evoid of waterfowl but does have a few crayfish and goldfish. Apparently he eating habits of the large number of waterfowl within other areas of he zoo have restricted the snails within the zoo to the one pool. On the asis of infected snails of both species obtained from the plant pool and on he basis of the knowledge of infected snails in the northern effluent, we vere able to localize the adult trematode infection to 12 waterfowl pens hrough which the water was traveling.

Fifty random lots of fecal samples from the 12 pens were examined and ound negative for trematode eggs. However, ducks from these pens were utopsied and found to harbor a trematode on the nictitating membrane of the eye. No other adult trematodes were recovered from the ducks.

The unusual shape of the metacercariae of this fluke and the occurrence of the adult fluke in the eye of ducks indicate that the trematode is in the amily Philophthalmidae. In order to verify that the fluke recovered from he eyes of ducks was of the same species as the rediae occurring in the snails, ercariae were hatched from *T. granifera* and allowed to form metacercariae. These metacercariae were introduced in three ways to six chickens one day old. Metacercariae were placed directly in the eyes of two chickens, into the nasolacrimal ducts of two chickens, and in the oral cavities of two chickens. The chickens were autopsied 30 days after infection, and adult flukes were recovered from the eyes of all chickens.

It is concluded that the adult trematode existing in waterfowl within the northern part of the San Antonio Zoo and the rediae found in *T. granifera* and *M. tuberculatus* within and immediately outside the zoo are of the family Philophthalmidae, genus *Philophthalmus*. The species is not yet determined because properly stained and mounted adult specimens have not been processed.

We are aware of no human having been infected by a philophthalmid in the U.S. There are, however, at least three human cases of philophthalmids in other areas of the world, mainly Asia. Inasmuch as this trematode cycle is occurring in a city park visited by thousands weekly, efforts will be undertaken to control or eradicate this trematode cycle.

THE PLEUROCERID FAUNA OF THE TENNESSEE RIVER GASTROPODA: PROSOBRANCHIA

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The snails of the family Pleuroceridae in the Tennessee River system have been the subject of extensive collecting and study since pre-Civil War days. Effects of sewage, industrial wastes, siltation, and impoundment have considerably altered the fauna of the Tennessee River System since the time

[1] Most of the collections were made under the auspices of the Tennessee Department of Public Health.

of these investigations. Later studies (1900 to 1940 ca) made by Ortmann, Adams, Goodrich, Van der Schalie, and Clench demonstrated changes in the fauna. However, later changes have followed impoundment and industrialization.

The present study is based on samples from over twenty stations on the river from Paducah to Knoxville from 1956 to 1966. Both hand picked and Petersen grab samples were utilized. Wading and hand picking when the reservoirs were being lowered in the fall, was productive. Samples from Indian kitchen-middens were also examined for species comparison. For convenience the river is divided into three sections: the lower northward flowing section (Kentucky Reservoir); the middle and westward flowing section (Pickwick, Wilson, Wheeler, and Guntersville Reservoirs); the upper and southwestward flowing section (Nickajack, Chickamauga, Watts Bar, and Fort Loudoun Reservoirs). The river is 652 miles in length from the junction of the French Broad and Holston at Knoxville to the Ohio River at Paducah, Kentucky. The only remaining unimpounded section of twenty-two miles is below Kentucky Dam, although this tailwater area is occasionally subject to flow reversal patterns from the Ohio River.

The original fauna of seven species (five genera) has been reduced to only three. These seven are:

1. *Pleurocera canaliculata* (Say) 1821. Contrary to several published reports, this species is still present on the lower Tennessee. It is a dominant form found throughout the entire reach.
2. *Pleurocera alveare* (Conrad) 1854. This species is recorded only from the middle section, Muscle Shoals area, by Goodrich. It apparently did not survive impoundment.
3. *Lithasia armigera* (Say) 1821. Originally found in the middle and lower sections and now apparently restricted to the tailwater of Kentucky Dam.
4. *Lithasia verrucosa* (Rafinesque) 1820. This species once inhabited the entire reach but is now found sporadically in the tailwaters of Kentucky and Pickwick Reservoirs.
5. *Anculosa praerosa* (Say) 1824. This species once occurred throughout the entire reach but is no longer represented by recent records.
6. *Nitocris virgata* (Lea) 1841. This species once was found throughout the eastern section and the upper part of the middle section. It is apparently no longer present.
7. *Io fluvialis* (Say) 1825. This species was originally found in the upper section but is no longer present.

In the upper section all seven species (except *P. alveare*) were once common. Recent records reveal only *P. canaliculata* remaining. The middle section once had populations of all seven species; however, *I. fluvialis* and *N. virgata* were limited to the uppermost area of this section. *P. canaliculata* apparently is the lone remnant of the original fauna of this middle section. The lower section of the river (Kentucky Reservoir) had fewer species (four) represented in pre-impoundment years. *P. canaliculata* is now dominant and found all the way downstream, along with *L. armigera* and *L. verrucosa*. The former distribution of *A. praerosa* in this lower section is not clear, however it is not represented in recent samples. This absence cannot be attributed to pollution, including siltation.

Extensive sampling in Kentucky Lake and Pickwick tailwaters in 1959 and in 1960 revealed only populations of *L. verrucosa*. The discharge by Pickwick (Big Bend Shoals) is located at this point. Further downstream where the current is less turbulent *P. canaliculata* populations were numerous. At the Perryville Bridge (Decatur Co., Tennessee) large numbers were found on the rocks in shallow water. At Trotters Ferry Landing (Benton Co., Tennessee) this same species was found in abundance in the shallow margins on rocks and clay flats. In fact *P. canaliculata* and the exotic clam (*Corbicula manilensis* Philippi) were the dominant invertebrate species at this particular location. This same situation prevailed on the marginal rock rip-rap on Wheeler Reservoir at Decatur, Alabama, according to Billy Isom (personal communication).

On large tributary streams of the Tennessee River, *P. canaliculata* and *L. verrucosa* were found to be the most resistant species of pleurocerids to a variety of pollutants including siltation. The few shoal areas below the mainstream TVA reservoirs could possibly have remaining populations of the latter. These same tailwaters also harbor remnant populations of commercial mussel species.

A PRELIMINARY REVISION OF THE LAND SNAIL GENUS *RABDOTUS IN TEXAS*

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Six species of *Rabdotus* are known to occur in Texas: *R. dealbatus, R. mooreanus, R. alternatus, R. schiedeanus, R. pilsbryi,* and *R. pasonis.*

Three subspecies of *R. dealbatus* occur in the state. *R. d. dealbatus* (Say) occurs in the Austroriparian, Texan, and Balconian biotic provinces of Blair (1950) and in the Neucian district of the Tamaulipan province. *R. d. ragsdalei* (Pilsbry) occupies the southern part of the Kansan, the westernmost Balconian, and the eastern Chihuahuan biotic provinces. *R. d. neomexicanus* (Pilsbry) occurs in the Guadalupe Mountains of Texas and New Mexico and in the Sacramento and San Andreas ranges of New Mexico, all in the Navahonian biotic province.

R. mooreanus (Pfr.) occurs in the Texan, Balconian, northernmost Tamaulipan and eastern Chihuahuan biotic provinces. Intraspecific variation appears to be clinal and the nominal subspecies *R. m. mooreanus* and *R. m. pecosensis* are not worthy of nomenclatural recognition. *R. mooreanus* forms local hybrid swarms with *R. dealbatus,* but there apparently is little introgression between the two breeding systems.

R. alternatus is highly variable, and the variation is little known and poorly analyzed. However, the species may tentatively be divided into an eastern subspecies, *R. a. alternatus* (Say), which occupies the Tamaulipan province, and a western, Chihuahuan subspecies, *R. a. hesperius* (Pilsbry and Ferriss).

R. schiedeanus (Pfr.) occurs with *R. a. hesperius* in a fossil deposit near Terlingua from which only a single hybrid shell is known (Hubricht, 1960 and in litt.). Living populations of the same region, however, are hybrid swarms. It is thought that deterioration of previously distinct adaptive niches at this northern limit of the *R. schiedeanus* range led to the removal of a selective disadvantage formerly operating against hybrids. In Texas *R. schiedeanus* genes are present only in populations of the southwestern Big Bend region. In Mexico the two species remain distinct.

R. pilsbryi (Ferriss) is a member of the subgenus *Hannarabdotus* Emerson & Jacobson, 1964. At present it is known only from localities within 20 miles west of the type locality, Sanderson, Texas, but undescribed related forms were found in the Chihuahuan desert of Durango and Chihuahua during August of 1968.

R. pasonis (Pilsbry) occurs in arid mountain ranges of the western Transpecos region of Texas and adjacent New Mexico. A related, possibly identical, species, *R. durangoensis* (von Martens), has been described from Lerdo, Durango.

Key to Texas Species of *Rabdotus*

1a. Small species, less than 30 mm long or if longer then not from the Tamaulipan or Chihuahuan biotic provinces 4

1b. Larger, most specimens over 30 mm long, if smaller then usually with a columellar tooth or swelling 2

2a. Spire short, barely equal to body whorl; width equals or exceeds ½ of length, white, without markings .... *R. schiedeanus* (Hybridizes with 3b).

2b. Spire usually longer than body whorl, or if not, then a Tamaulipan province form; width usually less than ½ the height or else Tamaulipan; brown markings usually present on at least some of a population. *R. alternatus* 3

3a. Ragged brown streaks usually present on at least some individuals of a population; spire not much longer than body whorl, outline oval; columellar tooth or swelling often present .... *R. a. alternatus*

3b. Ragged brown streaks never present, smooth-edged ochre streaks usually never present on some individuals of a population; spire conspicuously longer than body whorl, outline conic; no trace of a columellar tooth .... *R. a. hesperius*

4a. Lip of adults broadly expanded, outline of shell before expansion fusiform; markings of smooth to ragged brown streaks; surface glossy .... *R. pilsbryi*

4b. Not as above 5

5a. Shell length 16 mm or less; markings ragged brown streaks on cinnamon ground; arid mountain ranges of western Trans-pecos region .... *R. pasonis*

5b. Shell length more than 18 mm or else not from western Transpecos .. 6

6a. White, without ragged color streaks, or rarely a few streaks on the spire, base may be light buff .... *R. mooreanus*

6b. Pattern of ragged streaks on a light ground or if plain then conspicuously rib-striate. *R. dealbatus* 7

7a. Area of ground much exceeds ragged streaks or occasionally without markings; outline relatively more slender; shell conspicuously rib-striate .... *R. d. ragsdalei*

7b. Ragged streaks nearly equal to exceeding area of ground; shell relatively wider; shell smooth 8

8a. Shell less than 30 mm long, usually less than 26 mm; eastern .... *R. d. dealbatus*

8b. Shell usually over 30 mm tall; mountains of southern New Mexico and adjacent Texas .... *R. d. neomexicanus*

All of the taxa treated here are described in detail in Pilsbry (ANSP Monogr. 3, 2(1): 1–21, 1946) except *R. schiedeanus*, his treatment of which actually applies to *R. a. hesperius*. The right-hand specimen in his figure 7a is *R. schiedeanus*.

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SOME RESEARCH NEEDS AND METHODS FOR PROTECTING NAIADS FROM EXTINCTION

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Last year at Corpus Christi, Dr. Stansbery described the dwindling numbers and extinction of one to two dozen naiad species. There is a need for considerable effort to reverse this trend. I would like to describe some needs and methods I am aware of and some of my own experimental findings. One of the most important needs is documentation of existing populations so that legal evidence is available next year or ten years from now of "what was there" where pollution is serious but not yet entirely irreversible. It is also important that shell clubers let their feelings be known about the loss of these exotic animals. Another point that should be kept in mind is that the freshwater mussels not only have intrinsic value but also a significant and increasing commercial importance. One of the best descriptions of this that I have seen is the paper by A. C. Lopinot on the Illinois Mussel published in Outdoor Illinois Magazine, May, 1967. The shells are sold for as much as five hundred dollars a ton to Japan and are necessary as nuclei for cultured pearls which form about a third of Japan's marine trade. One may also buy pearl buttons from almost any American department store.

In my own capacity at the National Water Quality Laboratory at Duluth, Minnesota I have devoted most of my efforts to the freshwater mussel. My objective is to find out how much oxygen is required and how much copper and other toxicants are harmful for the ultimate survival of naiad species. Specifically this means finding the parts per million by weight that prevent survival, growth, and reproduction for all life stages. Some of my findings so far are that adult riffle species require 2½ ppm of oxygen over the 10 week period in the summer when oxygen is normally lowest and die in 25 ppb of copper in about that period of time. Data such as this is used by organizations establishing standards of maximal allowable concentrations of toxicants. If mussels follow the pattern of other organisms, growth of juveniles and reproduction of adults will be more sensitive parameters than survival and these results should be used for establishing standards. In a few species, however, it has happened that the animals grow and reproduce up to the time of death but eventually do die.

In order to study the effect of toxicants on growth of juvenile mussels it was first necessary to learn how to grow them in the laboratory. I found no method described in the literature and have spent many months on this problem. A method was finally worked out by my technician Miss Margaret Paige. The method was to add glencoe starter granules of trout fry food from Glencoe Mills, Inc., Glencoe, Minnesota.* One-half gram was added every Monday, Wednesday, and Friday and was forced through a tube to settle at one corner of a 6 gallon aquarium. The clams were in a finger bowl in the center of the aquarium and the drain was at the other end. Water was continuously dripping in at the feeding end of the aquarium at such a rate that the aquarium initially took eight hours to fill up. Five sphaeriid clams each grew 0.9 to 1.1 mm in three weeks in this system.

In addition, it may well be that some of the most significant toxicants are not yet under consideration. Koshtoyants and Salánki (1958) found that addition of 10^{-3}M KCl (39 ppm K) exceedingly altered the normal behavior of *Anodonta cygnea*. This concentration is not considerably greater than that found in some rivers. Mortality was not reported but their studies were only one week in duration so I conducted a preliminary exposure of 30.1 ppm K in the form of KCl to see if there was any effect over a longer exposure period at the highest concentration of potassium one could expect to find naturally. Slide 7 shows that no clams died in the first 17 days of exposure but then more than half died in the next 15 days. These were 4 *Lampsilis* out of 8, and 5 *Fusconaia flava* out of 8.

Final experiments were performed with six concentrations including a control. Ten specimens of *Lampsilis siliquoidea* and *Actinonaias ligamentina* from Yellow River were placed in each concentration. 90% of these clams were wiped out at 11 ppm K. A slightly delayed but similar rate of kill occurred with *Amblema costata* and *Fusconaia flava*. From extrapolation of these curves and from the fact that Lábos and Salánki (1963) found *Anodonta* glochidia to react abnormally to as little as 3.9 ppm K, I predicted that streams in the USA with more than 7 ppm K would have no mussels, those with less than 4 ppm would have mussels and 4–7 would be considered marginal. Dr. van der Schalie's map published in 1950 shows that mussels are generally found only in the predicted areas. Dr. Stansbery has communicated to me that none of the six streams containing more than 7 ppm K was known to have mussels. Of the streams with less than 4 ppm K, Dr. Stansbery was unsure of two rivers but for the others, 28 of 39 were known to have mussels.

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* Mention of commercial products does not constitute endorsement by the Federal Water Pollution Control Administration of the United States Department of the Interior.