THE NAIAD FAUNA OF THE ROCK RIVER SYSTEM: A STUDY OF THE LAW OF STREAM DISTRIBUTION.*

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During the past twenty years the method of studying animal life, under the stimulating influence of the laws of organic evolution, has greatly changed. Instead of the description of hosts of new species which was largely in vogue during the time of Conrad, Lea, and Tryon, often based on material from little known, or even unknown, habitats, we now have the comparison of thousands of specimens from different habitats, studied from the standpoint of the relation of the animal to its environment, the changes of the same species in different environments, and search for the reasons for such changes or adjustments—the Science of Ecology.

Among the varied themes which have attracted the attention of ecologists, none is more interesting than the study of the inhabitants of a stream from its source to its mouth. Dr. C. C. Adams was one of the first to make a study of this sort on a large scale, which he called longitudinal distribution in streams (1915, p. 73). His study of the genus Io is classic and is a pattern for any one wishing to carry on similar investigations. Ortmann (1920, 1925) has conducted such studies for the naiades or river mussels and has found that there is a general law of distribution which affects certain species, which are of more or less primitive structure, while others of more complex organization are not so greatly affected. More recently, Grier has studied the Lake Pepin mussels from the same viewpoint (1926). Studies in Wisconsin and Illinois indicate that the law may be more universal than at first thought by Ortmann.

Ortmann formulates this law as follows: certain naiades change their shape along the course of one and the same river in such a way, that

1. "The more obese (swollen) form is found farther down in the large rivers, and passes gradually, in the up-

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stream direction, into a less obese (compressed) form in the headwaters;

2. "With the decrease in obesity often an increase in size (length) is correlated.

3. "A few shells, which have, in the large rivers, a peculiar sculpture of large tubercles, lose these tubercles in the headwaters (1920, p. 311)." In a study of the Big Vermilion River, in Illinois (Baker, 1922) this law was found to operate in the case of several species.

Another law which affects the fauna as a whole and is strictly ecological, is the increase in number of species from headwaters to mouth of a system. This was strikingly shown in the study of the Big Vermilion River, where the naiad fauna increased from three to 28 species in a length of 27 miles (Baker, 1922, p. 22). During the course of studies on the fauna of Wisconsin rivers and streams this law was observed to be universal for the type of species mentioned by Ortmann and also upon others of the higher and more complex types—Lampsilis.

The accumulation of considerable data on the fauna of the Rock River system, both in Illinois and Wisconsin, has suggested that a similar study of this fauna might bring out added facts in corroboration of this law. (Pl. II.)

PHYSIOGRAPHY OF THE ROCK RIVER SYSTEM.

The Rock River System drains a portion of southeastern and southern Wisconsin and a large part of northwestern Illinois. Its basin is said to cover an area of upwards of 11,000 square miles—5,566 in Wisconsin and 5,419 in Illinois (Leverett). The drainage basin is 50 miles wide in Wisconsin, swells to 80 miles in width near the Illinois State line, and contracts to 40 and then to 25 miles in Illinois, toward its junction with the Mississippi River. Its total length is about 175 miles. Throughout the greater part of its length it flows through glaciated territory, mostly Wisconsin drift, although in the western part of the Illinois basin there is an older drift, the Iowan. In the western part of the Wisconsin basin it flows through the driftless area, and here the streams have formed the dendritic pattern of an old stream system, quite unlike the simple drainage pattern of the outer portions of its basin, which is that of a young river basin. In the area of the Wisconsin drift, where the youngest portion of the stream is found, there are numerous lakes of various sizes and depth and a quantity of swamp land, all indications of a youthful stream system which has just begun to fashion its bed after the withdrawal of the great Wisconsin ice sheet.

There are several notable tributary streams of good size; the Sugar, flowing mostly in Wisconsin and emptying into the Pecatonica in Illinois, the Pecatonica, with a length of 150 miles and a drainage area of 2,225 square miles, a greater part of which is in the driftless area of Wisconsin, the Kishwaukee, wholly in Illinois, about 50 miles long, and draining an area of some 1,266 square miles, and the Green River, also in Illinois, with a length of 100 miles and an area of 1,131 square miles. In Wisconsin the Yahara River drains the chain of lakes near Madison, the Crawfish River drains a portion of the northern drainage area of the Rock River system, and the Bark River another portion, including several small lakes. There are many small tributary streams.

The Rock River system is admirably adapted for ecological study on account of its diversity of form, embracing every variation of vital character—large and small lakes, swamps, creeks, small, medium and large size rivers. For comparison of fauna with physiography it is unsurpassed. It is to be regretted that it has not been possible to make systematic surveys of the different branches of the system, from source to mouth, so that exact comparisons might be made as to parallel variation of the fauna. This would require a large amount of time, but the resulting data would be of value.

SOURCE OF MATERIAL.

While the material upon which the present study is based is insufficient for a complete comparison of the fauna of the whole system, it is still large and varied enough to be of value and to indicate in a decisive manner the working of Ortmann's law of stream variation. The material studied is from the following sources:

Wisconsin areas, Dr. A. R. Cahn, University of Illinois; Prof. Chancey Juday, University of Wisconsin; Mr. D. S. Bullock, Madison; Mrs. E. C. Wiswall, Kenosha, Wis., the University of Wisconsin collection. The Illinois material is from the collection of the veteran collector and student, the late Anson A. Hinkley, whose splendid collection is now in the museum of the University of Illinois. Mr. R. E. Richardson, of the State Natural History Survey, has supplied data for the lower part of the Rock River in Illinois, and to him the author is deeply indebted for notes and material.

DISTRIBUTION STATIONS (See map, pl. II.).

For the better and more comprehensive comparison of the different parts of the system certain stations have been arbitrarily made. These and listed below and are shown under the same numbers on the map.

I. Small lakes—Oconomowoc, La Belle, Golden, etc.
II. Ashippun River.
III. Neosho mill pond, Rubicon River.
IV. Bark River, at Donsman.
V. Rock River, Ashippun to Ixonia.
VI. Crawfish River at Aztalan.
VII. Rock River, Jefferson to Ft. Atkinson.
VIII. Rock River, Rock Co., Wis.
IX. Rock River, Winnebago Co., Ill.
X. Rock River, near Oregon, Ill.
XI. Rock River, Dixon to Como.
XII. Rock River, Lyndon to Cleveland.
XIII. Kents Creek, near Rockford, Ill.
XIV. Sugar River, Wis., near Brodhead.
XV. Pecatonica River, Ill., mostly near junction with Rock River.
XVI. Kishwaukee River, Ill., above junction with Rock River.

DISCUSSION OF THE DISTRIBUTION.

A study of the table and map shows that there is a gradual increase in number of species toward the mouth of the river. The lakes are poor in forms of naiades, indicating that this is not their normal habitat, a fact shown by the decrease in size of the individuals and the small number of species—only six in all small lakes combined. It is to be noted that five of these are varieties of normal stream species and the sixth is normally a lake species *(Anodonta marginata)*.

DISTRIBUTION OF NAIADES IN ROCK RIVER SYSTEM.

Stream section	Main stream.												Large tributaries			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
A. grandis footiana	*															
Anodonta marginata	*															
L. siliquoidea rosacea	*															
L. ventricosa canadensis	*															
A. grandis gigantea	*					*	*	*			*	*			*	*
Anodonta grandis		*	*	*	*								*			*
Lasmigona compressa													*			
Anodonta imbecillis																*
An. ferussacianus													*			*
An. subcylindraceus			*													
Alasmidonta calceolus		*											*			*
Lampsilis siliquoidea		*	*		*	*	*				*					
Fusconaia flava				*	*	*	*						*	*	*	*
Amblema costata							*									
Pleurobema coccineum					*		*							*	*	*
E. dilatatus delicatus				*	*	*	*						*		*	
Ligumia ellipsiformis				*												
Alasmidonta marginata				*	*	*		*	*	*	*			*		*
Strophitus rugosus				*	*		*	*	*	*	*	*	*	*		*
Amblema rariplicata					*	*		*	*	*	*	*			*	*
Lasmigona complanata			*		*	*	*	*	*	*	*	*			*	*
L. recta latissima					*	*	*	*	*	*	*	*				
Actinonaias carinata			*		*		*	*	*	*	*	*		*	*	*
Carunculina parva			*					*	*	*						*
Quadrula pustulosa					*		*	*	*	*	*	*			*	*
Lasmigona costata					*			*	*	*	*			*	*	*
P. alata megaptera					*			*	*	*	*	*				*
Lampsilis ventricosa					*		*	*	*	*	*	*				
Obliquaria reflexa							*		*	*	*	*		*		
Fusconaia undata								*	*	*	*	*		*		
Elliptio dilatatus								*	*	*	*	*				
Lampsilis fallaciosa								*			*				*	
Tritogonia verrucosa										*	*	*		*	*	*
Fusconaia ebena									*	*	*	*				
Pleurobema solida									*	*	*	*			*	*
Cyclonaias tuberculata									*	*	*					
Plethobasus cyphyus									*	*	*	*				

DISTRIBUTION OF NAIADES IN ROCK RIVER SYSTEM—Concluded.

	Main stream.												Large tributaries			
Stream section	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Leptodea fragilis									*	*	*	*				
Anodonta corpulenta											*	*				*
Truncilla truncata											*	*				
Truncilla donaciformis											*	*				
Quadrula metanevra											*	*				
Plagiola lineolata											*	*				
Lampsilis anodontoides											*	*				
Obovaria olivaria												*				
Proptera laevissima											*					
L. higginsii											*	*				
F. undata trigona																
Totals	5	3	6	6	15	8	13	15	19	20	31	26	7	9	13	19

Small stream or creek forms are numerous in the smaller streams of the upper part of the system, as well as in small creeks which occur along the large stream farther down in its course. The principal creek species are *Anodonta grandis, Alasmidonta calceolus, Lampsilis siliquoidea, Fusconaia flava, Ligumia ellipsiformis, Ellipto dilatatus delicatus, Lasmigona compressa, Amblema costata, Pleurobema coccineum, Anodontoides ferussacianus subcylindraceus.* When the river has increased to a good size, as in Rock County in Wisconsin and Winnebago County, Illinois, the fauna assumes a different aspect, such species as *Fusconaia undata, Amblema rariplicata, Proptera alata megaptera, Elliptio dilatatus, Quadrula pustulosa, Tritogonia verrucosa, Pleurobema coccineum solida, Plethobasus cyphyus, Cyclonaias tuberculata,* and *Obliquaria reflexa* being characteristic. It will be noted that the species taking the places of the small stream species are larger and more corpulent, though they may not be as great in length as the small stream species in which there is a lengthening in connection with the flattening of the shell.

In the lower part of the system (XI, XII) the fauna changes again and such species as *Anodonta corpulenta, Truncilla truncata* and *donaciformis, Quadrula metanevra, Plagiola lineolata, Lampsilis anodontoides, Obovaria olivaria, Proptera laevissima, Lampsilis higginsii,* and *Fusconaia undata trigona* become characteristic. These are large and heavy species, for the most part, quite unlike the small, thin or delicate forms of the upper part of the stream. It is to be noted that the progression down stream is gradual, one set of characteristic species extending both above and below into the next characteristic group of species. The change from one set of conditions to another is so gradual that it will not be appreciated unless the stream is studied in the manner previously indicated.

The ecological features of the distribution of the naiades in different kinds of habitats is strikingly shown in the study of a river system. Several species of Rock

River naiads admirably illustrate this law, as noted in the table below:

Lakes	Creeks	Medium Rivers Rock	Large Rivers Mississippi
A. footiana	*grandis*	*gigantea*	*corpulenta*
L. rosacea	*siliquoidea*	*siliquoidea*	*siliquoidea*
L. canadensis	*ventricosa*	*ventricosa*	*occidens*
F. sterkii	*flava*	*undata*	*trigona*
E.	*compressa*	*costata*	*costata*
A. plicata	*costata*	*rariplicata*	*peruviana*
L. recta	*latissima*	*latissima*	*latissima*
P. alata	*megaptera*	*megaptera*	*megaptera*
P.	*coccineum*	*catillus*	*solida*

Each of the above types of habitat have physiographic characteristics that are doubtless reflected in the life inhabiting such habitat. Thus, the lakes usually have more or less exposed shores upon which the waves ceaselessly beat with more or less violence, the bottom is made up of sand, gravel or boulders, or, more usually, a combination of all three, and there is usually little vegetation to bind the bottom firmly together. The naiad life in this habitat consists of small-shelled mussels, easily anchored between boulders or in the gravelly-sand, and from their small size are less liable to be rolled about and destroyed by the waves.

In the creeks, the bottom is a succession of riffles interspersed between pools of deeper water, the naiads usually living in the riffles where the bottom is gravelly or sandy, sometimes bouldery, with a good to rapid current. The mussels usually lie with their siphons pointing upstream, the better to catch the floating plankton-like food in the current. The mollusks of this habitat are of medium size, more or less elongated and compressed, usually clean and polished, the water of such a habitat usually being a few inches to a foot or more in depth in summer. In the medium sized rivers, the water is deeper, there are no riffles, the bottom is usually of mud or fine sand and the naiads live all over the bottom, excepting in the deeper places. The mussels are here large and more swollen than in the creek environment. In the large rivers, as the Mississippi and Ohio, and also in the mouth of the Rock River, the water is deep, the river has a strong, steady current, the bottom is of mud

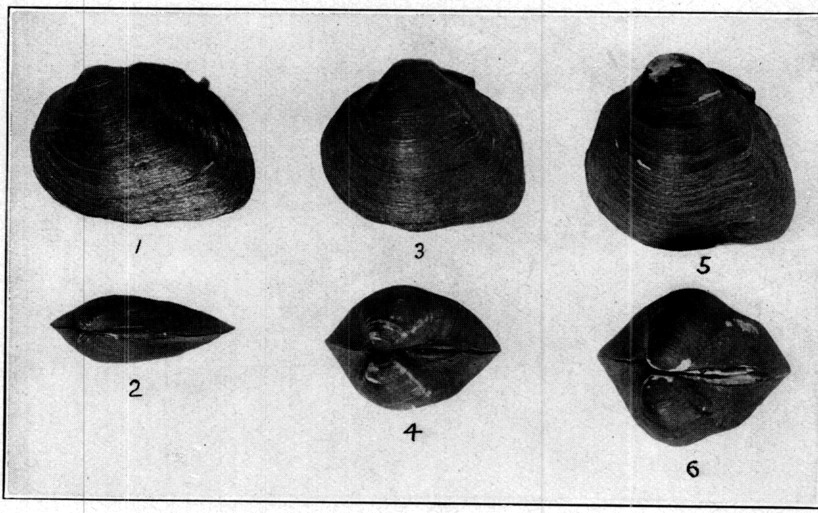
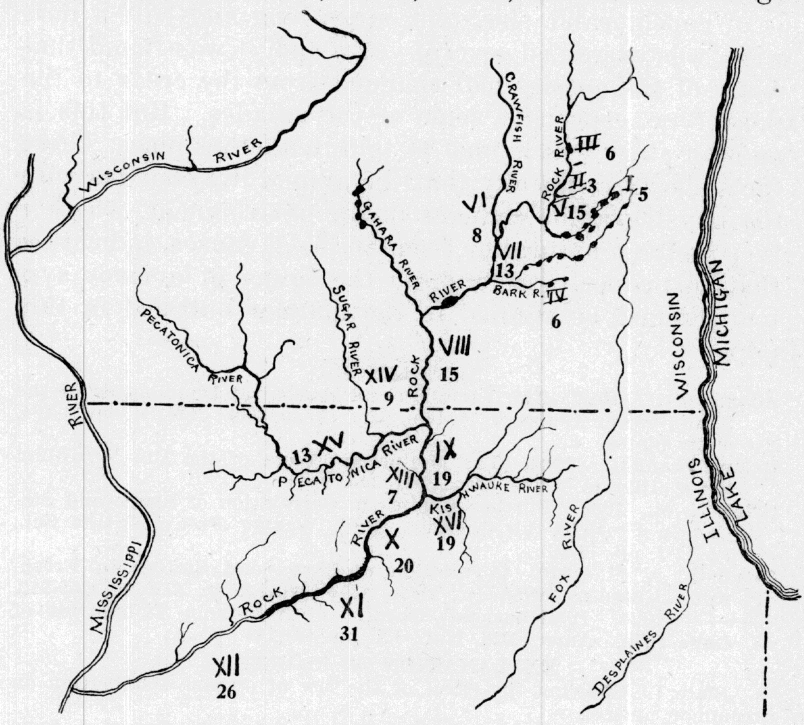


Plate I.

and the mussels are large, very robust, and usually live in a zone bordering the shore. They have, however, been dredged in water 20 or more feet deep but are more common in from 5 to 7 feet.

The history outlined above appears to be repeated in every river system, with more or less minor variation. When a fauna is studied from the ecological standpoint, the great individual variation is easily understood, each type of habitat—lake, creek, small, medium and large



NAIAD DISTRIBUTION IN ROCK RIVER
Plate II.

rivers—having a more or less central type which is fairly distinct but which merges into the one above and below by almost imperceptible gradations. The time-honored statement that such and such species 'run into each other' is based on this variation in stream habitat, which was, of course, not appreciated by the older students.

That the physical environment does have a decided influence on the formation of varieties, and even species, is most convincingly shown by the study of the life in a large river sytsem, with its varied habitats of swamp, lake, creek, and river. That the naiad type of one kind of a habitat will change to that of another in a short period has been observed in several places, especially in Wisconsin. In one instance, a small stream was dammed some 60 years ago for the purpose of carrying on lumbering operations. The fauna of the original locality was that of a creek. When this artificial lake, which is of considerable size, nine miles long and half a mile wide, was examined several years ago, it was found that many of the species had changed from the creek to the pond type, especially some of the naiades. But this is another story which must be told in another place. These facts show graphically that the animal life changes with the physiographic changes in the environment, whether they be from natural or from artificial causes, indicating that to properly understand the fauna of a river system it must be studied in the manner outlined in this paper.

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EXPLANATION OF PLATES.

Plate I. Showing the effect of the law of stream distribution on a common mussel.

1, 2. *Fusconaia flava* (Raf.). The compressed, elongated form that is characteristic of creeks and small streams. From Kents Creek, near Rockford, Ill. Z5447, U. of Ill.

3, 4. *Fusconaia undata* (Barnes). The more corpulent, less elongated form found in rivers of medium size. Winnebago Co., Ill. Z3863, U. of Ill.

5. *Fusconaia undata trigona* (Lea). The more corpulent, much shortened form with very high umbones, characteristic of the large rivers, as the lower Rock, the Wabash, and the Mississippi. From Wabash River, White Co., Ill. Z5480, U. of Ill.

6. The Mississippi River form, the maximum of corpulosity. From Hudson, St. Croix River, Wis. U. of Wis., 810.

Plate II. Map of the Rock River in Illinois and Wisconsin showing the distribution of the Naiades of that stream. Note that the number of species increases toward the mouth at the Mississippi River.

I, II, III, etc., Stations; 5, 14, 30, etc., number of species at this station.