UNIVERSITY of NORTH ALABAMA
SINCE 1830
Florence, Alabama 35632-0001

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11 August 1993

Mr. Neil Woomer
Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402

Dear Mr. Woomer:

Enclosed you will find a copy of the progress report we discussed a few weeks ago. As you can probably see, I may have gone overboard, but I felt too much was better than too little. If this particular format is not appropriate, please feel free to provide editorial comments and return it to me to have them incorporated. We are still collecting data and will continue to do so until near the end of September. At that time I will assimilate all the data with appropriate statistical analyses into essentially this same paper for the final report. I hope to provide you with that report sometime late in October.

Please keep me posted with regard to what I need to do (e.g., submit a proposal, etc) for receiving another year of funding (note that I have included recommendations in the Future Work section of this progress report). Schools starts August 26 and I will be quite busy after that date, so the sooner I know what needs to be done the better. I hope you are successful in finding money for continuing this project and I look forward to hearing from you soon.

Sincerely,

Terry Richardson

Terry Richardson

Attn: Contract No. TV-89958V

Colonization of Tennessee River Bivalves by the Invading Zebra Mussel, *Dreissena polymorpha* (Pallas): A progress report

by

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Summary

A program was established to monitor the progress, success, and effects of the invading zebra mussel, *Dreissena polymorpha*, on native mussel assemblages. This was arranged as a cooperative agreement with the University of North Alabama and employed five student workers on a part time basis. Five mussel beds were picked as sites for the monitoring project: two overbank soft sediment sites in Wheeler Lake both open to commercial harvesting of mussels, two channel sites in the upper Pickwick reservoir mussel sanctuary, and one channel site in upper Pickwick open to harvesting. All sites were sampled using divers and quadrats. The sanctuary sites had the highest mussel densities and species richness followed by the channel site open to harvesting. The overbank populations in Wheeler lake had few species and appeared to suffer from lack of recruitment of young into the populations. Commercially important species at all sites open to harvesting showed indication of impact by mussel divers. One federally listed endangered species, *Lampsilis abrupta*, was represented by 19 specimens at the sanctuary sites. Two zebra mussels were found at one of the sanctuary sites and Alabama Conservation officers confirmed zebra mussels attached to bivalves near the channel site open to mussel divers. Six navigation buoys in Wheeler Lake and six in upper Pickwick reservoir surveyed for zebra mussels showed no signs of infestation. In conclusion, the sanctuary appears to be an important refuge for endangered species and for protecting seed stock of commercially important mussels. Zebra mussel abundances are currently low in the southern bow of the Tennessee River but are showing up in the sanctuary as well as in commercially harvested areas. In order to aid in preserving this valuable natural resource it is recommended that this monitoring project be continued until it is clear what effect the zebra mussel will have on native bivalves.

Introduction

The zebra mussel (*Dreissena polymorpha*) was first reported in the Tennessee River in 1991 at Kentucky Lake (S. Ahlstedt, personal communication, Tennessee Valley Authority) and has now been seen as far upstream as Lake Nickajack. The zebra mussel was probably introduced into the Great Lakes in 1985 or 1986 and was first discovered in Lake St. Clair in 1988 (Herbert et al. 1989). Since then it has spread throughout many of the navigable waterways of the northern U.S. and can now be found as far south as the Mississippi River in Louisiana (K. Brown, personal communication, Louisiana State University). The zebra mussel's spread has been rapid and intense. With densities reported as high as near 700,000/m^2 (Griffiths et al. 1989, Kovalak et al. 1991), these mussels are significant biofoulers clogging water intakes, and adhering to boats, navigation buoys, and other hard surfaces. In addition, these exotic bivalves can have significant negative impact on the ecology of aquatic ecosystems and indigenous populations of aquatic organisms (Schloesser and Kovalak 1991), and, as such, have been the focus of much recent research. Because the invasion of the waters of the Tennessee Valley by the zebra mussel took place only recently, relatively little is known about how populations of these exotics will respond in these southern waters.

Rivers and reservoirs in the southeastern U.S. generally provide longer growing seasons with warmer temperatures than do their northern counterparts. Because these factors are important determinants of individual growth and reproduction, the zebra mussel will likely have an economic and ecological impact of considerable magnitude in the Tennessee Valley. One of the more significant of these will be the impact of zebra mussels on native unionid mussel populations. The native mussels of the Great Lakes region have already suffered considerably from the invasion of zebra mussels. By settling on native mussel shells, zebra mussels effectively smother these individuals and, as a result, have essentially eliminated the indigenous mussel populations in lakes Erie and St. Clair (Hunter and Bailey 1992, Hebert et al. 1991, Schloesser and Kovalak 1991).

The Tennessee River is an important habitat for many native mussels and supports one of the largest and most diverse mussel assemblages in the world. Furthermore, included among the indigenous mussel species of the Tennessee River are several that are rare and/or endangered. These mussels along with numerous additional species are at risk of becoming extinct as the zebra mussel becomes established. In addition, zebra mussels will likely reduce the abundance of other, commercially important species to the point of seriously impacting the multimillion dollar shell industry of the Tennessee Valley.

From and economic and ecological perspective, it is extremely important to establish monitoring programs to document the abundance and diversity of native unionid mussels in sanctuaries and commercially important beds, and monitor the progress, success, and effects of the zebra mussel on these native populations. In this report, I provide preliminary information on the establishment of such a program to monitor the invasion of the zebra mussel into native bivalve assemblages. This program was established in accordance to

Contract No. TV-89958V and pursuant addenda between the Tennessee Valley Authority and the University of North Alabama. In keeping with T.V.A.'s focus on the environment and education, and to provide valuable research experience to U.N.A. students, only university students were employed to help in this program (*see Appendix*).

Methods

Native Mussel Assemblages

Initially, five mussel beds have been chosen for the monitoring program. Divers first surveyed an area to determine the general extent of the bed with subsequent sampling taking place within the bed (Isom and Gooch 1986). Two overbank beds in Wheeler reservoir and three channel beds in upper Pickwick reservoir were selected. The two beds in Wheeler Lake were chosen because they are open to commercial harvesting and they represent mussel populations in soft sediments (in soft sediment habitats, such as in overbank areas, native mussels often represent the majority of solid substrate available for zebra mussel attachment). The two beds, Wheeler Site 1 and Wheeler Site 2, are located just downstream of Brown's Ferry Nuclear Power Plant at T.R.M. 292.7 and are near the north and south banks, respectively. Plans have been made to incorporate additional beds upstream of B.F.N.P. near T.R.M. 295 or 296.

Two beds in upper Pickwick were located in the mussel sanctuary below Wilson Dam at T.R.M. 253.2-256.4. These sites were chosen because this area is closed to commercial harvesting of mussels, contains one of the most diverse assemblages of unionid mussels along the Tennessee River, and is known to contain one or more federally listed endangered species. The McFarland Park bed lies at T.R.M. 255.5-256.2. The second site lies downstream from Cypress Creek extending from T.R.M. 254.5-254.7. The third Pickwick site is located upstream from Buck Island at T.R.M. 249.7. This site is open to commercial harvesting and was chosen because of previous reports of zebra mussels in the vicinity.

Mussels were sampled using the scuba/quadrat method (Miller and Payne 1988). Within a bed, divers would randomly locate a 0.25 m^2 metal quadrat and excavate the substratum from the quadrat to a depth of 15 cm (before excavation of a sample would begin all exposed surfaces were examined for zebra mussels). All excavated materials were placed into a bucket, hauled to the surface via a boat-mounted winch, and washed over a 6 mm sieve. Mussels were removed, identified, and the length and width of each specimen measured to the nearest millimeter using a vernier caliper. All specimens were returned to the bed from which they were sampled. All notes and measurements were recorded onto an audio cassette and the data later enter into a spreadsheet at the laboratory (using audio cassettes significantly speeds up the data recording process and eliminates the need for an extra pair of dry hands).

At the Cypress Creek site (T.R.M. 254.7) a second method of sampling was employed. In addition to random quadrats, line transect sampling was used. In this

procedure, a line was stretched 100 m parallel to river flow along the river bottom 20 m from the north shore. Subsequent transects were stretched at 20 m intervals to a distance of 180 m from the north shore (8 transects total). Two divers, one on either side of the line, would then remove all mussels encountered within an arms reach of the cable (approx. 1 m reach for each diver for a total of 2 m surveyed for the length of the transect) for a specified length along the transect. This method has the advantage of covering a large area in a short period of time and allows data to be related to exact location. However, it is not as effective as quadrat sampling in terms of sampling the entire size distribution of mussels available.

Zebra Mussel Watch

Navigation buoys served as the principle source of artificial substrate for monitoring zebra mussel colonization. Periodically, navigation buoys at T.R.M. 249.7-256.2 and T.R.M. 292.7-293 were examined for attached zebra mussels. Divers would look for zebra mussels attached to the submerged portion of the buoy, anchor cable, and on the concrete anchor slab.

Results

Native Mussel Assemblages

The highest densities of mussels were found in the Pickwick locations (Table 1, T.R.M. 249.7-255.5). The sanctuary bed located at McFarland Park (T.R.M. 255.5) had an average density of 32 mussels/m^2 ($\pm$4.4 S.E.), considerably higher than the 12 $\pm$2.0 mussels/m^2 found in the sanctuary bed below Cypress Creek (T.R.M. 254.7). Interestingly, the site open to commercial harvesting (T.R.M. 249.7) had densities intermediate to the sanctuary sites (19.2 $\pm$2.0 mussels/m^2). Mussel densities at the two overbank beds in Wheeler lake (T.R.M. 292.7 north and south) did not differ from those at the Cypress Creek location.

The three beds in Pickwick had the highest diversity of mussels (Table 1). The greatest number of species was taken from the sanctuary site at McFarland (15 species). A similar number of species were collected from the commercial site at Buck Island (12) and the sanctuary site at Cypress Creek (12). The diversity of mussels at the two Wheeler Lake sites were somewhat lower than those in Pickwick and fewer mussel species were collected.

The dominant mussel species differed among sites. At the two sanctuary sites in Pickwick *Fusconaia ebena* was the most abundant species representing 47% and 34% of the mussels collected at Cypress Creek and McFarland, respectively. At Buck Island, however, *F. ebena* represented only 17% of the mussels sampled and was replaced by *Quadrula pustulosa* as the dominant species (38%). *Megalonaias nervosa* represented over 60% of the mussels collected at the two Wheeler Lake sites. *Obliquaria reflexa* was the next most abundant species making up 15% and 29% of the mussels sampled at Wheeler sites 1 and 2, respectively.

Average size of the dominant unionids also differed among sites. For example, *F. ebena* was, on average, larger in the two sanctuary sites than in the site at Buck Island (Table 2). Furthermore, the largest *F. ebena* sampled at Buck Island was a least 18 mm smaller than the largest individuals at either Cypress Creek or McFarland Park. All three Pickwick sites did, however, show signs of relatively recent recruitment into the *F. ebena* population. Numerous individuals were sampled from these sites that were <20 mm in shell length which roughly corresponds to an age class of less than 3 years (estimated from shell growth rings). The average size of *M. nervosa* at the two Wheeler Lake sites were similar and neither site showed any indication of recent recruitment. At both Wheeler sites the smallest individuals collected were near 100 mm in shell length which would conservatively relate to an age of about 9-12 years.

The line transect survey at the Cypress Creek location yielded more species at than did quadrat sampling. A total area of 1000 m^2 was surveyed and 21 species collected (Table 3). Divers collected 2441 specimens, 18 of which were the federally listed endangered species *Lampsilis abrupta*. Average mussel density was 2.4 mussels /m^2 and *Fusconaia ebena* was the most abundant unionid representing over 38% of the mussels collected. The elephant ear, *Elliptio crassidens*, was the second most abundant species and comprised over 15% of the mussels sampled. All specimens sampled, with the exception of a few *F. ebena*, *Q. pustulosa*, and *O. reflexa*, were estimated to be greater than 10 years old with most greater than 15 years.

Zebra Mussel Watch

During the line transect survey at Cypress Creek two *D. polymorpha* were found. The first was found on 18 June '93 at T.R.M. 254.7, 60 m from the north shore (well outside the navigation channel). This individual had a 28.2 mm length, 12.5 mm width, and a 14.3 mm height. The second zebra mussel was found on 19 June '93, 160-170 m downstream from T.R.M. 254.7, but at 180 m from the north shore and within the navigation channel. This specimen was accidently crushed before measurements could be made, but was smaller than the first zebra mussel. No zebra mussels were observed during the quadrat sampling.

Six navigation buoys between T.R.M. 249.7 and 256.2 and six between T.R.M. 292.7 and 293.3 were periodically examined for zebra mussels. No zebra mussels were found attached to the buoy, anchor cable, or concrete anchor.

Conservation officers for the Alabama Department of Conservation retrieved a live *F. ebena* with one attached zebra mussel from a commercial mussel harvester around 23 June '93. This specimen was collected in the immediate vicinity of the Pride Ferry coal loading facility at T.R.M. 247.2. Conversations with other mussel fishermen and with the conservation officers indicate that zebra mussels turn up rather frequently at this location but not in large numbers. This location is just downstream from the Buck Island site at T.R.M. 249.7.

Discussion

Native unionids in the overbank areas of Wheeler Lake were not as abundant or diverse as their counterparts in upper Pickwick Reservoir. The Wheeler Lake sites do not have the flow or substrate suitable to sustain many of the species found in the high current, and gravel/cobble areas below dams. Furthermore, these sites appear to be subject to heavy harvesting. None of the washboards (*Megalonaias nervosa*, a commercially important species) sampled at Wheeler Lake sites 1 and 2 were above the legal size limit (102 mm height) suggesting that both sites had been harvested (this was confirmed in conversation with some mussel divers in the area). Interestingly, no recruitment of any species was observed at these sites. This may have been because too few samples were taken or perhaps because samples were not excavated deeply enough to reveal young. In a recent survey of Wheeler Lake conducted by TVA biologists, S. Ahlstedt (personal communication) indicated that little or no recruitment was observed. Why these species are not having successful recruitment in this lake remains unclear.

The sanctuary locations are, on average, the richest in terms of species and have the overall highest densities of the sites examined in this study. A total of 22 species were sampled in the sanctuary sites, one of which was a federally listed endangered species. At Buck Island, only one *L. abrupta* was found while 19 were found at Cypress Creek and McFarland Park. In addition, specimens of *F. subrotunda* and *Pleurobema pyramidatum* were found at Cypress Creek (species rare in this portion of the Tennessee River). Hence, these sanctuary beds seem important for preserving the diversity of Tennessee River mussels by providing refuge for rare or endangered species.

Furthermore, these sanctuary beds appear to be important commercially as well. The *F. ebena* at Buck Island, a site open to commercial harvest, were reduced in abundance and relatively small compared with those in the sanctuary. *Fusconaia ebena* were two to three times more dense at the sanctuary sites than at Buck Island. In addition, most *F. ebena* specimens from Buck Island were smaller than the legal size for harvesting (60.3 mm). At the two sanctuary sites, many *F. ebena* were well above the minimum commercial size limit. Larger mussels can typically hold more young in their gills and therefore contribute more to the reproductive effort of the population. Hence, by affording a refuge for the larger, mature individuals these sites may provide valuable "seed stock" for commercially important species like *F. ebena*.

Unfortunately, these sanctuary sites, as well as areas open to commercial harvesting, are threatened by the invading zebra mussel. Zebra mussels were collected at the Cypress Creek site and have been documented from the heavily harvested area near Buck Island. In addition, zebra mussels have been found attached to native bivalves in the Buck Island vicinity. Furthermore, in July '93, at Pickwick lock TVA biologists found zebra mussels in excess of 200 per 20 minute dive. While the abundance of zebra mussels at the upper Pickwick sites is not yet as high as those at the lock, they are present and it appears to be only a matter of time before they reach densities sufficient to threaten the native fauna.

Future Work

This contract represents the initiation of a program designed to monitor native mussel assemblages and the progress, success, and effects of the invading zebra mussel into these assemblages. The ecological and economic importance of these mussel beds cannot be overestimated and the potential impact of the exotic zebra mussel on these beds could be serious. It is, therefore, recommended that this monitoring program be continued under essentially the same guidelines of the current contract until it is clear what effect the invaders will have on our native mussels. The current sites should continue to be monitored and additional sites should be added. We are fortunate that the zebra mussel has not yet become well established. Because scientist of the Great Lakes region were unable to foresee the incoming surge of the zebra mussel and its effects on native fauna, they have urged us to monitor the exotic's progress and effects on native mussels as they become established (Zebra Mussel Symposium at the annual meeting of the Alabama Academy of Science in Huntsville, AL).

As the zebra mussel becomes established, the monitoring program should be expanded to include studies on the population biology of the zebra mussel in this southern location. Southern rivers and streams often afford warmer temperatures and longer growing seasons for their inhabitants than do their northern counterparts. Because all information to date on zebra mussel biology is from northern locations, we need studies to help us understand how this invading species will respond to the conditions in the southern reaches of the Tennessee River. Hopefully this information could then be implemented into management strategies for zebra mussel control.

Acknowledgements

I would like to acknowledge the help of the mussel divers in the Tennessee Valley with which we had the good fortune to converse; their information was extremely valuable in helping this program get off to a smooth start. I would also like to thank Steve Ahlstedt and Larry Neil of TVA for their helpful advice. Finally, I wish to thank Dr. Paul Yokley, Jr. for his consultation and help in mussel identification. This study was made possible through a cooperative agreement between the Tennessee Valley Authority and the University of North Alabama.

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Appendix

One aspect of this contract was to actively involve University of North Alabama students allowing them the opportunity to gain practical knowledge and experience in field research while at the same time providing them with some income. Indeed, almost 50% of the overall budget was for student salaries. Because UNA is a small, primarily teaching institution, research opportunities rarely present themselves to our students; this project has made such options available.

Since the initiation of the project in October 1992, five students have actively participated in the program in some capacity. Two students joined the project in October and one of those is still aboard. Unfortunately, the second had to return to his home in Tennessee and is no longer at UNA. In June 1993, two more students joined the project bringing the current student participants up to three. These students are rapidly becoming experts in the identification of local unionids and, as divers, are gaining knowledge and experience in the use of diving to gather biological data. All are certified SCUBA divers and are now experienced in the use of HOOKA rigs (light commercial, surface-supplied air diving equipment) with underwater communications and in quadrat sampling. In addition, these students are learning about community and population ecology first hand. All of these students are college juniors or younger. If this project continues for at least another year, some of these students will graduate already having two years practical experience!

One of these students has been with the project from the beginning and actively participates in computer assisted data entry and analysis. Also, this student was invited to Calhoun Community College in Decatur, Alabama on August 9, 1993 to give a presentation on zebra mussels in the Tennessee River to the environmental biology class. While working with students has its limitations-- short work days because of classes, juggling sampling trips around classes, excused absences due to exams, etc.-- it is, overall, extremely rewarding. The students working on this project have all gained a new perspective on their education and what college can offer them. Some are even making better grades since coming on board the project. They are more enthusiastic now about school than they have ever been and at least two of the three are now discussing graduate school. My only regret in using students is that I cannot employ all that would like to participate. In my opinion, this project is well worth the money if for no other reason but to involve students.

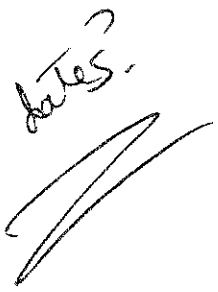

Table 1. Average density (No. /m²) of mussels at the five locations. Mussels were sampled by divers using a 0.25 m² quadrat.

	Buck Island (249.7)	Cypress Creek (254.7)	McFarland Park (255.5)	Wheeler Site 1 (292.7N)	Wheeler Site 2 (292.7S)
Taxa:					
F. ebena	3.2	5.6	10.8	—	—
O. reflexa	2.0	0.4	5.2	1.2	2.0
Q. pustulosa	7.2	1.2	6.8	0.4	0.4
Q. metanevra	—	0.2	—	—	—
Q. quadrula	0.4	—	0.4	0.4	—
T. donaciformis	2.4	0.4	4.0	—	—
E. crassidens	0.4	2.0	1.6	—	—
T. parva	—	0.2	—	—	—
P. alata	—	0.2	0.1	0.4	0.2
E. lineolata	1.2	0.8	0.4	—	—
C. tuberculata	1.6	0.4	0.8	—	—
P. cordatum	—	0.4	—	—	—
L. fragilis	0.4	0.2	0.4	—	—
L. abrupta[a]	0.1	—	0.1	—	—
A. confragosus	0.4	—	0.1	—	—
M. nervosa	—	—	—	4.8	4.4
A. plicata	0.4	—	0.8	0.4	0.2
L. recta	—	—	0.4	—	—
T. verrucosa	—	—	0.1	0.4	—
No. of samples	34	28	30	14	27
No. of species	12	12	15	7	5
No. of specimens	163	84	240	28	46
Total No./m²	19.2	12.0	32.0	8.0	6.8
D[b]	0.79	0.73	0.79	0.61	0.49
D_{max}	0.92	0.92	0.93	0.86	0.80

[a] Federally listed endangered species
[b] Simpson's diversity index (Krebs 1985).

Table 2. Average size (length, mm) and range of selected mussel species from each site.

	Buck Island (249.7)	Cypress Creek (254.7)	McFarland Park (255.5)	Wheeler Site1 (292.7N)	Wheeler Site 2 (292.7S)
F. ebena	26.2 7.6-78.6	57.1 10.4-99.7	38.9 8.8-97.4	— —	— —
Q. pustulosa	39.2 7.6-64.2	— —	— —	— —	— —
M. nervosa	—	—	—	123.2 114.0-137.8	112.3 97.5-128.7

Table 3. Data collected using the line transect method at the Cypress Creek site (T.R.M. 254.7).

	Distance from North Shore								
	20 m	40 m	60 m	80 m	100 m	120 m	140 m	180 m	Total
Taxa:									
F. ebena	14	148	239	149	213	122	46	—	931
F. subrotunda	—	—	—	—	1	—	—	—	1
O. reflexa	25	18	24	2	7	6	5	13	100
Q. pustulosa	39	61	95	43	41	25	11	—	315
Q. metanevra	—	1	3	—	3	2	—	—	9
Q. quadrula	38	—	1	3	—	1	5	4	52
T. donaciformis	—	—	6	1	—	—	—	—	7
E. crassidens	11	18	86	69	69	100	33	—	386
E. dilatata	—	1	1	4	—	—	—	—	6
P. alata	21	2	—	—	2	5	9	3	42
E. lineolata	—	24	67	31	29	10	3	—	164
C. tuberculata	3	24	26	19	30	36	21	—	159
P. cordatum	—	15	20	9	25	24	4	—	97
P. pyramidatum	—	—	—	—	1	—	—	—	1
L. abrupta	—	—	1	4	—	12	1	—	18
L. ovata	1	—	—	—	—	4	1	1	7
A. confragosus	1	1	—	—	—	—	—	—	2
M. nervosa	13	2	6	—	—	—	—	—	21
A. plicata	23	2	8	8	—	2	1	—	44
L. recta	1	—	—	—	—	—	2	—	3
T. verrucosa	58	1	5	7	—	1	1	3	76
Area surveyed (m^2)	420	80	80	60	60	100	80	120	1000
No. of species	13	14	15	13	11	14	14	5	21
No. of specimens	248	318	588	349	421	350	143	24	2441
Average No./m^2	0.6	4.0	7.4	5.8	7.0	3.5	1.2	0.2	2.4

EVR.063

October 26, 1993

Terry Richardson
Biology Department
University of North Alabama
Florence, AL 35632-0001

Dear Terry:

I learned recently that you returned to your alma mater to hopefully fill the niche vacated by Paul Yokley. Dick Biggins sent me a copy of your progress report on the zebra invasion. We are particularly concerned in Virginia about the impact on native mussels. Your project on the Tennessee River will hopefully tell us what to expect here, and I'm pleased that someone is monitoring the mussel beds there.

Keep up the good work and please let me know the outcome of your study. We have retrieved "big river" mussels from the Cumberland River and are holding them in ponds, away from the zebra mussel threat. We have begun propagation studies and hope to use these animals as broodstock for culture experiments. My belief is that we will lose most of the big river species in the Tennessee River basin, so the creation of refugia is imperative.

Sincerely,

Dick Neves
Unit Leader

RJN/akb