THE FRESHWATER NAIADS OF THE LOWER END OF THE WABASH RIVER, MT. CARMEL, ILLINOIS TO THE SOUTH

Clarence F. Clark

Associate Consultant, Environmental Consultants, Inc.
14325 Proton Road, Dallas, Texas 75240

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PRESENTATION OF DATA

The freshwater naiads of the Wabash River have been studied intermittently for over 100 years by both conchologists and commercial shell collectors. Dating from the 1820's, the papers of Thomas Say, of New Harmony, Indiana, are among the first published on the American freshwater Mollusca. Call (1900) referred to Say as the father of American conchology. The extensive work of Say facilitated the description of many new species of freshwater naiads, updated distribution data for others, and established the Mollusca of the Wabash River among the best known in the United States.

From the 1820's until the 1880's, little was published on the Wabash River. Stein (1881) issued a catalogue of Indiana naiads which listed species from the area but did not give exact collection locations. Most of the material of R. Ellsworth Call was published between 1885 and 1902. He assembled the scattered data on Indiana Mollusca and listed 92 species of naiads from the Wabash River. His descriptive catalogue of Indiana fauna (Call, 1900) is one of the most complete publications on the fauna of any state to date. Unfortunately, like most of the early conchologists, Call apparently considered unnecessary the delineation of collection locations. He did state that species and individuals abounded in the Wabash River below Terre Haute, Indiana; and that *Quadrula metanevra* (Raf.), *Q. undulata* (Raf.), *Q. cylindrica* (Say) and *Cyprogenia irrorata* (Say) often were found in large numbers on gravel bars in fairly swift water (Call, 1900). Call (1896b) compared the molluscan faunas of ten drainage basins of Indiana, and demonstrated that the richest faunas occurred in the Wabash and Ohio drainages. He stated that he knew of beds of naiads, '... miles in length, /with/ enormous quantities of these animals' (Call, 1900).

Blatchley and Daniels (1902) published a supplement to Call's catalogue (based primarily on collections by Daniels) which added 91 species and varieties of land and freshwater Mollusca to the fauna of Indiana. They gave specific collection locations for only two species (Table 1). Daniels' (1903) report is a check list of Indiana Mollusca with the first extensive data on collecting sites (refer to Table 1).

Baker (1906) assembled the available information on the molluscan fauna of Illinois. He checked private and public collections and included data from unpublished lists provided by Illinois conchologists. Baker reported the collection of 11 species of naiads from Mt. Carmel, Illinois (refer to Table 1).

Goodrich and van der Schalie (1944) compiled the information on Indiana Mollusca, and analyzed it in relation to Ortmann's theories regarding the succession of mussels throughout drainage basins. This paper (Ortmann and Walker, 1922) provides the best coverage of the naiads of the Wabash River. It therefore has been used as a basis for Table 1 and for nomenclature throughout the report. Three transitional zones were noted in the Wabash River. The Southern Zone extends from Grand Chains to the mouth of the River (Zone of Influx), and the Large River Zone extends generally between Tippecanoe County and Posey County near the mouth. The Zone of Influx and the lower portion of the Large River Zone are in the study area: Mt. Carmel, Illinois to the mouth of the Wabash River. The Lower Zone is unique for it contains several species atypical of the Wabash drainage fauna. Fifty-two species are recorded from this zone (Goodrich and van der Schalie, 1944). Records for *Cumberlandia monodonta* (Say), *Dysnomia flexuosa* (Raf), *D. personata* (Say), *D. sampsoni* (Lea), *Proptera capax* (Green) and *Simpsoniconcha ambigua* (Say) are restricted to this lower area of the Wabash River.

The most comprehensive study of the naiads of the Wabash River drainage was the survey of the commercially valuable mussels of the Wabash and White Rivers by Krumholz, Bingham, and Meyer (1970). During the years 1966 and 1967 they made 99 collections using a crowfoot bar, by scuba diving and hand-picking at 63 sites in the Wabash River, the White River, and the East Fork of the White River. Nine of these collections were made below Mt. Carmel at river miles 8-9, 16-17, 20-21, 30-31, 40-41, 51-52 (highway bridge at New Harmony, Indiana),

62-63 (Grayville, Illinois), 71-72, and 83-84 (Crawleyville, Indiana). Species taken at each listed site (personal communication, Dr. Krumholz, 1975) are included in Table 1. Unless the sites correspond with other categories listed in the table, they are listed primarily under the heading Mt. Carmel to the mouth.

Parmalee (1967) compiled the available literature on Illinois Mollusca (naiads) but his statement '... that systematic collecting in recent years ...' suggests considerable work had been done in the lower Wabash shortly before he prepared his paper. He specifically located the collecting site of *Dysnomia simpsoni* (Lea) at the Little Chains archeological site in White County, Illinois, thus indicating its ancient distribution in the lower Wabash River during prehistoric time. He assigns the distribution of many species to the lower Wabash River, but unfortunately does not note definite collection sites.

The report of Meyer (1968) was based on work done during the study made by Krumholz, Bingham, and Meyer (1970). His summarized data include the specific site locality for collected species (Table 1). Meyer (1974) reports the collection of several naiad species in the lower Wabash; but definitive site records are not included.

METHODS

In order to include all possible components of the naiad fauna of the study area, a complete literature survey was conducted. The preparation of a baseline for the present naiad population was complicated by the lack of definitive records from the early 1800's to the present. Generally specific location data are not given for most of the collection sites, collection methods are not detailed, and stream conditions at the time of collecting are not defined. Additionally, the synonymy is such that extensive library work was necessary to discriminate between species. For example, *Micromya nebulosa* Conrad, not included in this report, had been known by 26 names by 1944. Presently the generic name has been changed to *Villosa* (Burch, 1973).

In reviewing the data available from the time of Thomas Say in the 1820's, through the less intensive work of many other conchologists of Indiana prior to 1900, it appears that only the extensive field work of Call may have covered the part of the Wabash under consideration in this study. The comprehensive survey by Krumholz, Bingham, and Meyer (1970) was directed toward the commercial species; but their samples should have produced a representative collection of the species at each sampling station.

If a close correlation exists between the 1966-1967 and 1975 data, the report by Krumholz, Bingham, and Meyer should be representative of present day populations. Their data were of specific value in providing the baseline data for present day naiad fauna of the lower Wabash River. For these purposes it was assumed that spot sampling of the section of the stream under study would permit a comparison with spot samples from the above mentioned collections, and thus provide a basis for speculating about the present naiad community.

It was recognized that, regardless of the type of survey, only a portion of the available stream bottom habitat could be sampled. Call (1894) sets a classical guide for comparisons and projections of data, 'Often in the case of the most common species, numbers of individuals are spasmodically great; then years go on and few of certain forms are to be found.' Apparently, speaking of rare species, Meyer (1974) wrote, 'They may live in unsampled habitats, or simply be rare and very difficult to obtain. ... their absence may be more apparent than real.'

In an effort to resample properly (in part) the areas sampled during the 1966-1967 survey, a long-time commercial mussel collector, buyer and button cutter was employed. A second collector, who operated the boat was utilized. Collectively, their experience on the Wabash River totaled 115 years.

Techniques used included a complete set of brail equipment as is used on the river today. A ¾ inch metal bar (a crowfoot bar) to which 56 strings of two hooks each were attached, was used for dragging the bottom for shells. The hooks were treble hook-like in nature, without barbs. A 'mule' made of a piece of plywood was used to steer the boat while floating with the bar on the bottom. It was not needed to increase the floating speed, because the current during high water transports the boat at ample floating speed. The brail was secured over the front end of the boat and the 'mule' was fitted behind the outboard motor where it could be used for the desired boat maneuverability.

It was believed that intensive brailing at eight locations from Mt. Carmel to the mouth of the Wabash (Figure 1) would provide sufficient data for a comparison with data of Krumholz, Bingham, and Meyer (1970). A spot sampling survey was conducted during the week of June 23-27, 1975. The collecting began at Mt. Carmel and a new location was sampled each day. Brail sampling varied from four 30 minute tows in productive areas to twelve 20 minute tows in less productive areas. The number of tows insured that bars, if they were present, would be sampled. Table 2 reflects the data resulting from the 1975 survey.

Mussel collectors, on the Wabash River, consider that high spring waters yield optimum brailing conditions; however, flood stage prevents brailing. Too much silt after sharp rises of water level in midsummer causes the shells to close; however, silt does not seem to have the same effects during the high spring waters. Increased water temperatures of midsummer either cause the mussels to bury themselves or close, indicated by the number of sample sizes which are diminished under such conditions. A greater variety of mussels can be taken during low water, when the bars were partially exposed. The Ohio River area on both sides of the mouth of

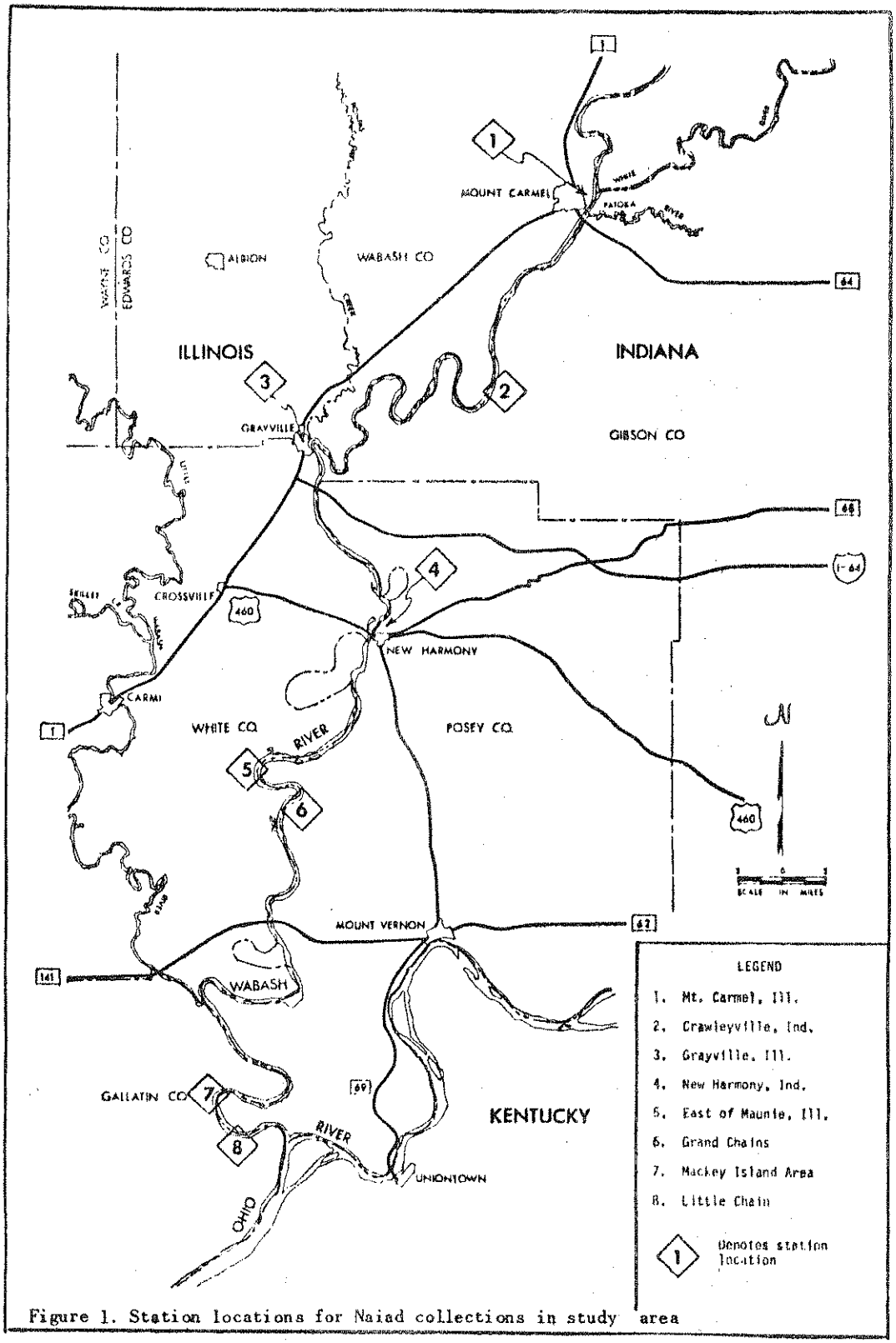

Figure 1. Station locations for Naiad collections in study area

Table 1. Species collected in study area with collector and site locations. (continued)

Species	Site Locations									
	Mt. Carmel, Ill.*	Crawleyville, Ind.	Grayville, Ill.	New Harmony, Ind.	East of Maunie, Ill.	Grand Chain	Above mouth Little Wabash	Muckty Isle Area	Little Chain 10 miles above mouth	Mt. Carmel to
Actinonaias carinata	3									4
Alasmidonta marginata			9							
Amblema costata										9
Amblema peruviana	10		10							
Anodonta grandis					4,8					
Anodonta imbecillis										
Anodonta suborbiculata										
Anodontoides ferussacianus										
Arcidens confragosus				2,1						
Carunculina glans				1						
Carunculina parva				1,2						
Cumberlandia monodonta						2,1,6,7				
Cyclonaias tuberculata										
Cyprogenia irrorata	3									
Dysnomia flexuosa										
Dysnomia perplexa rangiana				2,2						
Dysnomia personata				2,2						
Dysnomia sampsoni										
Dysnomia sulcata						1,2				
Dysnomia triquetra									6	
Elliptia crassidens	3,10		10		10	7				
Elliptia dilatatus										
Fusconaia ebenus	10,9				10	2				
Fusconaia flava										9
Fusconaia subrotunda										
Fusconaia undata	10		10	2						
Lampsilis anodontoides	3		10							
Lampsilis anodontoides fallaciosa					10			9		
Lampsilis fasciola										
Lampsilis orbiculata										
Lampsilis ovata										
Lampsilis siliquoidea								9		
Lampsilis ventricosa	3,9		9	9,10						
Lasmigona complanata			10		10			9		9
Lasmigona compressa										4
Lasmigona costata										
Lastena lata										
Leptodea blatchleyi				1,2						
Leptodea fragilis	10,9		9,10	9	10	7,1				
Leptodea laevissima			10					9		9
Leptodea leptodon				1,2						4
Ligumia recta latissma										
Megalonaias gigantea	10		10							
Micromya iris										
Obliquaria reflexa	10		10		10					
Obovaria olivaria	10,9		10	2,1,9				9		4
Obovaria retusa				2,1						9
Obovaria subrotunda										
Plagiola lineolata				2		2,1				

Table 1. Species collected in study area with collector and site locations. (continued)

Species	Mt. Carmel, Ill.*	Crawleyville, Ind.	Grayville, Ill.	New Harmony, Ind.	East of Maunie, Ill.	Grand Chain	Above mouth Little Wabash	Mackey Isle Area	Little Chain 10 miles above mouth	Mt. Carmel to mouth
	Site Locations									
Plethobasus cicatricosum										
Plethobasus cyphyus										
Cyclonaias clava				2,1						
Cyclonaias cordatum				4,8	10					
Cyclonaias cordatum coccineum										
Pleurobema alata			10							4
Pleurobema capax	3			2,10		1,2		10		
Obovaria fasciolaris										
Obovaria cylindrica	3									
Obovaria metanevra	10,9		9		10					9
Obovaria nodulata	10		10	2,1						
Obovaria pustulosa	3,10,9		10		10					
Obovaria quadrula	5,10,9		9,10	2,1,9	10					9
Dysnomia ambigua						1,2				
Amphitus rugosus										
Quadrigonia verrucosa	10		10							9
Truncilla donaciformis	5				10					
Truncilla truncata			9,10					9		4

(1) Blatchley and Daniels, 1902
(2) Daniels, 1903
(3) Baker, 1906
(4) Krumholz, Bingham and Meyer, 1970
(5) Hinckley, 1885
(6) Parmalee, 1967
(7) Goodrich and van der Schalie, 1944
(8) Meyer, 1968
(9) Personal conversation with Krumholz (1966-67 records)
(10) Clark 1975 records

*Mt. Carmel 1975 and Crawleyville 1966-67 data combined

the Wabash River was not sampled. The Kentucky Department of Fish and Game, the Illinois Department of Conservation, the Indiana Department of Natural Resources, and several local mussel collectors were contacted for results of studies. After reviewing Williams (1969), it appeared that his findings might fill the disparity of information on the naiad population around the mouth of the Wabash River. Personal communication with Dr. Williams provided the information necessary to speculate about the present naiad population in the vicinity of the mouth of the Wabash River.

DISCUSSION OF DATA

Understandably, some of the species reported from the Wabash River in the early 1820's have not been collected for many years. Call (1894) stated, 'The habits of our mollusks are so peculiar that certain seasons present sometimes many forms which fail to appear again for several successive years.' His insight into present day problems of environmental concern is suggested by his interest in biological significance of the naiads in the total faunal setting. He believed that many of the best collecting grounds sampled by Say and other early naturalists had been physically, chemically, and biologically altered by his time. He called attention to the need for more information. 'A further necessity for immediate action so that the original inhabitants of the state may be listed lies in the danger of extinction of very many forms' (Call, 1894).

Three of the species listed in Table 3 have been questioned. Goodrich and van der Schalie (1944) considered *Plethobasus cicatricosus* Say to be a deformed or 'unique' specimen. They also felt that *Leptodea blatchleyi* (Daniels) needed more study to determine the relationship between it and *L. leptodon* (Raf.). Daniels (1902) remarked about the similarities of anatomy and shell characters of the two species. It appears from the literature that specimens of the mentioned species have been collected only at the type locality listed in the Goodrich and van der Schalie report, '... more careful study may suggest that *Dysnomia sampsoni* (Lea) is a variant of *purplexa* representing a *rangiana* aspect of it as it appears in the larger rivers.'

Table 2. Species of Naiads collected in the lower Wabash River during the 1975 survey, with common names and estimated abundance in the area.

Scientific Name	Common Name	Abundance *
Amblema peruviana		Common
Elliptio crassidens	Elephant ear	Common
Fusconaia ebenus	Niggerhead	Rare
Fusconaia undata	Pig-toe	Rare
Lampsilis anodontoides	Yellow sand shell	Rare
Lampsilis anodontoides fallaciosus	Bank creeper	Rare
Lampsilis ovata ventricosa		Uncommon
Lampsilis ventricosa	Pocketbook	Uncommon
Lasmigona complanata	White heel splitter	Rare
Leptodea fragilis	Thin paper shell	Common
Leptodea laevissima	Pink paper shell	Common
Megalonaias gigantea	Washboard	Rare
Obliquaria reflexa	Three-horned Wartyback	Abundant
Obovaria olivaria	Glossy-back	Rather Common
Pleurobema cordatum		Rare
Proptera alata	Heel-splitter	Rare
Proptera capax	Pocketbook	Rare
Quadrula metanevra	Monkey-face	Rather Common
Quadrula nodulata	Warty-back	Rather Common
Quadrula postulata	Pimple-back	Abundant
Quadrula quadrula	Maple-leaf	Abundant
Tritigonia verrucosa	Buckhorn	Uncommon
Truncilla donaciformis	Fawn's-foot	Rare
Truncilla truncata	Deer-toe	Rare

* Adapted from Meyer 1974 for comparison

Abundant--Found at 3 of 5 stations-one of the predominant species
Common --Found at 3 of 5 stations-three or more specimens at each
Rather Common--Found 2 of 5 stations-three or more specimens at each
Uncommon--Found at 2 of 5 stations-one or two taken at each
Rare--One one or two taken during the survey.

Table 3. Wabash River Naiads from the lower portion of the stream, which are reported as rare and endangered with estimates of abundance (from Stansbery, 1970).

Species	Abundance		
	Call (1900)	Goodrich & van der Schalie (1944)	Parmalee (1967)
Cumberlandia monodonta (Say)	Very rare	Rare	Of doubtful occurrence
Fusconaia subrotunda (Lamarck)	- - -		Of doubtful occurrence
Lastena lata (Rafinesque)	Rare	Rare	Of doubtful occurrence
Plethobasus cicatriosus (Say)	- - -	Relatively rare	Of doubtful occurrence
Plethobasus cooperianus (Lea)	Common	Rare	Uncommon to rare
Plethobasus cyphyus (Rafinesque)	Common	Relatively rare	Of doubtful occurrence
Pleurobema clava (Lamarck)	Common		Not common?
Quadrula cylindrica (Say)	Common		Not common
Anodonta suborbiculata (Say)	Common	Not common	Of doubtful occurrenc
Simsoniconcha ambigua (Say)	Very common		Uncommon to rare
Carunculina glans (Lea)	Rather common	Rather common	Of doubtful occurrenc
Dysnomia flexuosa (Rafinesque)	Very rare	Relatively rare	Rare
Dysnomia personata (Say)	Very rare	Rare	Uncommon to rare
Dysnomia perplexa (Lea)	Abundant	"Quite well represented"	"Now absent?"
Dysnomia sampsonii (Lea)	- - -	Rare	Of doubtful occurrenc
Dysnomia sulcata (Lea)	Rather rare	Relatively rare	Uncommon to rare
Lampsilis orbiculata (Hildreth)	- - -		Of doubtful occurrenc
Leptodea leptodon (Rafinesque)	Rather common	Rare	Not included
Leptodea blatchleyi (Daniels)	Described 1903	Rare	Of doubtful occurrenc
Micromya fabilis (Lea)	Common	Relatively rare?	Of doubtful occurrenc
Obovaria retusa (Lamarck)	Rather common	Relatively rare?	
Proptera capax (Green)	Not common	Rare	

Table 4. Numbers of Species of mussel collected by crowfoot bar from the same 10 one-mile sections of the Wabash River in 1966 and 1967.

Species	1966 No. Taken	1967 No. Taken
Alasmidonta marginata	1	--
Anodontoides terussacianus	1	--
Lasmigona complanata	8	2
Lasmigona compressa	1	1
Strophitus rugosus	5	--
Actinonaias carinata	43	9
Lampsilis anodontoides	2	--
Lampsilis ovata ventricosa	9	4
Leptodea fragilis	16	4
Obliquaria reflexa	--	1
Obovaria olivaria	44	15
Obovaria subrotunda	3	--
Proptera alata	5	--
Truncilla truncata	1	--
Amblema costata	1	1
Fusconaia ebenus	1	--
Fusconaia undata	1	--
Plethobasus cyphyus	1	--
Quadrula metanevra	15	--
Quadrula pustulosa	24	--
Quadrula quadrula	110	17
Tritogonia verrucosa	5	1
TOTALS	297	56

It is suspected that implications of Call (1894) concerning the extinction of many forms in Indiana may have become a reality during his life. He described two of the species listed in Table 3 as very rare. His comment that he had seen specimens of *Cumberlandia monodon* Say raises the questions as to whether he found one during his intensive collecting or if it for all practical purposes had become extinct in his day. *Dysnomia flexuosa* (Raf.) was considered by Call (1900) to be a species which was, '...by no means common in recently formed collections.' He only collected this species from the Ohio River. Call (1900) considered *Dysnomia personata* (Say) to be very rare; as he did not take a specimen during his intensive collecting. Additionally, he reported *Dysnomia sulcata* (Lea) to be, '... regarded as rare.' He stated that his description, '... is based solely on two females, the male not being at hand when it was made, though it was afterwards received for figuring.' Such a comment indicates a scarcity of specimens and raises questions as to whether Call actually collected it, for 'only two females were available when he wished to sketch it.'

Lastena lata (Raf.) was described as rare by Call (1900). Its habit of burying itself deep into mud and gravel bars may be why Call considered difficulties in collecting were related directly to its apparent paucity. All Indiana authors have considered it rare.

Call (1900) commented that *Proptera capax* (Green) was by no means a common shell in Indiana, and was known only from the Wabash. Goodrich and van der Schalie (1944) restricted its distribution in Indiana to the lower part of the river and reported it rare.

It thus appears that at least five of the species included in Table 3 and in the list of rare and endangered species of naiads (Stansbery, 1970) were rare and endangered before 1900. From an analysis of Indiana literature on freshwater naiads, it appears that some of these may have been collected only once. The old records were carried through the literature each time a new list was prepared. Thus, only a few specimens of each were known from the State of Indiana.

Table 3 indicates that Call (1900) reported three of the listed species as Rather Common, six as Common, one as Very Common, and one as Abundant. The status of four others was not reported. Of those considered Rather Common by Call, one is reported

to be Uncommon to Rare by Parmalee (1967), and the other two to be of doubtful occurrence. Parmalee also considers three of Call's common species to be of doubtful occurrence and three more to be Uncommon to Rare. Table 3 shows that Call considered *Dysnomia perplexa* (Lea) to be Abundant, and *Simpsoniconcha ambigua* (Say) to be Very Common, as compared to Parmalee who reports the first to be Uncommon to Rare and the latter to be of doubtful occurrence.

It is evident that considerable change in the abundance of the Mollusca of the Wabash has occurred since the species were first studied. Others that could be added to the list of species discussed above are included in Table 3.

It is possible that such species as *Uniomerus tetralasmus* (Say), *Anodonta grandis* (Barnes), *Proptera alata* (Say), *Lampsilis anodontoides* (Lea) and *L. ventricosa* (Barnes) have increased in abundance since many of the oxbows have become severed more completely from the main stream, and sand and silt have replaced the gravel bars.

None of the species listed in Table 3 were taken during the 1966-1967 collections. Only two specimens of *Proptera capax* (Green) were taken in 1975, one in the New Harmony area and the other in the Mackey Island area. This would indicate its rarity.

The 1966-1967 survey (Table 4) produced two species not taken during 1975 spot sampling: *Anodonta grandis* Say and *Actinonaias carinata* (Barnes). In general the conditions during the 1975 sampling period must have been exceedingly favorable, for nine species were collected in the study area which were not found by Krumholz, Bingham, and Meyer. These authors use *Amblema costata* Rafinesque, the small stream form, and the 1975 data use *Amblema peruviana* (Lamarck), the large stream form. Similar statements could be made about *Lampsilis ovata ventricosa* (Barnes) used in the 1966-67 survey data. Goodrich and van der Schalie (1944) stated, '*L. ovata* is definitely a species that inhabits large rivers and there are transitions into the headwaters that connect *L. ovata* through the form *L. o. ventricosa* with *L. ventricosa*.'

Only brail sampling was used in the 1975 survey as compared to that method plus scuba diving and hand-picking in the 1966-1967 survey. The effort made at the 'East of Maunie area' illustrates the incongruities of sampling in a large river. Six brail hauls were made at intervals across the stream so as to obtain a representative sample. The hauls were approximately one-half mile long. Mussels were obtained during two of the six hauls and these were collected in adjacent brailed areas. Each time hauls were made over a relatively hard bottom of gravel and rubble, shells were taken. Shells were not collected a few hundred feet on either side of the bar. The chances of finding these bars, known to mussel collectors as mussel beds, are remote unless the stream has been visited at low water. The vast experience of the two collectors used during the 1975 study is believed to have made the differences in the hauls of the 1966-1967 and the 1975 collections. Sizes and ages of the specimens taken in the 1975 survey indicated they were available during the earlier study; but as previously suggested, every habitat in a stream cannot be sampled.

Two collectors brailing over the same area can reap different harvests quantitatively. The difference in harvest from the same area in two consecutive years is evident from data given by Krumholz, Bingham, and Meyer (1970). The sample dropped from 21 species and 297 shells in 1966 to 11 species and 56 shells in 1967. Only one species was taken in 1967 which was not found in the 1966 harvest. The reduction per collection site ranged from 10 down to 2 species and 45 down to 7 shells.

The abundance of the naiads of the Wabash River has been reported in general terms: Abundant, Very Common, Common, Rather Common, Rather Rare, Rare, and Very Rare. These terms are biased in accordance to the experience of each collector; but they offer some means of quantifying the populations as indicated in each study. Meyer (1974) has defined the use of these terms as they are related to his report. A comparison of data from Table 2 with Table 5 from Krumholz, Bingham, and Meyer (1970) indicates slight differences of minimal importance. Sampling problems discussed previously could account for differences found in the data of these two tables. The greatest difference is in the rating of *Obliquaria reflexa* (Raf.) -- (Rare in the 1966-1967 survey and Abundant in the 1975 reports). A review of the standards used by Meyer (1974) and those set up for the 1975 data, indicates that considerable error in judgement is possible. The reports agree that *Quadrula quadrula* (Raf.) and *Quadrula pustulosa* (Lea) are the most Abundant species, that *Obovaria olivaria* (Raf.) is Relatively Common to Abundant, and that the *Amblema*, *Leptodea fragilis* (Raf.), *Tritogonia verrucosa* (Barnes), and *Lampsilis ovata ventricosa* complex follow in order of abundance.

The 1975 take of shells revealed only a small number of immature mussels. Most of the shells collected would have satisfied the 2½-inch legal height required by Illinois law. For example, of 36 *Quadrula pustulosa* (Lea) taken east of the Maunie, only six were of illegal size. On the other hand most of the *Obliquaria reflexa* Rafinesque collected were undersize and many were under 1½ inches in height. Lopinot (1969) reported the percentages (by species) of shells under the 2½ inches in height in the stock piles of buyers. This information was collected by Illinois biologists and indicated that approximately 42 percent of the shells harvested from the Wabash River in 1967 were less than 2½ inches in height. Over 50 percent of the *Fusconaia undata* (Barnes), *Quadrula metanevra* (Raf.), *Q. pustulosa* (Lea), *Q. quadrula quadrula* (Raf.), *Q. nodulata* (Raf.), *Obliquaria reflexa* (Raf.), and *Obovaria olivaria* (Raf.) were of small sizes. If a crowfoot bar is designed for selectivity, larger specimens are collected more readily than the smaller ones.

Table 5. Distribution and abundance of unionid mussels in the Wabash, White, and East Fork of the White rivers of Indiana based on 99 collections in 1966 and 1967 (from Krumholz, Bingham and Meyer, 1970).

Species	Wabash River			White River	
	Upper	Middle	Lower	Main Stream	East Fork
Subfamily Anodontinae					
Alasmidonta marginata	R	-	-	-	-
Anodonta grandis	-	-	R	-	-
Anodontoides ferussacianus	R	-	-	-	-
Lasmigona complanata	C	C	C	C	C
Lasmigona compressa	R	-	-	-	-
Lasmigona costata	R	R	-	-	-
Strophitus rugosus	C	-	-	-	-
Subfamily Lampsilinae					
Actinonaias carinata*	A	A	C	C	C
Cyprogenia irrorata	-	R	-	-	-
Lampsilis anodontoides	C	C	C	-	-
Lampsilis ovata ventricosa	C	C	C	C	C
Leptodea fragilis	C	C	C	C	C
Leptodea laevissima	-	-	R	-	-
Obliquaria reflexa	R	R	R	R	C
Obovaria olivaria*	A	A	A	C	C
Obovaria subrotunda	R	-	-	-	R
Proptera alata	C	C	C	C	C
Truncilla truncata	R	R	R	R	R
Subfamily Unioninae					
Amblema costata*	C	C	C	C	A
Cyclonaias tuberculata	-	-	-	-	R
Elliptio crassidens	-	-	-	-	C
Fusconaia ebenus*	R	R	R	C	C
Fusconaia undata*	R	R	-	R	C
Megalonaias gigantea*	R	C	-	R	C
Plethobasus cyphyus	R	-	-	-	R
Pleurobema cordatum	-	-	-	-	R
Quadrula metanevra*	R	R	R	R	R
Quadrula pustulosa*	A	A	A	A	A
Quadrula quadrula*	A	A	A	A	A
Tritogonia verrucosa*	C	C	C	-	-

*The 10 species of greatest commercial value.

R, rare; --, not present; C, common; A, abundant. Upper Wabash River: Delphi to Terre Haute, Indiana; Middle Wabash River: Terre Haute to Mount Carmel, Illinois; Lower Wabash River: Mount Carmel to Ohio River

Table 6. Species and abundance of mussels collected on the Ohio River, miles 842-862, September 5, 6, 1967.

Location	Species	Abundance
Mile 843.2-844 (from mouth of Lost Creek to lower Highlands Rocks, ending one mile above Dam 49). Specimens taken 40 yards from Kentucky shore in water 12-17 feet	Fusconaia ebenus	1
	Pleurobema cordatum	1
	Quadrula quadrula	13
	Quadrula pustulosa	3
	Lasmigona complanata	1
Mile 857-858 (from directly opposite Millrace Slough to immediately above Shawneetown light). Specimens taken 125 yards from Illinois shore in water 12-18 feet deep.	Fusconaia ebenus	9
	Pleurobema cordatum	3
	Amblema costata	5
	Quadrula quadrula	12
	Quadrula pustulosa	5
	Megalonaias gigantea	3
	Elliptio crassidens	2
	Tritogonia verrucosa	5
Mile 859-859.5 (SCUBA collections from 23 square yards, 10 yards from shore on Illinois side of river).	Fusconaia ebenus	2
	Pleurobema cordatum	4
	Amblema costata	65
	Quadrula quadrula	23
	Quadrula pustulosa	9
	Lampsilis anodontoides	2
	Megalonaias gigantea	4
	Plagiola lineolata	2
	Obliquaria reflexa	5
	Proptera alata	1
	Tritogonia verrucosa	4
	Leptodea laevissima	4
Mile 859-859.5 (brail samples taken 50-125 yards from the Illinois shore in 12-18 feet of water).	Fusconaia ebenus	10
	Pleurobema cordatum	5
	Amblema costata	19
	Quadrula quadrula	49
	Quadrula pustulosa	24
	Quadrula metanevra	1
	Obovaria olivaria	13
	Megalonaias gigantea	1
	Plagiola lineolata	2
	Elliptio crassidens	3
	Obliquaria reflexa	25
	Tritogonia verrucosa	1
	Lampsilis anodontoides	1

These data suggest that natural recruitment exists in the Wabash for the species mentioned. We might add that three specimens of *Quadrula cylindrica* (Say), and listed on rare and endangered list of Stansbery (1970), were measured by the biologists. All three were under the 2½ inch measurement. Data by Lopinot (1968) indicate a large harvest of young mussels will affect the future harvest and possibly the obtaining of large shells.

Messrs. Collins and Carroll, who assisted in the 1975 spot sampling, stated that they rarely had seen a *Megalonaias gigantea* (Barnes) or an *Amblema* spp. under three inches in length. Lopinot (1968) measured 896 of the former and 925 of the latter species. Most of the *Megalonaias* and only three of *Amblema* were under 2½ inches in size.

The bed of Ohio River naiads, closest to the mouth of the Wabash was studied by Williams (1969). Although not considered to be a large bed, its inhabitants are commercial species (Table 6). Williams believed the bed to have been a part of the larger bed downstream.

In June 1975, Dr. Williams spot sampled some of the beds of naiads which he had worked during a 1967 survey. He found them to be essentially the same as when first sampled. Species composition was about the same and recruitment was occurring. He is of the opinion that conditions in the Ohio, near the mouth of the Wabash, are approximately the same as in 1967, and that there is little reason to believe the mussel beds of the area have been altered since that survey.

REASONS FOR CHANGES IN THE WABASH RIVER NAIAD POPULATION

Call (1894) found that factors exister at least 100 years ago which could have caused the demise of the less adaptive and/or tolerant species of freshwater naiads. Call further stated, 'The sewage of towns and villages, the refuse of factories and other manufacturing plants, the gradual encroachment on the primitive forest, the drying up of streams, the drainage of swamps, the general increase in tilled lands, these all conspire against the chances of perpetuity of a rich molluscan fauna.' He described man as the greatest enemy of molluscan life, and added, 'It is believed that many of the fine collecting grounds known to Say and the early naturalists have in this way been completely destroyed.' (Call, 1900). Further, he implicates dam building, which prevents free fish migrations, as causing the almost complete extinction of some forms of unionids. A report by van der Schalie (1938) stated that M. M. Ellis found the Mississippi River, from the mouth of the Missouri to the Gulf of Mexico, to be practically devoid of mussels. Ellis (1931) attributed this condition to the tons of silt carried downstream and deposited in the Mississippi River by the Missouri. As van der Schalie stated, 'Mussels, for the most part, are extremely sensitive to such changes .... relatively few species adapt themselves to the altered habitats.'

Wurtz (1956) stated that unionid mussels were quite intolerant to pollution of any kind and reported unequivocally that freshwater mussels disappear from streams carrying moderately heavy burdens of pollutants. Krumholz, Bingham, and Meyer (1970) cited the work of Forbes and Richardson (1919) which directly correlated the increasing levels of pollution and decreasing ranges and numbers of mollusks in the Illinois River. Starrett (1971) documented changes in the distribution of the more common mussels of the Illinois River. Meyer (1974) wrote, 'A trend toward restrictions of ranges and declines in abundance of many members of the unionid fauna of the Wabash and White Rivers is clearly indicated, as is extirpation of certain species.'

Parmalee (1967) commented that, 'Species adapted to sand and gravel bottom environments cannot long survive in one composed of mud and they are quickly destroyed by the smothering effects of silting.' He also considered the changing structure of stream beds as one of the major factors causing changes in mussel populations. A constantly changing or shifting bottom will limit and/or prevent the establishment of mussel beds. 'Each species has evolved its own combination of optimum habitat requirements and these differ considerably among the various kinds' (Parmalee, 1967). He speaks of pollution and silting as if they were not synonymous, but of equal importance.

During the 1975 survey on the Wabash, at least twenty-five of the older mussel collectors, who had spent their lives along the Wabash River, were contacted to learn the causes for the decline of the gravel removal operations as the chief cause. They explained that the gravel companies employed many of the mussel collectors to aid with the removal. The collectors knew the locations of the good gravel bars because these were also the good mussel collecting sites in the stream. When the gravel was removed, the sand and silt washed from it was carried downstream.

Very little of the bottom sampled in the 1975 study was composed of gravel. Most of the bottom was sand with varying amounts of silt. Every specimen of *Megalonaias gigantea* (Barnes) and *Amblema peruviana*)Lamarck), taken during 1975, contained large amounts of silt in and around the gills. The heavy silt load derived from cultivated fields in the drainage area, the continuous disturbance of the bottom by removal of gravel and the resulting release of sand and silt have combined to produce a tremendous sediment load, especially during high waters. Stream bottoms of silt and sand are usually unstable and constantly changing. Such conditions are not suitable for the establishment of mussel beds.

Call (1900) provides us with one of the early causes for the reduction of the mussel populations, a cause which has received little attention. He stated, 'I have seen hogs rooting the largest of the mollusks from their beds in the rivers of the south and crushing them as they would apples, rejecting the shells and using only the soft portion.'

Call (1900) also emphasized the importance of mollusks as food for wildlife, '... raccoons and muskrats destroy thousands yearly, so many indeed that one wonders how they manage to perpetuate their species.' The 'kitchen middens' have long been known by conchologists as a source from which many of the smaller and rarer shells of a stream may be found. *Simpsoniconcha ambigua* (Say) at one time were located by finding a pair of shells in a 'midden' on the shore. In their specialized habitat, the smaller and rarer shells which were possibly rare or endangered in the time of Call, were of the sizes most often collected for food by muskrats and raccoons. The vast populations of these predators in early days, their habits of underwater food collection, and their use of small shells may have made them a greater factor in the demise of many species than has received consideration.

Call (1900) ranked man as the greatest enemy of mollusks but did not list commercial collecting of mussels as one of his crimes. Both Virgil Carroll and Charles Collins of Mt. Carmel, Illinois stated that mussel collecting started in 1905 on the bar below the bridge at Mt. Carmel. Since the first pearl button factory was established in Muscatine, Iowa in 1892 (Lopinot, 1967), it would seem that the Wabash, especially near the Mt. Carmel area, has been collected for as long or longer than most areas in the United States. Carroll and Collins related experiences of early collecting when up to 1000 pounds of mussels were collected per day in this area. The 1975 survey included eight 20 minute brail hauls over this bar. This sampling net-

ted a total of 16 species and 54 specimens. The total weight of the live mussels was approximately 25 pounds.

The total weight of shells taken per day during the 1975 spot sampling never exceeded 40 pounds. Total brailing time per day did not exceed 4 hours. Thus, in an 8-hour day, 80 to 100 pounds of shells, including non-commercial species, might be collected.

The presence of a population of freshwater mussels large enough to support a profitable commercial collecting industry is doubtful. Table 4 is a presentation of the harvest from 10 one-mile sections in the upper Wabash where shells are said to be more abundant. Only 297 specimens were collected during the 10 miles of brailing. The 18 plus actual hours of brailing during the 1975 survey produced 178 naiads (less than 10 per hour). Some were not of legal size or of commercial value.

Messrs. Carroll and Collins of Mt. Carmel described a combination commercial fishing and mussel collecting industry which supported approximately 50 families in the Mt. Carmel area in the 1930's. Mr. Collins, who has purchased shells since 1945, estimated that he purchased about 600 tons of shells in 1964 as compared to 14 to 15 tons in 1974. Homer Booton of Grayville, Illinois, has collected shells for 40 years, but had difficulty in collecting enough shells to make 10 to 15 dollars a day in 1974. Other collectors spoke of earning $30.00 per day when shells brought only 3¢ per pound (today they bring 10¢ to 15¢ per pound). Residents along the river, east of Maunie, estimated that they could collect $10.00 to $15.00 in shells per day; but this does not cover the cost of equipment and labor.

Lopinot (1968) reported a decrease in the Wabash River harvest from 919 tons in 1965 to 317 tons in 1967. Collins paid between $350 and $400 per ton for mussels in 1965 as compared to $300 for three ridge (*Amblema* spp.) and niggerheads (*Fusconaia ebenus* (Lea), and $200 for muckets (*Actinonaias carinata* (Barnes) in 1975. According to Lopinot (1968), 4,688 mussel collecting licenses were sold in 1934; but the sale dropped to a few hundred, or less, for a period of nearly 30 years. Sales returned to 1,279 in 1966. These figures reveal the pressures which may have been exerted on the Wabash mussels by licensed Illinois clammers. Indiana sales of licenses may have been equivalent. At least sales probably followed a similar trend because Wabash River shells brought a higher price than those from other streams, and would have attracted mussel collectors.

Collins recalled that one year, probably during the late 1920's or early 1930's, his uncle sold nearly $1500 in pearls from mussels collected in the Wabash. He stated that his father collected several times as many mussels as his brother, but he found very few pearls of any value. Collins stated that he paid $500 for a pearl in 1963, but he recalled two or three that had sold for $800 to $900 in earlier years.

Regardless of the factors discussed which would contribute to the decline in the Wabash River naiad fauna, contacts with numerous commerical fishermen revealed that a considerable quantity of 'hacklebacks' (*Scaphirhynchus platorhynchus* (Rafinesque), or shovelnose sturgeon are taken in the lower part of the Wabash. One fisherman stated that he could show weigh bills for 1500 pounds taken during the spring of 1975. This fish could act as a major predator on small naiads. Their presence would indicate that the stream bottom in many areas still provides desirable habitats for the small mussels. Trautman (1957) quoted several fishermen as reporting that this sturgeon congregates wherever there are large quantities of small clams and snails. Most of the fishermen contacted along the Wabash reported that the sturgeon were taken in large numbers only in the lower part of the river, probably below the Grand Chains area.

CONCLUSIONS

The history of mussel collecting in the Wabash River was reviewed to determine the species reported in early collections. Some of the species which are considered 'rare and endangered or extinct' (Stansbery, 1970) may have been taken only once in the Wabash or were rare or endangered 75 years ago. Thus, factors which caused the demise of several species have existed for possibly 100 years, and are not necessarily of recent origin.

Changes have occurred in the naiad fauna, from 70 listed by Call (1900), 75 by Goodrich and van der Schalie (1944), and 30 in the 1966-1967 survey by Krumholz, Bingham, and Meyer (Meyer, 1974). However, no recent intensive and extensive survey has been made of the entire Wabash River drainage from which comparisons can be made with the state-wide compilations of Call (1900) and Goodrich and van der Schalie (1944) who included all known records. Krumholz, Bingham, and Meyer (1970) proved that different collecting methods produced different results, and that sampling the same area in different years produced dissimilar results. Each method has its value under different stream conditions; and only a combination can provide the most reliable data. Thus, the comparisons of the data on Indiana naiads are not necessarily valid unless the methods used to collect them are the same.

The 1975 data compare quite favorably with those obtained during the 1966-1967 survey when compared on the basis of abundance used during the earlier survey. These data from the two surveys indicate that a population of commercially valuable mussels exists in the area of the Wabash from Mt. Carmel to the mouth; but the numbers are such that they cannot support a viable collecting industry. The data also suggest that few if any of the rare or endangered species exist, although intensive collecting during low water stages would add considerably to the credibility of this supposition.

The shifting sand and silt bottom of this lower section of the Wabash River does not present a desirable habitat for most of the rare or endangered species of freshwater naiads, or the more commercially valuable shells. The constant and systematic removal of the better habitat (gravel bars),

the resulting resuspension of sand and silt, plus that carried by the stream during high waters, suggest a degradation in the habitat in the future, considering no control measures.

The suggested possibility of the construction of one or more locks and dams, in the Mt. Carmel to the mouth area, raises the question of their detrimental effects on the mussel population. Clark (1971) raised the question if the large beds of mussels in the Muskingum River in Ohio were present prior to the construction of the dams, or did the dams create a set of conditions downstream which resulted in the creation of the favorable habitat, and thus the establishment of the mussel beds. There seems to be a definite correlation between the locations of the mussel beds and the dams.

Impoundments do not have the same effects on different species of mussels. The 38-foot power dam in the Auglaize River near Defiance, Ohio, in the area collected by Clark and Wilson (1912) created an impoundment behind it. Personal collections from the area would indicate that *Quadrula quadrula* (Raf.), *Q. pustulosa* (Lea), *Lasmigona complanata* (Barnes) and *Proptera alata* (Say) were benefited by the impoundment and were reproducing in large numbers. Undocumented information coming from work in the TVA reservoirs indicates that mussel fisheries are becoming reestablished in some reservoirs where species have thrived under impoundment conditions. Even some of the rare or endangered species seem to be abundant in muddy bottoms. Call (1900) stated that *Dysnomia flexuosa* (Raf.), '...should be sought in deep and muddy bottoms ...' It is inconceivable that impounding the Wabash behind relatively low dams will bring back such rare species, but some could thrive under conditions similar to those which may be created both above and below dams and locks.

Finally, a quick appraisal of the area would seem to indicate that most of the rare or endangered species of mussels already are extinct, and that the populations of commercially valuable species are too low to provide a viable mussel economy. Both the removal of the gravel bars and the heavy sediment load are rapidly destroying the desirable habitat so that the future for the survival of the mussels which are present is rather dim. The installation of locks and dams, the building of stable bars unmolested by dredging barge channels, and the discontinuation of dredging operations on existing bars, might stimulate a recovery of at least a few of the remaining species of naiads.

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