Since four different sampling groups were taken from the farm pond, an analysis of variance was made to see if there might be differences indicated among the sample groups. Twenty-one analyses presented in Tables II, III, IV, and V shows these analyses along with the coefficients of variations. Differences were indicated among the sample groups on 19 of these variables. This indicates that one should study the correlations among the variables within each sample group. Wrong conclusions might be made if this procedure was not followed. In most cases the coefficients of variation were found to be within the range of those expected in biological data. This indicates, in general, the variations in the measurements of this study are in agreement with other work in the biological field.

Description

Pimephales vigilax (Baird and Girard) is dusky green above with silvery sides and a dark lateral band starting at the opercular bone and ending in a tiny, sometimes very faint, dark spot at the base of the caudal fin. There is a prominent dark blotch beyond the center of the first three or four rays of the dorsal fin. During the breeding season, the head of the male fish becomes dark grey to black, hence they are often called black-head, parrot, or bullhead minnow. A dark brownish-grey or black rugose pad is formed by a thickening of the epidermis overlying the scales; it is very striking in shape and color. The half-ray of the dorsal fin is white. A golden-orange band as wide as the dorsal fin base extends from each side of the dorsal fin to the belly. Two white, narrow bands are formed on the ventral edge of both sides, starting from the proximity of the opercular bone, extending lateroventrally to the caudal peduncle, then, continuing dorsally until the bands are joined. No color changes were noted in the female during the breeding season. Sparsely spaced, black-dotted malanaphores can be seen in a regular pattern over the entire body.

At about 50 mm or greater of total length the range of measurements in millimeters (unless otherwise stated) are: total length, 49-85; standard length, 39-74; weight, 0.688, 7.271 grams; head length, 9-18; head width, 6-12; head depth, 5-15; snout length, 3-6; snout length into head length, 2.4-3.6 (proportion); length of upper jaw, 1.5-5; length of mandible, 3-5; diameter of eye, 2-4; gape width, 2-7; body depth, 8-16; nape length, 10-22; predorsal length, 19-34; caudal peduncle length, 10-20; caudal peduncle width, 2-4; caudal peduncle depth, 5-9; length of paired fins, 5-11; dorsal fin height, 3-15; dorsal fin base length, 6-12; anal fin height, 3-9; and height of pectoral fin, 5-13.

The lateral line is complete with the posterior end covered with a blackish caudal spot. The mouth is almost terminal, and moderately oblique. The breeding males have one or two rows of large sharply-pointed tubercles on the snout. The pharyengeal teeth are usually 4-4. The head is never wider than long. The dorsal surface of the head and back before the dorsal origin is notably flattened.

With the usual eight well developed dorsal fin rays there is a rather stout, blunt-tipped, half-ray. The half-ray and the first developed ray are joined by a membrane. The pectoral rays are thickened and slightly roughened. Anal rays are 7, rarely 8.

The scales of the predorsal area are small. irregular, and crowded in appearance. There are usually more than 20 scales in a row along the predorsal ridge from head to dorsal origin. Scales in the later line vary from 39 to 49. Scales around the caudal peduncle are usually 14.

The intestine is S-shaped but not coiled. The digestive canal extends to the posterior end of the coelom, loops, returns to the anterior end of the coelom, loops again, and returns posteriorly to the anus.

In Oklahoma, the fish may spawn from early April through mid-September.

Those characters that were not used in the above description may be generic or familial rather than specific characters. Also, the characters or character measurements may fit other species of pimephalines. There are some characters that specifically apply to P. vigilax. To distinguish the specific characters for a particular species one would need the characters and character measurements of all the species of the genus.

To determine which characters best fit specific, generic and familial categories one should first determine which have variations or lack variations at the particular level of grouping being considered. When variations are present among individuals, those variations should have statistically significant differences in order to assist in dividing the individuals into the different categories.

CHAPTER VII

SUMMARY

1. *Pimephales vigilax* was studied and its known distribution, life history and taxonomic characters are presented.

2. Forty specimens were examined for food content and food volume, descriptive characters, and scale profile.

3. Twenty-two genera of algae, 6 families of animals including eleven genera of invertebrates were identified as food organisms.

4. The kind of food utilized was found to vary with the size of the specimens and the food particles available. The minnows ate more freely upon animals than plants even though algae were more abundant. Copepods, cladocerans and larvae of Chironomidae and Psychodidae were the most used animals. The bullhead minnow can be best regarded as a general feeder, using all small food organisms.

5. The species was found to frequent large rivers and lakes through its natural range.

6. The habitat of *P. vigilax* is discussed.

7. The spawning habits of *P. vigilax* are described.

8. Annuli were found to be missing from the scales. The growth rate of the species was not determined.

9. The following correlations were computed: correlation coefficients on 34 characters within each of four collection groups, correlation coefficient for all forty fish combined, analysis of

variance to test collection effects on each of the 34 characters and coefficient variation on each of the 34 characters.

10. A description of _P. vigilax_ based upon the study is given.

BIBLIOGRAPHY

American Fisheries Society. 1960. A list of the common and scientific names of fishes from the United States and Canada. Am. Fish. Soc. spec. Publ. No. 2, 102 p.

Bailey, R. M. 1956. A revised list of the fishes of Iowa, with keys for identification. In, Harlan, J. R. and E. B. Speaker. Iowa Fish and Fishing, 327-377.

Belding, David L. 1927. Toxicity experiments with fish in reference to trade waste pollution. Trans. Am. Fish. Soc. 57: 101-119.

Blatchlev, W. S. 1885. A review of the species of the genus Pimephales. T. C. Proc. of Acad. of Nat. Sci. of Phila. 37: 63-69.

Bonn, Edward C. 1949. Notes on Lake Texoma Species. Unpublished manuscript. Texas Game, Fish, and Oyster Comm. Austin, Texas.

Breder, C. M. 1929. Certain effects in the habits of schooling fishes as based on the observation of Jenkinsia. Am. Mus. Novit. 382: 1-5.

Breder, C. M. Jr. 1942. Social and respiratory behavior of large tarpon. Zoologica, 27: 1-4.

Bowen, Edith S. 1931. The role of the sense organs in aggregations of Ameiurus melas. Ecol. Monogr. 1: 1-35.

1932. Further studies of the aggregation behavior of Ameiurus melas. Biol. Bull. Woods Hole 63: 258-270.

Bullough, W. S. 1939. The study of the reproductive cycle of the minnow in relation to environment. Proc. Zool. Soc. London 109: 79-102.

Carlander, K. D. 1950. Some considerations in the use of fish growth data based upon scale studies. Trans. Am. Fish. Soc. (1949) 79: 187-194.

_______, and R. E. Cleary. 1949. The daily activity patterns of some freshwater fishes. Am. Midl. Nat. 41: 447-452.

Chambers, R. 1934. A study of the pharyngeal teeth in the blunt-nosed minnow. Trans. Ill. Acad. Sci. 26: 30.

Clemens, H. P. and P. B. Summers. 1954. A phase in managing refinery wastes polluting streams. Proc. Okla. Acad. Sci. 33: 86-96.

Coyle, E. E. 1930. The algae food of Pimephales promelas (fathead minnow). Ohio Jour. Sci. 30: 23-35.

Crandall, Catherine Ann and Clarence J. Goodnight. 1959. The effects of various factors on the toxicity of sodium pentachlorophenate to fish. Limnol. and Oceanog. 4: 53-57.

Creaser, Charles W. 1926. The structure and growth of the scales of fishes in relation to the interpretation of their life history with special reference to the sunfish Eupomotis gibbosus. Misc. Pub. No. 17, Univ. Mich. Mus. of Zool. 1-82.

Cross, F. B. 1953. Nomenclature in the Pimephalinae, with special reference to the bullhead minnow, Pimephales vigilax perspicuus, Cirard. Trans. Kans. Acad. Sci. 56: 92-96.

Dobie, J. R. and O. L. Meehean and G. N. Washburn. 1948. Propagation of minnows and other bait species. Cir. 12, Fish and Wildl. Serv. Washington, D. C.

Emmons, C. W. 1953. Keeping and breeding aquarium fishes. Acad. Press Inc. N. Y. 202 p.

Ewers, Lela A. 1933. Summary report of the crustacea used as food by the fishes of the western end of Lake Erie. Trans. Am. Fish Soc. 63: 379-390.

________, and M. W. Boessel. 1935. The food of some Buckeye Lake fishes. Trans. Am. Fish. Soc. 65: 57-69.

Fahy, W. E. 1954. The life history of the northern greenside darter, Etheostoma Blennoides Blennoides (Rafinesque). J. Elisha Mitchel Sci. Soc. 70: 139-205.

Forbes, S. A. 1883. The food of the smaller fresh water fishes. Bull. Ill. State Lab. Nat. Hist. 1(6): 65-95.

Forney, J. L. 1955. Life history of the black bullhead, Ameiurus melas (Rafinesque) of Clear Lake, Iowa. Iowa St. Col. J. Sci. 30: 145-162.

Galtsoff, P. S., F. E. Lutz, P. S. Welch and J. G. Neeham. 1937. Culture methods fro invertebrate animals. Comstock Pub. Co., Ithaca, N. Y. 590 p.

Goodrich, H. B., C. B. Cramton, and D. A. Wilson. 1933. Oxygen consumption in different genetic types of goldfish. Am. Nat. 67: 76.

Hampton, R. 1954. Intergradation of the bullhead minnow. Trans. Kans. Acad. Sci. 57: 480-481.

Harrington, Robert W. Jr. 1948. The food of the bridled shiner, Notropis bifrenatus (Cope). Am. Midl. Nat. 40: 352-361.

Hay, Oliver P. 1888. A contribution to the knowledge of the fishes of Kansas. Proc. U. S. Nat. Mus. 10: 242-253.

Helm, William Thomas. Some notes on the ecology of panfish in Lake Wingra with special reference to the yellow bass. Univ. Wis. Doctoral dissertation, 1958.

Henderson, C. and C. M. Tarzwell. 1957. Bioassays for control of industrial effluents. Sewage and Industrial Wastes. 9: 1002-1017.

Hooke, Robert. 1667. Micrographia; of some physiological descriptions of minute bodies made by magnifying glasses. With observations and inquiries thereupon. 246 ;;. London.

Hubbs, C. L. 1943. Terminology of early stages of fishes. Copeia 1943: 260.

_______, and A. I. Orteburger. 1929. Further notes of fishes of Oklahoma and descriptions of new species of Cyprinidae. Univ. Okla. Biol. Surv. 1: 17-43.

_______, and J. D. Black. 1947. Revision of Ceratichthys, a genus of American cyprinid fishes. Misc. Pub. Mus. Zool. Univ. Mich. 66: 1-56.

_______, and K. F. Lagler. 1947. Fishes of the Great Lakes Region. Full. Cranbrook Inst. Sci. 26: 1-186.

Jordan, D. S. 1856. Identification of the species of Cyprinidae and Catostomidae. Proc. Acad. Nat. Sci. Phila. for 1856. 118-127.

Koster, W. J. Outline for an ecological life history study of a fish. Ecol. 36: 141-153.

Kraatz, W. C. 1928. Study of the food of the bluntnosed minnow Pimephales notatus. Ohio. J. Sci. 28: 86-98.

Leonard, E. M. 1950. Limnological features and successional changes of Lake Carl Blackwell, Oklahoma. Thesis, Okla. State Univ. Libr. 75 p.

Leeuwenhoek, Antony. 1686. An abstract of a letter concerning the scales of eels. Phil. Trans. Royal Soc. London. 15: 883-895.

Lord, Russell R., Jr. 1927. Notes on the use of the blackhead minnow, Pimephales promelas as a forage fish. Trans. Am. Fish. Soc. 57: 92-99.

Markus, H. C. 1934. Life history of the blackhead minnow Pimephales promelas. Copeia 1934(3): 116-122.

McLane, William McNair. 1955. The fishes of the St. Johns River system. Univ. Florida, Doctoral dissertation, 1955.

Morrow, James E. 1948. Schooling behavior in fishes. Quar. Rev. Biol. 23: 27-36.

Newman, E. 1876. Mr. Saville Kent's lecture at the Society of Arts, on "The Aquarium: Construction and Management." Zoologist Ser. II, 11: 4853-4858.

Parr. A. E. 1927. A contribution of the theoretical analysis of the schooling behavior of fishes. Occ. Pap. Bingham Oceanogr. Coll. 1: 1-32.

_______. 1931. Sex dimorphism and schooling behavior among fishes. Am. Nat. 65: 173-180.

Pearse, A. S. 1915. On the food of the small shore fishes in the waters near Madison, Wisconsin. Bull. Wis. Nat. Hist. Soc. 13: 7-22.

_______. 1918. The food of the shore fishes of certain Wisconsin Lakes. Bull. U. S. Bur. Fish. 35: 245-292.

_______. 1921. The distribution and food of the fishes of three Wisconsin Lakes in summer. Univ. Wis. Studies in Sci., No. 3, 1-61 p.

Petravicz, J. J. 1936. The breeding habit of the least darter, Microperca punctulata Putnam. Copeia 1936(2): 77-82.

Rafinesque, C. S. 1899. (1920). Ichthyologie ohiensis. 108 p.

Riggs, Carl Daniel. 1953. Studies of the life history of the white bass. Univ. Mich. Doctoral dissertation, 1953.

Romer, A. S. 1955. The vertebrate body. W. B. Saunders, Co. Phila. 644 p.

Shaw, Evelyn. 1962. The schooling of fishes. Sci. Am. 206(6): 128-138.

Smith, Gilbert M. 1933. The fresh water algae of the United States. McGraw-Hill Book Co. Inc. New York. 716 p.

Snedecor, George W. 1946. Statistical methods. Iowa State Col. Press. Ames, Iowa, 485 p.

Thomson, J. Stuart. 1902. The periodic growth of schales in Gadidae and Pleuronectidae as an index of age. J. Mar. Biol. Assoc. New Ser. 6(3): 372-375.

Trama, Francesco B. 1954. The acute toxicity of some common salts of sodium potassium and calcium to the common bluegill (_Lepomis macrochirus_ Rafinesque). Acad. Nat. Sci. Phila. 185-205.

Van Cleve, Harley J. and Henry C. Markus. 1929. Studies of the life history of the blunt-nosed minnow. Am. Nat. 63: 530-539.

Van Oosten, John Deason, and F. W. Jobes. 1934. A microprojection machine designed for the study of fish scales. J. du Conseil. 9: 241-248.

Weese. A. O. 1949. Age and growth of _Lepibema chrysops_ in Lake Texoma, Oklahoma. Proc. Okla. Acad. Sci. 30: 45-48.

Wynne-Edwards, V. C. 1932. The breeding habits of the blackhead minnow _Pimephales promelas_ Raf. Trans. Am. Fish. Soc. 62: 382-383.

A P P E N D I C E S

Appendix A

Appendix A. DISTRIBUTION OF PIMEPHALES VIGILAX IN OKLAHOMA TO 1961

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Atoka County	John Mackin (Laura Hubbs)	7-9-44	Clear Boggy Creek	4
Atoka County	C. D. Riggs	7-9-44	Muddy Boggy Creek	3
Blaine County	G. A. Moore	3-13-49	Canton Reservoir	1
Blaine County	G. A. Moore	5-1-53	Canton Reservoir	4
Bryan County	V. E. Dowell	10-1-54	Region #188-214 Bis. Cr.	29
"	O.A.S. Class	5-19-54	U.S. 75A N. of Denison Dam	3
"	G. A. Moore	4-15-49	7E. IS. Durant Highway 70	14
"	"	4-15-49	R.R.S. of Yuba Highway 299	1
"	"	4-15-49	R2, T7, 8E, 1S. Durant	48
"	"	3-13-53	Red R. 1-1/2 SW. B.R.	46
"	"	10-17-53	2S. from Jackson	20
"	"	10-17-53	Red River & Blue River Mouth	45
"	"	7-17-58	Barrow Pits & Red River S.	28
"	C. D. Riggs	6-16-49	Lake Texoma Washita Arm. Sta. 13	1
"	"	6-19-49	"	4
"	"	7-7-49	"	1
"	"	7-9-49	Lake Texoma Red R. Arm Hickory Cr.	1
"	"	7-1-54	Sand Cr. N. of Denison Dam U.S. 77 Br.	10
"	"	7-8-54	R54,T16, 1/2E. Highway 271	5
"	"	7-24-56	Lake Texoma Washita Arm. Sta. IB Rock Cr.	7
"	"	7-26-56	R56, T15, Culbert U. S. 77	9
"	"	1-25-60	Newberry Creek Bridge	17
Comanche County	John Mackin	7-12-44	N. Cache Creek of Red River	15
"	"	7-12-44	Wichita Mtn. Wildlife Refuge Little Medicine Creek	1

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Comanche County	John Mackin	7-19-44	N. Cache Creek Red River	2
"	"	7-19-44	Cache Creek Red River	3
"	G. A. Moore	2-19-47	T3N, R12W, Medicine Park Hatchery	12
Carter County	R. M. Jenkins	6-27-57	Lake Murray Duck Trap Cove	2
"	C. D. Riggs (Class 349)	8-3-50	Lake Murray 2nd Cove	41
"	"	8-3-50	Lake Texoma, House Creek	41
"	"	1-19-58	Lake Murray 2nd Cove	3
"	Clay Wilson	1-14-55	Lake Murray 2nd Cove	3
Cherokee County	G. A. Moore	8-21,27-46	Illinois R.S. 26T, 17N, R22E	1
Choctaw County	C. D. Riggs	3-28-51	Honey Cr. 1/2E. Hwy. W. 271	3
Cleveland County	G. Hall and C. D. Riggs	5-28-53	Little River & Hwy. 9 Bridge	31
Craig County	G. A. Moore	6-24-55	Little Cabin Cr. 3E. Vinita on U.S. Hwy. 66	1
Custer County	G. A. Moore	9-29-47	Clinton Lake	12
"	"	7-1-48	Clinton Lake	7
Delaware County	G. E. Hall	7-31-48	Grand Lake Cary Boy	3
Harmon County	G. A. Moore	6-21,24-26	Salt Fork of Red River	1
"	A. I. Ortenburger	6-20-26	Buck Creek Hollis Sta. 4	1
"	"	6-21-26	Sand Creek Hollis Sta. 4	9
"	"	6-24-26	Salt Fork of Red R. Hollis	3
Jackson County	L. E. Horneff	5-5-56	Altus Sta. 6 Irrigation Ditch below dam walls	13

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Johnson County	John Mackin	7-7-44	Pennington Creek	3
Johnston County	G. A. Moore	8-20-46	Pennington Cr. at U. S. Hattchery	1
Kay County	G. A. Moore	3-16-40	Chikaskia R. 1N., 1E. Tonkawa R1W, T26N.	8
"	"	3-16-40	2E., 1N. Tonkawa Chikaskia R.	5
"	"	7-13-46	2N., 1E. of Tonkawa at bridge across Chikaskia R.	49
"	"	3-20-48	2E., 1N. Tonkawa Chikaskia R.	8
"	"	3-5-49	Lake Blackwell	4
"	"	3-5-49	Trib. of Chikaskia R. 1/4E. 1S. Blackwell	8
"	"	3-5-49	Below dam at L. Blackwell on Chickaskia R.	3
"	"	3-5-49	Chickaskia R. 4SW. Hornewell, Kans.	13
"	"	5-7-49	Chickaskia R. below dam at L. Blackwell	3
"	"	5-7-49	Chikaskia R. 4SW. Hornewell, Kans. 1/4E. of County line	1
"	"	5-17-40	1N., 1E. of Tonkawa Chikaskia R.	12
"	"	5-1-54	Sand Creek near Hobart	6
Kiowa County	John Mackin	3-7-44	Elk Creek	5
LeFlore County	Hill, King, Finnell and Summers	5-11-55	Winter Reservoir in a 3 A. cove	41
"	G. A. Moore	8-26-47	Poteau Rat Slate Ford	101
"	"	8-27-47	Brayil Creek T8N, R25E, S.2021	6
"	"	8-27-47	Mouth of Poteau River	25
"	"	8-28-47	Poteau River Bridge Hwy. 271	21
"	"	8-18-50	Poteau River at Slate Ford near Shady Point	4
"	A. I. Ortenburger	7-24-27	Arkansas R. 5-1/2SW. of Ft. Smith	2
Logan County	G. A. Moore	11-29-47	Beaver Creek 5S. Sect. 51&77	2

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Logan County	G. A. Moore	11-29-47	Skeleton Creek T18N, R3W, S15, 16	3
Love County	C. D. Riggs	7-11-49	Lake Texoma R. arm of Hickory Creek	1
Marshall County	V. E. Dowell	7-9-53	L. Texoma Buncombe Cr. 1/4N. of Camp Jack Little	3
"	"	5-28-54	Sundated Narrow Creek L. Texoma	1
"	"	6-1-54	L. Texoma U.O.B.S. boat house	2
"	"	6-13-54	Two coves on W. shore of Buncombe Cr. L. Texoma	2
"	"	6-20-54	Cove on W. side opposite Jack Little	12
"	"	6-20-54	Lake Texoma Buncmobe Creek	7
"	"	6-24-54	Lake Texoma N. rural Littlehouse	4
"	"	6-26-54	Kingston Road Bridge	4
"	"	6-27-54	L. Texoma Sundated Cr. Chann. 21-1/2 above Camp Jack Little	8
"	"	7-13-54	Buncombe Cr. E. shoreline opposite U.O.B.S.	9
"	V. E. Dowell and King	8-8-54	L. Texoma 1-2 above Camp Jack Little	37
"	V. E. Dowell	9-17-54	L. Texoma 1-1/2 above Jack Little	7
"	"	10-1-54	L. Texoma Buncombe Cr. 1/2 above Camp Little	6
"	"	10-8-54	L. Texoma above Camp Jack Little	12
"	"	10-22,23-54	L. Texoma Buncombe Cr. Cove across from Camp Jack Little	18
"	"	10-30-54	Buncombe Cr. below Shayford L. Texoma	3
"	"	10-30-54	Kingston Road Bridge	2
"	"	11-5-54	L. Texoma U.O.B.S. Boat House	5
"	"	1-7-55	Island N.W. of Jack Little (camp)	2
"	"	2-6-55	L. Texoma Kingston Road bridge 1S.	1
"	"	2-8-55	L. Texoma Buncombe Creek 1/2 above Jack Little	19

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Marshall County	V. E. Dowell	3-7-55	L. Texoma Buncombe Cr. pools in Nanow Creek	27
"	"	3-20-55	L. Texoma Buncombe Cr. 1/4 up creek 1/2N. Camp Jack Little	19
"	"	3-28-55	Mud Flats in Buncombe Cr.	1
"	"	3-29-55	2S. of Kingston Road, gravel pit	2
"	"	4-17-55	Kingston Road Bridge	2
"	"	5-27-55	L. Texoma Buncombe Creek 1-1/2N. of Camp Jack Little	22
"	"	6-7-55	Stream shoreline & island NW of Camp Jack Little L. Texoma	7
"	"	6-11-55	L. Texoma Buncombe Cr. 1-1/2 above Camp Jack Little	5
"	"	6-11-55	L. Texoma, Buncombe Cr. around shore line	21
"	"	7-13-55	U.O.B.S. boat house	3
"	"	7-13-55	L. Texoma U.O.B.S. swimming beach	23
"	"	7-18-55	Cove N. of rural Little House	4
"	"	7-18-55	Buncombe Cr. near mosquito cove L. Texoma	27
"	"	7-19-55	L. Texoma U.O.B.S. boat house	27
"	"	7-25-55	Kingston Road bridge	16
"	"	7-28-55	2S. of Kingston Rock Quary	1
"	"	8-1-55	L. Texoma Buncombe Cr. 1-1/2 above Camp Jack Little	4
"	"	8-3-55	L. Texoma Buncombe Creek	3
"	"	7-24-56	L. Texoma Buncombe Creek	15
"	F. Hopper	6-19-58	L. Texoma Briar Creek	2
"	G. A. Moore Class 240	8-28-59	L. Texoma Limestone Cove	177
"	Research Crew	7-29,30-58	L. Texoma Limestone Creek	376
"	C. D. Riggs	6-26-49	L. Texoma Red River Arm Buncombe Cr.	5
"	"	7-28-49	L. Texoma Red River Islands Station 7	1
"	C. D. Riggs and Class	7-17-50	L. Texoma Briar Creek	2

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Marshall County	C. D. Riggs and Zool. 309	6-23-50	L. Texoma Roland Creek at mouth	9
"	C. D. Riggs and Zool. 309	6-18-51	1/2W. of U.O.B.S. in road high water	1
"	C. D. Riggs	7-14-52	L. Texoma, Pondon Island II	6
"	"	1954	Shore line N. of U.O.B.S. L. Texoma	2
"	"	6-21-54	L. Texoma Buncombe Creek	6
"	"	7-19-54	L. Texoma shoreline	8
"	"	8-9-56	L. Texoma boat house Buncombe Cr. at U.O.B.S.	4
"	"	8-9-56	L. Texoma Sand Bars	2
"	"	6-17-57	L. Texoma mouth of Buncombe Cr.	1
"	"	7-8-57	L. Texoma Buncombe Cr.	2
"	"	3-13-50	L. Texoma Buzzard Creek 3-1/3W. of Millerton	15
Mayes County	G. A. Moore	3-27-32	Rock Creek 4-1/2S. of Big Cabin	6
McCurtain County	G. E. Hall	7-25-55	Little River N.W. of Idabel cut off Pool; T7S, R24E, S19.	85
"	"	7-25-55	Little River N.W. of Idabel	75
Murray County	G. A. Moore	5-8-48	Pucis Falls	2
"	"	5-8-48	Camp Classen	4
"	"	5-8-48	Washita R. at Daugherty Bridge	12
"	"	5-8-48	Washita R. at Daugherty	28
"	A. I. Ortenburger	6-20-24	Arbuckle Mts. Mark No. 1	1
"	"	7-4-25	Red River 4W. of Arkansas line	2
"	C. D. Riggs	7-31-50	Falls Creek	14
"	"	3-17-51	Washita River Highway 77	7
"	"	3-22-51	Honey Creek at Iron Bridge	7
"	"	7-8-54	U.S. 77 Bridge N. of Turner Falls, Honey Creek	114

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Murray County	C. D. Riggs	7-16-55	U.S. 77 Bridge of Washita River	10
"	"	7-16-55	U.S. 77 Bridge of Washita River	5
"	C. D. Riggs and U.O.B.S. Class	6-26-58	Creek S.E. of Prices Falls S3, T2S, R2E.	25
Muskogee County	G. A. Moore	3-26-32	Bayou Cr. 5-1/2E. of Ft. Gibson on Hwy. 62	3
"	"	6-27-50	Big Green Leaf Creek, Bolan Dam S10, T13N, R20E.	1
"	G. A. Moore and Survey	3-2-57	Verdigris R. & confluent with Arkansas R. T15N, R19E, S5.	1
Noble County	G. A. Moore	2-18-50	Red Rock Cr. 1/2W. of Hwy. 77N. of Perry 12 miles	1
Nowata County	G. A. Moore and Survey	6-12-56	Verdigris R. Coodys Bluff water dam T26N, R16E, S35.	7
"	"	6-14-56	Verdigris R. 1N. of bridge at Coodys Bluff; T26N, R16E, S25.	9
"	"	6-19-56	Double Creek 3S. of Nowata T25N, R16E, S7-8	2
"	"	7-16-56	Verdigris R. 2E. 1S. of Alluive T25N, R16E, S34 & 35	1
"	"	7-18-56	Verdigris R. S.E. 2N. of Talala T24N, R16E, S15	58
"	"	8-2-56	Verdigris R. 1-1/2S. of Coodys Bluff	17
"	"	8-10-56	Verdigris R. Lighten Creek Trib. T26N, R16E, S5	6
"	"	8-10-56	Verdigris R. at Highway 10 bridge 3E. of Lenapah	24
Oklahoma County	U.O.F. & G.S.	8-2-48	Lake Hefner	9

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Okmulgee County	G. A. Moore	7-2-47	Lake Okmulgee	8
Osage County	Curd & Walker	8-10-56	Hominy Cr. 10W. of Skiatook T22N, R10E, S13	6
"	G. E. Hall	7-31-48	Cleveland City Lake	5
"	G. A. Moore and Survey	7-31-56	Hula Reservoir T29N, R12E, S10	82
Ottowa County	G. A. Moore	4-24-48	Grand Lake at Wyandott	2
"	"	8-13-55	T29N, R23E, S21	8
"	"	8-13-55	T28N, R21E, S9	1
Pawnee County	G. A. Moore	2-18-50	Red Rock Creek near mouth	3
"	"	7-30-56	Arkansas R. T22N, R7E. above 5 below Black-burn	3
Payne County	G. A. Moore	3-20-48	Council Creek	30
Pittsburg County	John Mackin	7-44	Cool Creek	3
Pontotoc County	G. A. Moore	4-6-47	Clear Boggy R. 6S 1/2W. Ada	8
"	"	4-14-49	Chickasaw Clear Boggy Creek 1/2 off Hwy. 99	2
"	"	4-16-49	Jack Fork Creek S. of Ada T2N, R6E on Hwy. 99 Clear Boggy System	1
Pushmataha County	G. A. Moore	3-28-48	Lake near river on Kiamichi	1
Rogers County	G. A. Moore and Survey	6-26-56	Verdigris R. Hwy. 88 Bridge, T22N, R15E, S14	2
"	"	6-26-56	Sweet Water Creek 5N. of Claremore T22N, R16E, S18	1
"	"	7-18-56	5E. & 2N. of Talala T24E(N), R16E, S15 Verdigris River	2

Locality	Collector	Date of Collection	Remarks	No. of Specimen
Rogers County	G. A. Moore and Survey	7-24-56	Verdigris R. 3W. & 1/2S. of Sonola T19N, R16E, S14	1
"	"	7-24-56	Verdigris R. 4S. & 2-1/2W. Sonola T19N R16E, S36	4
Roger Mills County	A. I. Ortenburger	6-24,26-26	Washita River, Cheyenne Sta. 10	1
Sequoyah County	G. A. Moore	8-24-46	Illinois River T12N, R21E, 820-21 at River Mouth	88
"	"	5-5-50	Arkansas R. S. of Muldrow	4
"	C. D. Riggs and Class 240	5-7-55	Big Sallisaw Cr. near McKee Store above Red River Bridge	1
Stephens County	G. A. Moore	Summer 1947	Duncan Lake	3
Wagoner County	G. A. Moore and Survey Crew	6-29-56	Verdigris River T25N, R17E, S14	2
"	Sutton, Douglas and Walker	3-2-57	Near old road bridge at Opay T26N, R19E, S19	154
Woodward County	C. D. Riggs	5-26-53	Wall Creek at U. S. Hwy. 27 Bridge	7

Appendix B

Appendix B. MEASUREMENTS OF PIMEPHALES VIGILAX IN MILLIMETERS

Number	Total Length	Standard Length	Head Length	Head Width	Head Depth	Snout Length	Snout Length into Head Length	Postorbital Length of head	Interorbital Width	Orbital Length	Diameter of orbit	Length of Upper Jaw	Length of Mandible	Diameter of Eye	Gape Width	Body Depth	Nape	Predorsal Length
1.	59	50	13	7	6	4	3.25	6	4	5	4	3	4	3	4	10	14	24
2.	52	46	9	6	5	3	3.00	5	4	5	3	1.5	3	2	3	8	11	21
3.	65	54	14	9	9	5	3.00	7	4	5	4	3	4	4	4	10	15	25
4.	71	59	16	9	8	5	3.20	8	4	5	4	2.	4	3	4	14	16	28
5.	65	54	13	9	8	5	2.60	7	4	4	3.5	4.	3	2	5	11	15	26
6.	65	55	14	8	9	4	3.50	7	4	4	4.	2	3	3	4	10	15	29
7.	60	50	12	7	7	5	2.40	6	4	4	3	3	3	2	3	10	13	24
8.	55	46	12	7	8	4	3.00	6	3	4	3	3	3	2	3	9	10	20
9.	49	39	11	7	7	3	3.66	6	3	4	2	2	3	3	2	8	12	19
10.	60	59	13	7	8	3	4.33	7	4	4	3	3	3	2	4	8	14	22
11.	75	62	15	9	11	5.5	3.00	5	4	4	4	2	3	3	6	12	19	31
12.	55	42	11	7	8	4	2.75	8	5	5	5	4	5	3	4	10	13	21
13.	55	44	11	7	8	4	2.75	6	3	3	3	3	3	2	4	7	13	21
14.	58	47	13	7	8	4	3.25	6	3	3	3	3	3	2	4	8	14	22
15.	75	62	16	10	11	6	2.66	8	4	4	4	4	4	3	5.5	12	18	30
16.	59	47	11	6	7	4	2.75	6	4	4	4	3	4	3	5	8	14	22
17.	67	55	13	8	10	5	2.60	7	4	4	4	3	4	2	5	11	17	25
18.	75	62	16	9	10	5.5	3.20	8	5	5	5	4	4	3	5	13	20	32
19.	60	59	12	7	8	4	3.00	6	4	4	4	3	3	3	4	10	15	25
20.	60	59	12	7	8	4	3.00	5.5	4	4	4	3	3	3	4	10	15	23

Number	Total Length	Standard Length	Head Length	Head Width	Head Depth	Snout Length	Snout Length into Head Length	Postorbital Length of Head	Interorbital Width	Orbital Length	Diameter of orbit	Length of Upper Jaw	Length of Mandible	Diameter of Eye	Gape Width	Body Depth	Nape	Predorsal Length
21.	55	44	11	7	7	4	2.75	5	4	4	3	3	3	2	4	7	13	21
22.	76	64	15	10	11	6	2.50	8	5	5	4.5	5	5	3	6	14	19	30
23.	75	64	15	9	11	5	3.00	7	5	5	4	5	5	3	6	13	17	28
24.	85	69	18	10	12	6	3.00	8	5	5	4	5	5	3	6	12	19	33.5
25.	89	74	18	11	13	7	2.57	10	6	6	5	5	5	4	7	16	22	35
26.	80	66	16	10	11	5	3.20	9	5	6	4	5	5	3	6	14	18	31
27.	76	64	15	10	12	6	2.50	7	5	5	4	5	5	3	6	13	18	30
28.	74	63	16	10	11	6	2.66	8	5	5	4	5	5	3	6	13	18	30
29.	74	60	15	9	10	5	3.00	7	4	4	3	5	5	3	6	13	17	29
30.	78	66	15	10	11	5	3.00	8	5	5	4	5	5	3	6	13	20	32
31.	83	70	18	12	14	6	3.00	9	5	5	4	5	4	3	6	15	20	32
32.	80	65	18	12	14	5	3.60	9	5	5	4	5	4	3	6	16	22	34
33.	83	69	17	11	14	6	2.83	7	5	5	4	5	4	3	6	16	19	32
34.	62	49	13	8	10	4	3.25	6	5	5	4	3	4	3	4	12	15	25
35.	85	67	16	11	15	5	3.20	8	5	5	4	5	4	3	6	16	21	33
36.	80	67	17	11	14	5	3.40	7	5	5	4	5	4	3	6	14	18	31
37.	76	64	16	10	13	5	3.20	8	5	5	4	5	4	3	6	14	18	31
38.	85	72	16	12	14	5	3.20	9	6	6	5	5	4	3	6	16	20	36
39.	77	63	16	10	13	5	3.20	9	5	5	4	5	4	3	6	14	19	32
40.	66	50	13	8	10	4	3.25	5	4	4	3	3	3	2	4	11	16	25

Number	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length	Length of Paired fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Middorsal Line Scales	Lateral Line Scales	Weight of Fish in Grams	Cmm. Volume of Stomach Contents
1.	2	6	12	7	3	8	3	5	6	5	20	6	27	44	2.0040	.090
2.	2.5	5	11	6	3	7	3	5	5	5	20	5	27	44	1.1892	.020
3.	2.5	7	15	7	5	9.5	5	7	10	5	22	7	27	49	2.883	.420
4.	2	8	14	9	8	10	3	5	10	6	20	6	29	49	3.975	.016
5.	2	7	14	8	7	8	4	6	10	5	20	7	25	49	2.6788	.056
6.	2.5	6	13	8	7	9	6	8	11	6	20	5	26	44	3.9319	.048
7.	2	6	11	7	8	8	5	7	9	5	20	6	28	45	2.1390	.056
8.	2	5	11	6	6	7	5	7	8	5	20	5	29	44	1.7070	.060
9.	2	5	10	6	5	7	4	6	8	5	20	4	28	43	1.1462	.020
10.	2	6	13	6	7	8	5	7	7	4	20	6	25	49	1.5930	.036
11.	3	7	16	9	10	10	8	10	11	6	20	7	31	42	3.8662	.040
12.	2	5	12	7	7	7	5	7	8	4	20	5	23	49	1.5912	.020
13.	2	5	10	5	7	6	4	6	9	4	20	5	19	39	1.3562	.016
14.	2	5	11	8	6	7	4	6	7	4	20	5	21	44	1.8882	.036
15	4	7	15	10	11	9	7	9	12	6	20	7	29	42	4.2762	.132
16.	2	5	13	7	6	6	4	6	10	4	20	5	25	49	1.6692	.024
17.	2	6	12	10	10	8	7	9	10	6	20	6	26	44	2.6880	.060
18.	4	7	16	10	11	10	6	9	10	6	20	7	29	46	4.1852	.128
19.	3	6	13	8	8	8	6	8	8	4	20	6	27	44	2.0912	.044
20.	3	6	12	8	7	8	5	7	8	4	21	6	26	44	1.9602	.024

Number	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length	Length of Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Middorsal Line Scales	Lateral Line Scales	Weight of Fish in Grams	Cmm. Volume of Stomach Contents
21.	1	4	11	6	5	6	4	6	7	4	20	4	26	44	0.6980	.052
22.	1	8	17	10	13	10	7	9	10	6	20	7	25	45	4.5840	.044
23.	4	7	18	9	11	10	7	9	11	6	20	7	25	44	4.3560	.048
24.	3	8	19	10	13	10	8	10	11	6	20	8	25	45	6.0238	.108
25.	4	9	19	11	15	12	9	11	12	6	20	9	23	49	6.9979	.060
26.	4	8	17	10	11	10	7	9	11	6	20	7	25	49	5.4510	.100
27.	4	7	15	9	12	10	6	8	9	5	20	7	24	45	4.5740	.100
28.	3	7	15	8	10	9	6	8	10	6	20	7	25	42	4.3350	.120
29.	3	7	15	10	11	9	6	8	10	5	20	7	28	43	2.7470	.048
30.	4	8	16	9	12	9	7	9	10	6	20	8	27	43	5.2690	.120
31.	4	8	17	10	13	11	9	11	13	7	24	9	24	43	7.0912	.120
32.	3	9	17	10	12	10	8	10	10	5	20	9	23	47	6.6432	.100
33.	4	8	18	11	15	12	8	10	11	6	22	8	25	43	7.0490	.100
34.	3	6	12	7	9	8	7	7	8	4	19	6	20	40	2.6512	.040
35.	4	9	16	10	14	11	6	9	10	6	20	8	29	46	6.5879	.108
36.	3	9	17	9	12	10	7	9	10	6	20	9	24	44	5.6432	.060
37.	3	7	15	9	12	10	7	9	10	5	20	7	26	44	5.2412	.120
38.	4	9	20	11	14	10	9	11	11	7	20	9	26	48	7.2710	.100
39.	4	8	15	9	13	11	8	10	10	6	22	8	22	44	5.2992	.076
40.	2	6	14	8	7	7	5	7	9	6	20	8	23	44	2.7672	.024

Appendix C

Appendix C. THE OCCURRENCE OF FOOD ITEMS FROM STOMACH OF 40 PIMEPHALES VIGILAX ACCORDING TO DATES OF COLLECTIONS IN 1960-61. THE VOLUME OF FOOD FOUND IN EACH STOMACH ARE GIVEN IN CMM. THE (X) INDICATES THE ITEMS OF FOOD WHICH WERE FOUND IN THE STOMACH.

No. and Date of Collection	Altanaria	Spongi-improfecti	Bacillarieae	Myxophyceae	Chlorophyceae	Heterokontae	Euglenophyceae	Odonata	Culicidae Larvae	Chironomidae	Coroxidae	Heptugeniidae	Notonectidae	Psychodidae	Sialidae (eggs)	Unknown eggs	Rotifera	Crustacea (Copepoda)	Hydracarina	Setat Annelida	Mollusca	Unrecognizable Animal remains	Unrecognizable organic debris	Inorganic debris	Volume of Food
8-6-60																									
1.	x	x			x		x	x			x		x	x	x	x		x		x		x	x	x	.09
2.	x	x	x		x		x	x	x	x				x				x	x	x		x	x	x	.020
3.	x	x			x					x		x	x	x				x					x	x	.420
4.	x		x	x	x	x	x		x					x				x	x		x		x	x	.016
5.			x	x	x					x				x				x				x	x	x	.056
6.	x	x	x							x	x		x	x				x	x		x	x	x	x	.048
7.	x	x	x		x	x			x									x		x	x	x	x	x	.056
8.	x	x	x	x	x				x	x				x				x			x		x	x	.060
9.	x	x	x		x				x	x								x			x	x	x	x	.020
10.	x	x	x		x				x	x								x			x	x	x	x	.040
11-6-60																									
11.			x	x	x													x			x	x	x	x	.020
12.			x	x	x				x	x			x	x				x			x	x	x	x	.016
13.			x	x	x				x	x			x	x				x			x	x	x	x	.036
14.			x	x	x				x				x	x				x			x	x	x	x	.132
15.					x					x				x				x			x	x	x	x	.024
16.					x		x			x				x							x	x	x	x	.060
17.					x		x			x			x	x						x	x	x	x	x	.128
18.					x					x	x		x	x							x	x	x	x	.044
19.																									
20.					x		x						x									x	x	x	.024

No. and Date of Collection	Altanaria	Spongi-Improfecti	Bacillarieae	Myxophyceae	Chlorophyceae	Heterokontae	Euglenophyceae	Odonata	Culicidae Larvae	Chironomidae	Coroxidae	Heptugeniidae	Notonectidae	Psychodidae	Sialidae (eggs)	Unknown Eggs	Rotifera	Crustacea (Copepoda)	Hydracarina	Setat Annelida	Mollusca	Unrecognizable Animal Remains	Unrecognizable Organic Debris	Inorganic Debris	Volume of Food
1-6-61																									
21.					x					x	x		x		x			x	x	x	x	x	x	x	.052
22.					x					x			x	x				x				x	x	x	.044
23.								x		x	x		x	x			x	x		x		x	x	x	.048
24.					x		x						x	x				x				x	x	x	.108
25.			x					x		x			x				x	x	x			x	x	x	.060
26.					x					x			x	x	x			x				x	x	x	.100
27.					x								x					x				x	x	x	.100
28.					x					x		x	x	x				x				x	x	x	.120
29.					x					x			x					x				x	x	x	.048
30.					x			x		x			x					x	x			x	x	x	.120
4-6-61																									
31.					x					x			x	x				x				x	x	x	.120
32.					x					x			x					x	x			x	x	x	.100
33.					x					x			x	x				x	x			x	x	x	.100
34.										x			x	x			x	x				x	x	x	.040
35.			x		x					x			x	x				x				x	x	x	.108
36.										x			x	x								x	x	x	.060
37.			x							x			x									x	x	x	.120
38.			x							x			x						x			x	x	x	.100
39.			x							x			x	x					x			x	x	x	.076
40.			x							x		x	x						x			x	x	x	.024

Appendix D

Appendix D. ANALYSIS OF VARIANCE OF THE 34 BODY MEASUREMENTS.

Source	df	Total Length	Standard Length	Head Length	Head Width	Head Depth	Snout Length	Snout Length into Head Length
Sample Group	3	77.283**	41.189**	27.83**	20.57**	59.47**	3.69**	0.410949*
Within Sample Group	36	6.426	5.704	3.63	1.54	2.31	0.61	0.114168
Over-All Mean		69.48	58.03	14.28	8.85	10.10	4.78	3.0303

Source	df	Post-Orbital Length of Head	Inter-Orbital Width	Diameter of Orbit	Length of Upper Jaw	Length of Mandible	Eye Length	Diameter of Eye
Sample Group	3	4.80*	3.76**	2.40**	11.47**	4.20**	2.43*	0.33
Within Sample Group	36	1.48	0.29	0.34	0.56	0.31	0.61	0.26
Over-All Mean		7.10	4.43	4.60	3.80	3.90	4.85	2.80

Source	df	Gape Width	Body Depth	Nape Length	Predorsal Length	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length
Sample Group	3	10.89**	48.83**	57.77*	128.09**	4.17**	9.20**	40.29**
Within Sample Group	36	0.61	3.90	5.07	13.99	0.52	1.24	4.41
Over-All Mean		4.93	11.78	16.55	27.53	2.85	6.80	14.43

Source	df	Length Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length (Longest)	Height of Pectoral	Anal Base Length
Sample Group	3	12.10**	78.89**	10.69**	18.33**	17.20**	7.43*	1.80
Within Sample Group	36	1.82	4.92	1.90	1.64	1.79	2.49	0.69
Over-All Mean		8.45	9.43	8.88	6.00	8.00	9.53	5.30

Source	df	Caudal Fin Formula	Least Depth of Caudal Peduncle	Middorsal Line Scales	Lateral Line Scales	Weight of Fish	Volume of Stomach Contents
Sample Group	3	0.97	12.53**	14.30	4.57	25.64	0.00227850
Within Sample Group	36	0.68	1.08	6.08	7.28	2.00	0.00465188
Over-All Mean		20.25	6.70	25.55	45.05	3.77	0.07485

Appendix E

CORRELATIONS AMONG THE 34 VARIABLES

(ith line for each variable is associated with the correlations for the ith sample group. The 5th line for each variable is associated with the overall correlations; a blank space or an asterisk indicates zero value. The correlations are expressed as a 2-digit decimal; for example a 57 is .57.)

APPENDIX E.

	Standard Length	Head Length	Head Width	Head Depth	Snout Length	Snout Length into Head Length	Postorbital Length of Head	Interorbital Width	Orbital Length	Diameter of Orbit	Length of Upper Jaw	Length of Mandible	Eye Length	Diameter of Eye	Gape Width	Body Depth	Nape	Predorsal Length
Total Length	88+	89+	83+	61+	75+	15-	86+	63+	21+	62+	32+	50+	55+	31+	79+	84+	87+	91+
	82+	94+	91+	91+	89+	08+	25+	33+	33+	33+	04+	05+	10+	32+	81+	87+	97+	97+
	98+	96+	92+	94+	77+	07+	89+	79+	74+	79+	83+	83+	78+	89+	93+	86+	92+	97+
	97+	83+	92+	97+	80+	20-	72+	56+	56+	56+	91+	52+	58+	52+	91+	92+	86+	93+
	94+	94+	93+	90+	83+	07-	74+	78+	64+	55+	78+	62+	57+	53+	90+	92+	94+	96+
Standard Length		76+	58+	52+	43+	16+	78+	72+	14+	45+	28+	34+	45+	09+	81+	56+	78+	74+
		77+	71+	70+	65+	23+	04-	26+	26+	26+	08-	26-	09+	44+	52+	80+	85+	85+
		93+	95+	96+	78+	02+	89+	83+	77+	83+	87+	87+	78+	90+	95+	90+	94+	97+
		86+	93+	94+	84+	23-	76+	65+	65+	65+	93+	60+	67+	60+	93+	89+	79+	93+
		89+	86+	83+	76+	00-	69+	76+	62+	55+	73+	53+	57+	52+	86+	86+	89+	92+
Head Length			81+	71+	62+	10+	93+	33+	13+	70+	33+	59+	61+	48+	61+	79+	82+	76+
			93+	88+	86+	26+	33+	25+	25+	25+	17+	+	7+	23+	63+	81+	92+	93+
			87+	90+	80+	06+	85+	74+	68+	74+	79+	79+	84+	84+	87+	78+	84+	93+
			91+	87+	85+	02-	75+	40+	40+	40+	89+	59+	51+	59+	89+	81+	82+	82+
			92+	86+	80+	06+	76+	67+	57+	51+	73+	56+	55+	55+	81+	87+	89+	92+
Head Width				73+	75+	20-	85+	29+	12+	52+	41+	47+	54+	50+	66+	75+	79+	72+
				96+	94+	01-	41+	26+	26+	26+	22+	10+	08+	20+	60+	82+	85+	88+
				94+	85+	16-	91+	83+	77+	83+	85+	85+	82+	87+	92+	90+	94+	96+
				91+	77+	01-	80+	62+	62+	62+	87+	58+	64+	58+	87+	91+	89+	94+
				92+	78+	02-	77+	74+	63+	49+	78+	54+	51+	51+	81+	92+	89+	92+
Head Depth					45+	14+	77+	00+	33-	33+	41+	09+	09+	37+	41+	33+	51+	50+
					92+	08-	29+	23+	23+	23+	02+	06+	01-	11+	72+	82+	87+	86+
					86+	15-	81+	84+	73+	84+	85+	85+	83+	88+	93+	87+	89+	93+
					77+	08-	73+	54+	54+	54+	94+	63+	61+	63+	94+	92+	87+	91+
					69+	02+	67+	73+	53+	49+	79+	48+	44+	45+	83+	87+	87+	87+
Snout Length						69-	52+	36+	14+	39+	51+	44+	24+	25+	51+	78+	55+	65+
						25-	46+	23+	23+	23+	24+	22+	10+	16+	67+	75+	80+	81+
						53-	73+	80+	58+	80+	62+	62+	74+	83+	79+	73+	81+	79+
						54-	58+	35+	35+	35+	79+	52+	45+	52+	79+	75+	62+	69+
						52-	65+	62+	48+	48+	71+	64+	53+	49+	78+	75+	76+	78+
Snout Length into Head Length							20+	13-	12-	06+	23-	05-	19+	12+	08-	35-	07+	18-
							27-	03-	03-	03-	14-	46-	10-	09+	11-	09+	19+	22+
							01+	28-	01+	28-	09+	09+	05-	16-	06-	08-	14-	01+
							06+	05-	05-	05-	09-	06-	06-	06-	09-	13-	12+	03-
							+	10-	00-	12-	17-	28-	13-	01-	19-	05-	03-	03-
Postorbital Length of Head								31+	00+	50+	31+	40+	56+	37+	62+	72+	83+	70+
								56+	56+	56+	89+	80+	70+	09+	00+	40+	22+	24+
								83+	87+	83+	70+	70+	73+	88+	86+	88+	90+	90+
								66+	66+	66+	81+	66+	71+	66+	81+	75+	81+	88+
								71+	67+	61+	72+	66+	66+	52+	66+	74+	72+	74+
Interorbital Width									40+	40+	06+	32+	40+	07+	68+	37+	67+	68+
											52+	71+	90+	69+	23+	67+	39+	39+
									88+	00+	55+	55+	67+	83+	76+	74+	84+	78+
											55+	74+	95+	74+	55+	66+	43+	72+
									86+	74+	73+	69+	69+	55+	76+	80+	76+	79+

APPENDIX E. (Continued)

	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length	Length of Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length (longest)	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Mid-dorsal Line Scales	Lateral Line Scales	Weight of Fish	Food Volume
	+	92+	86+	87+	55+	92+	12+	12+	69+	46+		70+	16-	71+	90+	26+
Total Length	77+	94+	88+	84+	91+	89+	82+	88+	79+	93+		94+	85+	21-	98+	80+
	77+	96+	91+	90+	94+	93+	95+	95+	87+	79+		96+	43-	50+	99+	29+
	72+	89+	87+	92+	90+	84+	53+	86+	76+	81+		71+	71+	78+	97+	79+
	80+	92+	93+	90+	92+	90+	81+	85+	78+	76+		89+	02+	20+	96+	31+
	0 +	77+	82+	61+	52+	79+	17+	17+	42+	11+		68+	40-	78+	68+	15+
Standard Length	84+	94+	76+	77+	76+	88+	76+	80+	51+	67+		94+	88+	24-	81+	65+
	83+	96+	91+	86+	94+	94+	94+	94+	88+	84+		97+	46-	44+	99+	31+
	73+	85+	88+	90+	91+	84+	66+	91+	80+	82+		68+	63+	76+	97+	81+
	82+	90+	90+	85+	87+	90+	79+	83+	70+	71+		86+	08+	23+	91+	29+
	+	84+	75+	78+	48+	90+	16+	16+	69+	44+		50+	01+	60+	85+	25+
Head Length	81+	88+	81+	82+	86+	88+	69+	78+	63+	86+		88+	72+	26-	97+	87+
	64+	88+	88+	82+	86+	86+	90+	90+	90+	78+		91+	44-	41+	94+	34+
	54+	78+	70+	74+	75+	80+	64+	84+	76+	59+		69+	35+	50+	88+	76+
	71+	89+	86+	84+	83+	89+	76+	79+	77+	72+		84+	00+	16+	92+	36+
	0 +	87+	85+	78+	42+	76+	11+	11+	82+	43+		63+	11-	70+	79+	44+
Head Width	76+	88+	73+	74+	92+	83+	79+	83+	73+	89+		88+	68+	39-	94+	83+
	78+	94+	76+	79+	91+	89+	83+	83+	79+	79+		91+	49-	41+	94+	41+
	63+	89+	87+	87+	80+	74+	69+	90+	78+	73+		77+	50+	62+	96+	78+
	74+	92+	87+	82+	87+	86+	78+	81+	75+	75+		89+	03-	15+	95+	39+
	+	48+	63+	41+	56+	57+	70+	70+	85+	23+		32+	15-	50+	64+	40+
Head Depth	62+	86+	70+	76+	93+	84+	89+	90+	74+	95+		86+	70+	41-	91+	70+
	83+	90+	84+	80+	93+	94+	87+	87+	80+	75+		92+	57-	40+	94+	32+
	69+	91+	77+	84+	89+	86+	48+	80+	67+	69+		64+	69+	63+	94+	80+
	77+	84+	81+	79+	91+	82+	85+	87+	71+	64+		85+	13-	05+	92+	28+
	* +	75+	58+	72+	44+	62+	08+	08+	68+	42+		70+	16+	48+	67+	40+
Snout Length	66+	80+	68+	77+	90+	70+	76+	78+	85+	91+		80+	67+	30-	90+	84+
	48+	73+	65+	65+	82+	82+	73+	73+	65+	56+		76+	69-	35+	76+	16+
	71+	55+	67+	79+	82+	89+	65+	82+	88+	70+		50+	40+	75+	85+	77+
	64+	72+	74+	77+	78+	76+	66+	69+	78+	65+		70+	01+	17+	76+	37+
	+	17-	00-	28-	09-	00+	13+	13+	21-	29-		35-	29-	03+	14-	17-
Snout Length into Head Length	26+	14+	19+	11+	10-	32+	14-	03-	44-	11-		14+	08+	03+	12+	06+
	14+	04+	15+	09+	14-	12-	06+	06+	19+	17+		02+	51+	03+	6+	19+
	52-	18+	15-	31-	38-	43-	22-	23-	47-	40-		15+	22-	64-	22-	27-
	08-	04+	03-	14-	14-	00+	04-	5-	23-	08-		00+	00-	00+	-	5-
	* +	85+	79+	74+	61+	85+	18+	18+	73+	34+		48+	13-	74+	79+	17+
Postorbital Length of Head	28+	16+	22+	34+	44+	16+	13+	22+	27+	36+		16+	07+	30+	34+	64+
	69+	92+	78+	80+	81+	85+	87+	87+	86+	80+		85+	47-	61+	92+	27+
	69+	70+	57+	63+	72+	68+	75+	87+	63+	58+		49+	30+	34+	77+	79+
	62+	75+	69+	67+	71+	71+	62+	66+	65+	61+		64+	12-	37+	77+	31+
	* +	58+	60+	50+	15+	58+	10-	10-	10+	09+		66+	50-	50+	46+	18+
Interorbital Width	40+	38+	56+	41+	41+	46+	35+	44+	21+	32+		38+	53+	64+	37+	37+
	68+	77+	75+	58+	76+	84+	83+	83+	72+	72+		77+	78-	56+	84+	24+
	67+	59+	63+	55+	68+	47+	74+	66+	35+	49+		23+	28+	35+	62+	53+
	71+	74+	80+	68+	77+	73+	72+	71+	50+	54+		73+	16-	29+	78+	21+

APPENDIX E. (Continued)

	Standard Length	Head Length	Head Width	Head Depth	Snout Length	Snout Length in to Head Length	Postorbital Length of Head	Interorbital Width	Orbital Length	Diameter of Orbit	Length of Upper Jaw	Length of Mandible	Eye Length	Diameter of Eye	Gape Width	Body Depth	Nape	Predorsal Length
Orbital Length										58+	35-	80+	74+	49+	15+	33+	22+	18+
										+	52+	71+	90+	69+	23+	67+	39+	39+
										88+	52+	52+	71+	70+	67+	72+	71+	71+
										+	55+	74+	95+	74+	55+	66+	43+	72+
										68+	54+	67+	69+	61+	54+	72+	57+	64+
Diameter of Orbit											10-	80+	74+	80+	40+	56+	65+	69+
											52+	71+	90+	69+	23+	67+	39+	39+
											55+	55+	67+	83+	76+	74+	84+	78+
											55+	74+	95+	74+	55+	66+	43+	72+
											42+	57+	79+	71+	52+	59+	61+	60+
Length of Upper Jaw												05+	17-	11-	53+	16+	26+	12+
												70+	76+	21+	30-	25+	02+	06+
												+	70+	74+	90+	88+	76+	83+
												66+	64+	66+	00+	86+	80+	91+
												73+	54+	39+	83+	74+	73+	72+
Length of Mandible													85+	72+	32+	58+	52+	38+
													77+	26+	09+	27+	01+	00-
													70+	74+	90+	88+	76+	83+
													90+	00+	66+	67+	45+	60+
													77+	58+	68+	59+	57+	55+
Eye Length														65+	40+	62+	67+	48+
														53+	08-	46+	16+	14+
														67+	73+	67+	65+	78+
														90+	64+	71+	47+	72+
														67+	59+	57+	58+	56+
Diameter of Eye															07+	28+	48+	34+
															26+	50+	30+	41+
															95+	92+	91+	88+
															66+	67+	45+	60+
															47+	55+	54+	55+
Cape Width																52+	74+	72+
																59+	76+	73+
																96+	91+	92+
																86+	80+	91+
																80+	88+	86+
Body Depth																	68+	76+
																	89+	88+
																	87+	86+
																	89+	92+
																	88+	91+
Nape																		85+
																		97+
																		96+
																		90+
																		94+

APPENDIX E. (Continued)

	Caudal Peduncl Width	Caudal Peduncle Depth	Caudal Peduncle Length	Length of Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length (longest)	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Mid-dorsal Line Scales	Lateral Line Scales	Weight of Fish	Food Volume
Orbital Length	0 +	34+	31+	20+	50-	34+	65-	65-	28-	22+		27+	23+	16+	15+	38+
	40+	38+	56+	41+	41+	46+	35+	44+	21+	32+		38+	53+	64+	37+	37+
	70+	74+	69+	59+	63+	77+	74+	74+	71+	71+		64+	70-	77+	80+	31+
	67+	59+	63+	55+	68+	47+	74+	66+	35+	49+		23+	28+	35+	62+	53+
	59+	68+	70+	54+	55+	67+	50+	50+	35+	56+		60+	01+	40+	67+	34+
Diameter of Orbit	+	56+	57+	61+	12-	77+	04-	04-	37+	60+		27+	08+	16+	73+	43+
	40+	38+	56+	41+	41+	46+	35+	44+	21+	32+		38+	53+	64+	37+	37+
	68+	77+	75+	58+	76+	84+	83+	83+	72+	72+		77+	78-	56+	84+	24+
	67+	59+	63+	55+	68+	47+	74+	66+	35+	49+		23+	28+	35+	62+	53+
	57+	52+	59+	59+	52+	56+	55+	57+	47+	44+		45+	01+	31+	56+	26+
Length of Upper Jaw	+	31+	36+	12+	23+	05+	27+	27+	31+	37-		66+	32-	45+	7+	28+
	34+	04+	08+	17+	21+	02+	14-	04-	04+	06+		04+	05-	35+	16+	55+
	85+	86+	76+	80+	84+	81+	70+	70+	80+	80+		84+	17-	13+	82+	30+
	67+	83+	73+	79+	89+	88+	58+	85+	68+	66+		58+	57+	57+	90+	83+
	72+	70+	74+	68+	81+	65+	67+	70+	57+	45+		73+	23-	15+	76+	27+
Length of Mandible	* +	62+	53+	43+	27-	62+	41-	41-	09+	28+		46+	27+	35+	42+	53+
	03-	07-	15+	17+	17+	04-	04+	08+	22+	18+		07-	05+	64+	9+	25+
	85+	86+	76+	80+	84+	81+	70+	70+	80+	80+		84+	17-	13+	82+	30+
	70+	55+	33+	38+	73+	70+	66+	57+	32+	25+		03+	17+	12+	58+	63+
	56+	53+	62+	56+	59+	52+	46+	45+	46+	41+		46+	11-	17+	55+	26+
Eye Length	* +	70+	60+	57+	14-	70+	52-	52-	13+	38+		33+	06+	46+	51+	26+
	31+	15+	29+	29+	24+	19+	06+	17+	02+	11+		15+	26+	70+	16+	38+
	63+	68+	61+	59+	65+	73+	61+	61+	70+	59+		69+	58-	42+	78+	57+
	73+	61+	54+	52+	75+	60+	76+	66+	36+	42+		16+	25+	27+	65+	61+
	56+	54+	58+	58+	52+	54+	39+	41+	40+	36+		40+	06-	31+	53+	26+
Diameter of Eye	0 +	38+	44+	30+	28-	54+	03+	03+	37+	39+		13+	15+	12+	44+	68+
	58+	44+	67+	22+	21+	42+	29+	32+	27+	08+		44+	66+	46+	35+	24+
	74+	88+	78+	84+	89+	93+	88+	88+	84+	67+		91+	49-	49+	89+	05+
	70+	55+	33+	38+	73+	70+	66+	57+	32+	25+		03+	17+	12+	58+	63+
	54+	56+	58+	47+	43+	61+	46+	46+	50+	36+		44+	10+	23+	54+	49+
Cape Width	+	71+	84+	62+	23+	58+	02+	02+	37+	09+		80+	60-	70+	59+	22+
	34+	65+	77+	56+	65+	61+	71+	72+	83+	80+		65+	73+	07-	73+	40+
	84+	93+	83+	88+	93+	94+	86+	86+	88+	77+		94+	39-	37+	92+	16+
	67+	83+	73+	79+	89+	88+	58+	85+	68+	66+		58+	57+	57+	90+	83+
	74+	78+	85+	80+	85+	76+	75+	79+	71+	58+		79+	12-	14+	83+	21+
Body Depth	0 +	87+	58+	93+	46+	81+	25-	25-	58+	66+		47+	26+	49+	81+	03+
	77+	90+	85+	86+	89+	93+	84+	91+	56+	83+		90+	87+	04+	88+	74+
	84+	92+	77+	87+	89+	92+	80+	80+	84+	77+		87+	38-	44+	87+	09+
	75+	85+	80+	91+	91+	83+	61+	82+	62+	60+		54+	60+	64+	95+	83+
	79+	92+	84+	87+	88+	90+	75+	77+	68+	72+		86+	02+	21+	93+	23+
Nape	+	88+	82+	80+	36+	88+	02+	02+	61+	35+		62+	37-	67+	78+	26+
	76+	94+	87+	85+	91+	93+	80+	89+	68+	91+		94+	85+	17-	95+	78+
	73+	95+	79+	81+	93+	86+	90+	90+	77+	77+		96+	41-	40+	94+	29+
	57+	85+	69+	80+	72+	69+	48+	78+	60+	56+		68+	54+	50+	87+	76+
	79+	88+	86+	88+	88+	84+	79+	84+	72+	67+		86+	01-	11+	90+	28+

APPENDIX E. (Continued)

	Caudal Peduncle Width	Caudal Peduncle Depth	Caudal Peduncle Length	Length of Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length (longest	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Mid-dorsal Line Scales	Lateral Li e Scales	Weight of Fish	Food Volume
Predorsal Length	+	77+	72+	91+	45+	88+	14+	14+	69+	65+		50+	22-	43+	94+	14+
	84+	95+	92+	78+	90+	93+	79+	88+	70+	86+		95+	86+	20-	97+	80+
	76+	96+	83+	85+	93+	87+	90+	90+	83+	79+		97+	37-	41+	98+	40+
	71+	88+	85+	88+	86+	76+	69+	92+	69+	73+		68+	56+	63+	95+	81+
	80+	91+	90+	88+	88+	89+	81+	85+	76+	77+		87+	05+	13+	95+	31+
Caudal Peduncle Width		87+	78+	63+	73+	81+	54+	64+	50+	57+		87+	74+	16-	82+	82+
		79+	70+	70+	76+	81+	69+	69+	70+	70+		79+	32-	36+	80+	30+
		58+	54+	67+	89+	85+	67+	76+	62+	70+		25+	39+	62+	74+	66+
		73+	75+	75+	84+	79+	75+	78+	61+	61+		72+	01+	05+	80+	23+
Caudal Peduncle Depth			85+	84+	46+	88+	13-	13-	60+	37+		74+	08-	80+	77+	30+
			86+	79+	90+	95+	85+	90+	67+	83+		00+	90+	27-	94+	75+
			88+	91+	95+	90+	92+	92+	85+	85+		94+	34-	46+	96+	24+
			79+	76+	76+	68+	47+	74+	50+	65+		75+	53+	48+	85+	56+
			88+	82+	83+	89+	70+	74+	68+	73+		90+	04+	25+	92+	32+
Caudal Peduncle Length				64+	27+	78+	11+	11+	56+	19+		79+	39-	84+	71+	54+
				70+	75+	85+	71+	79+	69+	73+		86+	92+	10+	89+	68+
				84+	87+	89+	95+	95+	88+	84+		85+	44-	47+	90+	08+
				92+	73+	60+	61+	83+	71+	80+		79+	53+	81+	88+	58+
				84+	83+	84+	78+	82+	74+	72+		86+	03+	32+	90+	34+
Length of Paired Fins					49+	84+	10-	10-	70+	74+		44+	00+	44+	91+	00+
					80+	81+	75+	80+	49+	82+		79+	78+	04+	83+	77+
					92+	89+	86+	86+	77+	65+		85+	25-	54+	86+	04-
					85+	76+	58+	85+	74+	75+		67+	64+	87+	94+	74+
					86+	83+	76+	80+	72+	72+		77+	11+	24+	86+	19+
Dorsal Fin Height						46+	43+	43+	66+	23+		20+	00+	44+	51+	25-
						85+	86+	92+	74+	94+		90+	75+	27-	92+	83+
						93+	91+	91+	76+	73+		94+	41-	41+	93+	12+
						95+	63+	83+	65+	69+		41+	58+	71+	91+	80+
						85+	87+	89+	73+	66+		80+	07-	10+	90+	14+
Fin Base Length							07+	07+	66+	57+		50+	00-	59+	91+	29+
							83+	90+	50+	80+		95+	87+	16-	90+	68+
							90+	90+	84+	73+		88+	59-	57+	92+	05+
							58+	78+	67+	62+		37+	48+	64+	85+	78+
							74+	78+	68+	75+		79+	10+	27+	90+	33+
Anal Fin Height								+	52+	05-		01-	23-	00+	20+	25+
								97+	65+	84+		85+	83+	23-	79+	51+
								*+	86+	80+		92+	47-	54+	95+	11+
								85+	68+	57+		40+	06-	41+	67+	57+
								97+	72+	62+		76+	11-	01+	82+	22+
Soft Ray Length (longest)									52+	05-		01-	23-	00+	20+	25+
									66+	89+		90+	86+	18-	86+	62+
									86+	80+		92+	47-	54+	95+	11+
									85+	81+		68+	35+	69+	92+	78+
									75+	69+		78+	01-	07+	85+	25+

APPENDIX E. (Continued)

	Caudal Pedunc e Width	Caudal Peduncle[1] Depth	Caudal Peduncle Length	Length of Paired Fins	Dorsal Fin Height	Fin Base Length	Anal Fin Height	Soft Ray Length (longest)	Height of Pectoral	Anal Base Length	Caudal Fin Formula	Least Depth of Caudal Peduncle	Mid-dorsal Line Scales	Lateral Line Scales	Weight of Fish	Food Volume
Height of Pectoral										56+ 79+ 88+ 85+ 73+		31+ 67+ 85+ 66+ 65+	01- 64+ 37- 39+ 06+	39+ 23- 37+ 77+ 18+	80+ 75+ 87+ 80+ 76+	27+ 61+ 19+ 72+ 31+
Anal Base Length												14- 83+ 79+ 74+ 65+	39+ 72+ 31- 49+ 29+	14- 25- 24+ 82+ 14+	76+ 91+ 82+ 77+ 77+	08- 75+ 33+ 52+ 26+
Caudal Fin Formula																
Least Depth of Caudal Peduncle													38- 90+ 32- 30+ 8-	80+ 27- 33+ 55+ 18+	39+ 94+ 96+ 68+ 88+	53+ 75+ 30+ 31+ 35+
Mid-dorsal Line Scales														35- *7+ 61- 64+ 11+	1- 83+ 46- 60+ 2-	05- 59+ 05- 63+ 17+
Lateral Line Scales															41+ 20- 51+ 76+ 21+	36+ 09- 11- 56+ 21+
Weight of Fish																18+ 86+ 35+ 84+ 31+

VITA

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