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FRESH-WATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE)

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INTRODUCTION

Invertebrate animals have long fared poorly, even anonymously, before the bar. Only of late years has there been any legislation on their behalf. The present review is a response to an opportunity to complement the legislative effort. Determination (or even approximation) of the jeopardy of a dozen-odd mussels improves the legal posture of some South Carolina invertebrates, but also promises to strengthen a transcendent ecosystem.

Of the 17 taxa listed and discussed below, four (or 24%) are unequivocally threatened or endangered in South Carolina and beyond. For varying reasons, the balance are interpreted as of special concern in the State. The rationales behind these 13 determinations are unevenly satisfactory and form the bulk of this account.

Far more clear, on the other hand, are the reasons why fresh-water mussels deserve this calibre of consideration. There are more detailed treatments (e.g., Fuller, 1971, 1974c, 1976, 1977), but the central reason is that mussels, as filter feeders of great biomass under favorable conditions, cleanse waterways of prodigious quantities of suspended organic materials, both living and inert. They are, in a phrase, probably our best natural aquatic vacuum cleaners.

An historical and current account of these valuable animals in South Carolina is perhaps best organized according to the river basins of the State. Tiny streams of the Tennessee River drainage (Mississippi basin) and/or Apalachicola basin (eastern Gulf drainage) may arise in South Carolina, but no naiad species known to inhabit such waterways are considered jeopardized in this state. Fresh waters of

the State consist overwhelmingly (if not exclusively) of Atlantic drainage basins, whose members are readily apportioned for the purposes of this narrative.

The greatest river basin in South Carolina is the Santee-Cooper, which has been largely impounded and otherwise affected by man, especially in this century (Savage, 1968; Fuller, 1976; Hendrickson *et al.*, 1976). The wealth of naiad records for this basin (Johnson, 1970), but most of these have not been repeated during recent years. A characteristic naiad fauna seems to be establishing itself in the Santee-Cooper lakes, but, in the light of extant knowledge, commentary on the success or failure of relevant fresh-water mussels is premature.

The Savannah basin of Georgia and South Carolina is second to the Santee-Cooper, but it has received the greater environmental surveillance during recent years. Most of my knowledge of this basin's naiades depends upon data developed during biological surveys conducted by the Division of Limnology and Ecology at the Academy of Natural Sciences of Philadelphia on behalf of E. I. DuPont Co., which agent administers the Savannah River Plant on behalf of the federal Energy Research and Development Administration. My involvement in these surveys began in 1965 and has continued annually into the present. Thereto, several weeks in the company of W. J. Clench and K. J. Boss during the summer of 1961 were devoted to collecting mussels in Savannah tributaries on the Georgia side. Thus, though my experience of the Santee-Cooper basin is minor, it is more nearly authoritative for the Savannah, whose mussel fauna (see Fuller, 1971, 1974b, and Fuller and Bereza, 1975) is rather well understood. Fortunately, this understanding is ecological, as well as taxonomic; on it, in particular,

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habitats both are adjacent to bottomlands along two confluent Oconee County streams which are subject to stresses from agricultural activities. The beetle species *Lichnanthe vulpina* Hentz was once distributed from New England to South Carolina in association with streams and cranberry bogs. These bogs are frequently drained, which may account for the absence of any collections of this colorful insect in the southeastern states since the 1930's.

Very rare insects in South Carolina's waterways include at least 3 species of mayflies, 1 species of dragonfly, 2 species of stoneflies, and 24 species of caddisflies. At least 17 freshwater insect species are also recognized as peripheral in our state.

FRESHWATER INSECT SPECIES PROTECTION

Our knowledge of the native South Carolina freshwater insect fauna is still very limited. Unless protective measures are realized, we may never know much more about it because of extinctions, most often caused unwittingly by man's activities. The possibility of protecting particular species by means of the present federal and state endangered species acts is very poor because insects are so small and frequently go unnoticed and because the identification of most insect species, particularly rare ones, cannot be accomplished by the average layman. This leads to the ludicrous, frustrating likelihood that both the conscientious, law-abiding citizen and the law enforcement officer may be completely unaware that federal and state laws are being violated. Furthermore, most people do not empathize with the plight of insects in the same way as with birds and mammals. We should recognize the folly of losing

public support for the laws and the general environmental concern that they represent by the possibility of halting a badly needed structure or public works project for the sake of a single insect species, a species which perhaps may be positively identified by only a handful of people in the world.

It would be more appropriate, instead, to carefully select particular South Carolina watersheds with a wide variety of flow characteristics, at least partially document their faunal uniqueness to justify their selection, and then enforce protective, limited-use legislation. Natural, relatively undisturbed waterways with rich species diversity will thus provide refugia from which altered habitats may be repopulated. Through such legislation, the values of a diverse fauna discussed above will be realized and a significant proportion of our rare species will be saved for future generations.

The state's human population increases constantly and public and private economic demands continue to spread year by year. Consequently, we need to select and protect our most valuable natural watersheds *now* so that zoning of our resources into limited-use and multiple-use areas may be effected with a minimum of anguish and with a maximum of alternatives.

ACKNOWLEDGMENTS

Discussions with various members of the Committee on Arthropoda Other Than Crustacea contributed significantly toward the formation of various ideas expressed in this article. Dr. Jay Chapin, Dr. Harold Loyacano, and Dr. Richard Fox reviewed the manuscript and made useful recommendations. I am indebted to each of them.

are based the decisions to regard as endangered or threatened the four species so interpreted below.

As Speight (1976) has made clear, the entirety of the Savannah River at and above the Fall Line (near Augusta) is impounded with the exception of the Trotters Shoals reach—which, also, is threatened with impoundment. There are apparently no recent data on mussels of the upper basin, but they must be regarded as heavily impacted. Were Trotters Shoals to be lost as shoals, all that would be left of the original Savannah River naiad fauna would lie below Augusta, where for many miles water quality and the mussel fauna are impaired, in spite of recent years' improvements in treatment of affluent waters from the Augusta area. Lacking recent information about mussels from the federal highway 301 bridge to the sea, I am obliged to cite the vicinity of the Savannah River Plant (Aiken, Barnwell, and Allendale Counties) as the last *known* refugium of the mainstem river's naiades.

The remaining fauna, however, persists as a magnificent one, including some great rarities and, perhaps, unique populations. Indeed, the only recent records of three of the four species interpreted here as endangered or threatened are from the Savannah River Plant area, doubtless in part because the River, which serves as the ultimate receiving waters for the Plant, has suffered so little by this association. Ironically, as is somewhat exemplified in species accounts below, this enormous installation has proved to be something of a blessing in disguise to the surrounding ecosystem.

The same cannot be said of other, adverse games that are afoot. I refer especially to the notions that Augusta become an inland seaport and that the Savannah River be deepened as an access route. The attendant drawbacks would include petrochemical pollution all the way from the sea and deposition of dredged material in sloughs, which are prime mussel habitats in the Savannah River Plant area. Were these plans implemented, the two "only" threatened species (below) would surely become endangered.

Another "game afoot" is a more nearly "natural" one, the invasion of the Savannah basin by *Corbicula manilensis* (Philippi), the Asiatic Clam. This introduced exotic is believed to undermine mussels and thus to cast them loose into the current, which can cause death (Fuller and Richardson, 1977; see Imlay, 1972).

My third category of South Carolina streams consists of the Waccamaw basin. This narrow, short river system rises in Lake Waccamaw, southeastern

North Carolina, and roughly parallels the coast in the Carolinas until entering the Atlantic in Winyah Bay. Much of the lower Waccamaw River doubles as Intracoastal Waterway and is devoid of mussels (Fuller and Imlay, 1976), but the middle river supports some excellent populations, including the Nut Spike, a possibly undescribed species of *Elliptio* (Fuller, 1977). Until this animal's taxonomic validity is established and its geographic range is understood, it logically is not even of special concern to this symposium, but does deserve to be mentioned as an unresolved curiosity that may one day receive jeopardy status in South Carolina. Anything that this State can do in cooperation with North Carolina to preserve still largely unadulterated portions of the Waccamaw basin will be a great investment in its mussel fauna, much of which is considered endangered (Fuller, 1977).

My last category of South Carolina streams is the group whose mussel faunas are largely unexplored. These include the basins or sub-basins Pee Dee, Black, Sampit, Ashley, Edisto, Ashepoo, Combahee, Coosawhatchie, and New Johnson (1970) published records for some of them, but none has been adequately and recently surveyed. Here is a good example of an area of information where even the beginning investigator can make important additions to knowledge — provided, of course, that surveillance is thorough and that (see Fuller, 1971, 1972) samples are kept small and are properly preserved.

Constraints of time and space have kept this review shorter and less detailed than might have been advantageous to South Carolinians, but, as such, it should be regarded as a complement to the analagous document for North Carolina (Fuller, 1977), where more nearly exhaustive accounts (and illustrations) of some of the species in common can be found.

The present species accounts are designed to provide rather minimal, but essential information about geographic range, physical habitat and other aspects of ecological range, taxonomic problems and identification, previous interpretation in the rare and jeopardized species literature, and the present rationale for ascribing a given taxon to a given jeopardy category. These remarks are intended to be, not exhaustive, but useful for the purposes of this Symposium.

The literature upon which these species accounts are based is primarily taxonomic and to a lesser extent biogeographic, but there is a certain admixture of more nearly "pure" publications in natural history. Chief among the former is Johnson's (1970)

monograph, though its information has often been surpassed, as indicated below. Most of the textual references are concerned with taxonomic identification because recognition of species — group taxa is so necessary to proper dealing with jeopardized organisms, especially in the field, where the investigator, having secured an animal, must unequivocally identify the creature and, if unarmed with permits to the contrary, return it unharmed to its habitat in its normal orientation. A fairly wide variety of reference, if extant, has been cited in each case in order to increase one's opportunities for security at least a single reference with a good illustration of the shell of the mussel in question.

Some of these references deserve additional commentary. Ortmann's (1919) monograph on Pennsylvania naiades remains a classic of biology and illustration in spite of ineluctably changing nomenclature, whereas Clarke's (1973) monograph is taxonomically up to date and the single first overall treatment of Nearctic fresh-water malacology that exists. The monograph by Clench and Turner (1956), taxonomically somewhat outdated by Johnson's (1965, 1967, 1970, 1972) and other work (e.g., Fuller and Bereza, 1973, 1975), remains *the* work that rekindled interest in the naiads of the southeastern United States during recent years. Burch's (1973, 1975) manuals, especially the latter, are essentially up to date and are history's only fruitful attempts to cover the entirety of the nation's fresh-water mussel fauna.

Several relevant references warrant further comment. Atheam's (1970) list of taxa that are jeopardized in his opinion includes certain naiads considered in the present report. However, the Atheam list is not annotated, and no one other can now be sure of his reason(s) for citing this or that taxon as endangered or of whatever jeopardy rank. Consequently, Atheam's viewpoints, however valid they may prove to be, are rarely included in the species — accounts below.

The guidebook by Emerson and Jacobson (1976) is an ambitious (and in part pioneering) undertaking, but (at least) its section devoted to fresh-water mussels betrays the lack of a specialist's intervention before publication. Specifically, theirs is a cursory treatment, includes certain rarities, and omits some common species. The volume is of a sort that I wish I had had at hand when I was a youngster grappling for the smallest grasp at naiad nomenclature, but it poorly serves the modern public and professionals. In addition, the illustrations of fresh-water mussels in

this book are commonly of well oiled shells; these oleaginous representations are sometimes unfit for reliable taxonomic determination. Accordingly, I have referred to this work sparingly. Nevertheless, the Emerson and Jacobson work is unique within its geographic scope, and the uninitiate may depend upon it as an introduction to an otherwise completely bewildering array of nomenclature and species concepts.

Webb's (1942) *United States Mollusca* must be mentioned here as a largely forgotten manual, but a more or less generation — old and still useful classic. Many of Webb's illustrations and/or species — concepts are misleading or downright mistaken, but, as will be seen below, occasionally his guidebook is very helpful. Later generations may recognize this book as a minor classic, especially in virtue of Webb's sardonic wit: fond of advertising the riches of the Nearctic naiad fauna, he wrote that "Of one thing we may be very sure, the New Dealers had nothing to do with it whatever, and we can be very thankful for that."

Mazyck's (1913) classic *Catalog* provides numerous data on the geographical distributions of South Carolina fresh-water mussels, reviewed by Fuller (1978) in reference to the Coastal Zone. However, six decades and more have fled, and during that period there has been little concerted, organized effort to keep the Mazyck data current. The sad fact that this pioneer is never mentioned again in this report is chiefly a consequence of later workers' having failed to bear his wand. The dropped baton commonly ends the race, but this need not occur in the Palmetto State if we moderns promptly get about our business.

ACKNOWLEDGEMENTS

This report would not have reached its present degree of completeness; however, inadequate, without the aid of numerous persons. My predecessors in Savannah River studies, notably C. B. Wurtz and J. M. Bates, and present colleagues, especially R. R. Grant, Jr., and J. W. Richardson, have helped amass data extending back through the early fifties. Savannah River Plant staff, notably R. H. Harvey and E. W. Rabon and their associates, continue these efforts. D. J. Bereza, D. H. Stansbery, and K. E. Wright shared in their discoveries and observations. M. J. Imlay and J. D. Williams of the federal office of Endangered Species took part in a survey of the Waccamaw basin. F. W. Grimm, T. L. Laavy, and A. H. Shoemaker helped me arrive at decisions regarding

the animals discussed below. For their assistance in terms of time, energy, and information, these men deserve great thanks. For blunders, on the other hand, this reporter will shoulder the blame; however willingly though cheerlessly.

THE TAXA

Phylum Mollusca
Class Bivalvia
Subclass Palaeoheterodonta
Order Unionoida
Family Unionidae

- E *Fusconaia masoni* (Conrad), Atlantic Pigtoe
- E *Elliptio fraterna* (Lea), Brother Spike*
- OSC *E. waccamawensis* (Lea), Waccamaw Spike
- OSC *E. "lanceolata* (Lea)", Yellow Lance
- OSC *E. sp.* Fuller (1971, 1972, 1974b), Fat Spike*
- OSC *Lasmigona subviridis* (Conrad), Green Floater
- OSC *Alasmidonta varicosa* (Lamarck), Brook Floater
- T *A. triangulata* (Lea), Triangle Floater
- OSC *Anodonta couperiana* (Lea), Barrel Floater
- OSC *A. implicata* (Say), Alewife Floater
- OSC *Strophitus undulatus* (Say), Strange Floater*
- OSC "*Lampsilis*" *ochracea* (Say), Tidewater Mucket
- T *Carunculina pulla* (Conrad), Savannah Shore mussel
- OSC *Ligumia nasuta* (Say), Eastern Pond mussel
- OSC *Villosa constricta* (Conrad), Notch Rainbow
- OSC "*Lampsilis*" *radiata splendida* (Lea), Red Mucket*
- OSC *L. cariosa* (Say), Yellow Mucket

E = Endangered in South Carolina and the nation.

T = Threatened in South Carolina, but Endangered nationally.

OSC = Of Special Concern in South Carolina and nationally.

The suprafamilial classification in this tabulation is Newell's (1965). Use of a single family, Unionidae, for Nearctic fresh-water mussels (as opposed to the more complex Heard and Guckert (1971) system) reflects ongoing researches by George M. Davis, David J. Bereza, myself, and others at the Academy of Natural Sciences of Philadelphia. The phylogenetic order of the species and the questioning of certain traditional generic placements follow this chiefly unpublished work. Subfamilial and tribal designations, which are very meaningful among the Unionidae, are omitted because the studies by Davis *et al.* have not yet fully elucidated these relationships. Species concepts and nomenclature are those of Johnson (1970) and/or Fuller (1977). Vernacular ("common") names follow Fuller's (1974c, 1977) usage or, if marked by asterisk (*), are newly coined for this report.

ENDANGERED SPECIES

Only two animals have been ascribed to this category, for a different reason in each case.

Fusconaia masoni

The Atlantic Pigtoe is restricted to the Atlantic drainage, where it is known in four isolated populations from the Chowan basin in Virginia through the Ogeechee basin of Georgia (Fuller, 1974a). Historic populations are reasonably presumed for the Savannah basin (as *Pleurobema masoni* in Johnson, 1970), but none has been verified for many years, there or elsewhere in South Carolina, where this species may well be extinct. It favors small rivers and streams on beds of sand or muddy sand. A more detailed account occurs in Fuller (1977). Burch (1975), Fuller (1971, 1974a), and Johnson (1970) will aid in identification. This mussel is thought to be endangered in North Carolina (Fuller, 1977), and, as "*Fuscinia merris*", was designated as "rare and endangered" in South Carolina by The Nature Conservancy (1975).

Elliptio fraterna

The Brother Spike was first described in 1852, partly on the basis of Savannah River material, but it was apparently not until 1972 that additional specimens were secured there, near the Savannah River Plant in sandy shallows. Nothing further is

known of the biology of this species in the narrow sense of Fuller and Bereza (1975), who disagreed with Johnson (1970) and Heard (1975a) by not equating *E. fraterna* with *E. mcMichaeli*: Clench and Timer of the eastern Gulf drainage. This interpretation considers the true *E. fraterna* as of only the two rivers (and, presumably, their watersheds) from which it was originally recognized (Savannah and Chattahoochee). Heard (1975a) believed it extinct in the latter river*. These viewpoints continue to suggest that this Spike is among the rarest of Nearctic naiades and possibly extinct. Burch (1975), Fuller and Bereza (1975), and Johnson (1970) will aid in identification. Webb's (1942) figure is of no help.

THREATENED SPECIES

Only two species are ascribed to this category, also. Extant populations of each are apparently restricted to the Savannah basin. Paucity of the few published records of each suggests that these species have been naturally very rare during post-Columbian time. Recruitment in the Savannah River populations suggests that they are viable and that, in the absence of known activities that would seriously modify extant habitats, these two species are currently best interpreted as "only" threatened.

Alasmidonta triangulata

Once widespread in the southern Atlantic and eastern Gulf drainages, though apparently never common in post-Columbian time, the Triangle Floater was classed by Heard (1975a) as "rare throughout . . . entire range . . . in danger of extinction". The only known recent records of living material are based on specimens that I collected (1972 and 1976) in sloughs and guts along the Savannah River in the vicinity of the Savannah River Plant. Dr. Heard's assessment is accurate and a sound basis for considering this species nationally endangered, but, somewhat hesitantly, I suggest that in South Carolina it is "merely" threatened, because the known populations show reproduction and recruitment and because I am not satisfied that it has been adequately sought in the Savannah River. Should the notion of deepening the Savannah be

implemented, *A. triangulata* would doubtless be rationally considered endangered in the State**. The favored substrate is sand stabilized by an admixture of mud. Burch (1973, 1975), Fuller (1971), and Johnson (1970) serve as aids to identification.

Carunculina pulla

The argument in favor of considering the Savannah Shore mussel as threatened in South Carolina (though endangered nationally) is exactly that advanced for *Alasmidonta triangulata* (above). Already thought endangered in North Carolina (Fuller, 1977), this species is represented by only one known living population, that described by Bates (1966) as *C. patrickae* from the Savannah River Plant vicinity. This population continues to prosper. Its favored habitat is the same as the Triangle Floater's except that *CM pulla* will occur in the main Savannah River, as well as backwaters. Sources of identification include Bates (1966), Burch (1973, 1975), Emerson and Jacobson (1976), Fuller (1971), and Johnson (1970). The shell (as *C. parva*) was adequately represented by Webb (1942).

TAXA OF SPECIAL CONCERN

This category of possible jeopardy includes 13 species and subspecies that are characterized in South Carolina by rarity and/or limited geographical range, plus ignorance about them. The result is that to refer any of these taxa to a status other than "uncertain" is unwarranted, at least at this time.

On the other hand, members of this amalgam arrive here by various routes. Consequently, several groups within this jeopardy category are recognizable. The first (and by far the largest) consists of species that have been, and/or are being recorded from South Carolina — but these records demonstrate that these species are peripheral: in the State they near a terminus of their natural ranges.

It could, of course, be argued — and rather persuasively — that the historical record alone is a sufficient indication that many of these species should be regarded as endangered. Nevertheless, the Committee on Non-Marine Mollusks of this

*And had previously (1970) considered *E. mcMichaeli* as "rare and endangered" in Stansbery's (1971) terminology. The Nature Conservancy (1975) listed *E. fraterna* as "rare and endangered" in South Carolina

**Athearn (1970), for example, echoed by Stansbery (1971), has already listed the Triangle Floater as endangered, and Stansbery (1976) later considered it threatened in Alabama. The Nature Conservancy (1975) considered this species "rare and endangered" in South Carolina.

Symposium concluded that a jeopardy ranking more grave than the warning inherent in the category of special concern would be premature without thorough and recent information. The relevant information is placed at the reader's disposal in the remarks that follow.

GROUP I

Elliptio waccamawensis

The Waccamaw Spike is endemic to Lake Waccamaw in southeastern North Carolina at the head of the Waccamaw basin, most of which actually lies in South Carolina, where this species has not been discovered in spite of extensive searches for it (Fuller *et al.*, 1976). Stansbery (1971) had listed the Waccamaw Spike as "rare and endangered", and Fuller (1977) later considered *E. waccamawensis*, like most elements of the Lake Waccamaw molluscan fauna, as endangered in North Carolina, so, were this animal discovered in South Carolina, it should probably be considered identically jeopardized there, also. No larval host is known; this and other aspects of the Waccamaw Spike's biology were discussed by Fuller (1977), which reference and others (Johnson, 1970; Stansbery, 1971; Burch, 1973, 1975) will serve to identify the species unequivocally. The Waccamaw Spike inhabits sand and slightly muddy sand in Lake Waccamaw shallows.

Lasmigona subviridis

The Green Floater ranges extensively through the middle Atlantic drainage (Johnson, 1970), but published records are few, and the animal is only locally populous. Nevertheless, this species demonstrates unusual tolerance of sedimentation and other forms of environmental disturbance and is doubtless of special concern in South Carolina only because of the paucity of published records in the State. *L. subviridis* is characteristic of silted margins of larger waterways and may well have been widely overlooked in the State, especially because of its usually small size. Larval hosts are unknown, but the interested investigator might usefully be guided by the identities of hosts of the closely related *L. compressa* (Lea) of the Mississippi basin (tabulated by Fuller, 1974c, and Kakonge, 1972). Aids in identification of the Green Floater include Johnson (1970), Fuller (1971), and Burch (1973, 1975). Webb's (1942) figure of the shell is poor and misleading.

Alasmidonta varicosa

The Brook Floater is another, Atlantic drainage species that is on the periphery of its range in South Carolina. The character of its favored habitat (well oxygenated, fast-flowing, high-gradient, upland small streams) and the poverty of relevant published records suggest that this species might prove to be endangered in the State were additional information forthcoming. No larval hosts are known, but the experimentalist might find clues amongst the fishes tabulated by Fuller (1974c) for the closely related *A. marginata*, essentially of the Mississippi basin. Aids in identification of *A. varicosa* include Ortmann (1919), Johnson (1970), Burch (1973, 1975), Fuller (1971), and Clarke and Berg (1959).

Anodonta couperiana

The Barrel Floater has its metropolis in the eastern Gulf drainage and much of peninsular Florida. It is rarely encountered and usually not populous in the Atlantic drainage to the north. In South Carolina this species is surely on the periphery of its range. Like most of its congeners *A. couperiana* favors soft waterway bottoms in quiet areas. Because of continuing stream modification, this type of habitat is likely only to increase in South Carolina, so this species, despite its present apparent rarity, probably will not foreseeably require highly jeopardized status in the State. No larval hosts are known (see Fuller, 1974c), and none is even implicit as yet. Aids in identification of the Barrel Floater include Clench and Turner (1956), Johnson (1965, 1970, 1972), Fuller (1971), Burch (1973, 1975), and Emerson and Jacobson (1976). The role played by the Barrel Floater in the sexual vaguaries within the genus *Anodonta* — an undoubtedly important matter, but little understood — was considered by Heard (1975b).

Anodonta implicata

The Alewife Floater achieves its greatest development in New England and in Atlantic drainage basins immediately to the South. It had been thought not to occur below the Potomac basin (Johnson, 1970) until its recent discovery in North Carolina (*teste* R. M. Shelley in Fuller, 1977). This datum emphasizes the possibility that *A. implicata* may eventually be detected in the Palmetto State. If it were, immediate designation of jeopardy rank should await further information. In any case, unlike most of

its congeners, this species should be especially sought in stable (gravel or hardpack sand) substrates of tidewaters. The tidewater habitat reflects the fact that the dominant host for the larvae of this species in nature is the Alewife (Clupeidae), *Alosa pseudoharengus* (Johnson, 1946). Additional fishes were implicated experimentally by Davenport and Warmuth (1965), and further aspects of the biology of this unusual animal were discussed by Fuller (1977). Aids in the identification of the Alewife Floater include Johnson (1946, 1970), Burch (1973, 1975), Clarke and Berg (1959), Ortmann (1919), and Emerson and Jacobson (1976). Webb's (1942) figure of the shell is inadequate.

Stophitus undulatus

The pejorative expression Squawfoot (e.g., Coker, 1915) was long used as the vernacular epithet for *S. undulatus*. An alternative, Strange Floater, is employed in this paper. "Floater" reflects the ability of members of the genus *Anodonta* (see above) and their relatives actually to float in fine divided substrates (e.g., riverbed silt), and "strange" refers to the unique and wonderful packing of its contents in the marsupium (e.g., Ortmann, 1919). *S. undulatus* is yet another species that in South Carolina is at the southern terminus of its range in the Atlantic drainage and may thus be considered peripheral, as well as of special concern. The latter referral is deserved, not because of anticipation that this species will prove endangered or even threatened (I found occasional specimens in the Savannah River as recently as 1976), but because of the opportunities for research and education that are inherent in the Strange Floater's strange biology, briefly reviewed by Heard and Guckert (1971) and Fuller (1974c). The species exhibits cosmopolitan habitat tolerance with a preference for muddy sand in smaller streams and is often associated with submerged vascular vegetation. Aids to identification include Johnson (1970), Fuller (1971), Burch (1973, 1975), Ortmann (1919), Clarke and Berg (1959), and Emerson and Jacobson (1976). The shell figured by Webb (1942), as *S. rugosus* (Swainson), is atypical of Atlantic drainage populations and may not be a *Stophitus* at all.

"Lampsilis" ochracea

There are historical records of this species from South Carolina (Johnson, 1970), but no recent living

populations had been detected in the State prior to discoveries in the Waccamaw basin (Fuller *et al.*, 1976). The vernacular name (Tidewater Mucket) reflects this species' propensity for waterways (usually lakes and larger streams) near the sea and the parasitism of its glochidia on a probably anadromous fish (Fuller, 1971, 1977). Surveillance of the lower portions of South Carolina river basins might reveal that this Mucket does not deserve even special concern, but so disturbed have most of such environments become (Fuller, 1978) that it is likely that the species is jeopardized, even endangered, within the State. It is ironic that "*L. ochracea*", one of the earliest fresh-water mussels known in North America, remains biologically so poorly understood. No larval host has been identified, there is no correct genus for this species (its traditional placement in *Lampsilis* is erroneous), and it has commonly been confused with *L. cariosa* (discussed below). These matters were considered in detail and the animal was illustrated by Fuller (1977). Additional aids in identification include Burch (1973, 1975), Clarke and Berg (1959), Johnson (1970), Emerson and Jacobson (1976), Ortmann (1919), and Fuller (1971). Webb (1942) did not include "*L. ochracea*", and his figure of *L. cariosa*, being ambiguous, is of no help.

Ligumia nasuta

The Eastern Pond Mussel was long thought to occur no farther south in the Atlantic drainage than the Potomac basin in Maryland and Virginia (Johnson, 1970), but it has recently been verified in the Chowan basin in North Carolina (Fuller, 1977) and the Santee-Cooper basin in South Carolina (D. H. Stansbery, personal communication). *L. nasuta* has probably been widely confused with the conchologically similar *Elliptio lanceolata* (discussed below) and its relatives. This matter was considered and illustrated by Fuller (1977), and other aids to identification include Burch (1973, 1975), Clarke and Berg (1959), Johnson (1970), and Ortmann (1919). *The probability that this pond mussel will be encountered more often in South Carolina during informed surveillance suggests that it will not prove to deserve a jeopardy rank. Nevertheless, knowledge of this species' biology in the State is in its infancy. For example, it is far too early to describe its favored habitat except to recommend that tidewaters be searched (see "*Lampsilis*"

*Webb's (1942) figure is of a typical female shell.

ochracea, above). Similarly, no larval host is known for *L. nasuta*, but the interested investigator might be initially and usefully provoked by the identities of certain fishes, summarized by Fuller (1974c), that serve as hosts for the at least the nominally sibling species *L. subrostrata* (Say) of the Mississippi basin and western Gulf drainage. The ongoing researches of D. J. Bereza (personal communication) into the *Ligumia* complex strongly suggest that the South Carolina naturalist who gathers *L. nasuta* unto himself will make an important contribution.

Villosa constricta

There are historical records of the Notch Rainbow in the Santee-Cooper basin in South Carolina (Johnson, 1970), but none recent. This species may be endangered, even extinct, in the State, or, because of its small size and our general ignorance of mussel distribution in the middle Atlantic states, it may merely have been overlooked of late years. In any case, to assign *V. constricta* to a jeopardy rank in South Carolina is premature at this time. This species is an excellent exemplar of the great need for a careful naiad survey of the State. Knowledge of its biology is poor (see Fuller, 1977), but this Rainbow is easily recognized by referring to Johnson (1970) and Burch (1973, 1975). The optimal habitat of *V. constricta* is somewhat uncertain, but the animal appears to favor sandy streambeds, sometimes modified by admixture of mud, silt, detritus, etc. Apparently, stream size is of little moment to this species.

GROUP II

The second group of mussels of special concern consists of one or more legitimate taxa representing a taxonomically tangled complex of animals that is commonly encountered in the Carolinas. Obviously, it is possible that at least one of these taxa might prove to deserve a higher jeopardy rank in South Carolina, but this cannot be determined at present.

Elliptio "lanceolata"

Originally described from South Carolina coastal waters now in the joint (and largely impounded) Santee-Cooper basin, the Yellow Lance is the earliest recognized member of the "lanceolata-complex", which bears its name. The species undoubtedly no longer inhabits its type locality, which itself probably

no longer exists, either in its original guise or at all (see Fuller, 1978). Typical *E. lanceolata* is a yellowish shell (an unusual morph in this complex), which is rarely encountered and whose exact relationship to its relatives, possibly many, are not understood. The matter was illustrated and considered in greater detail by Fuller (1977), who, in addition, demonstrated how to distinguish these *Elliptio* from the conchologically similar *Ligumia nasuta* (discussed above).* Because of the chronological position of the taxon, there is little doubt that *E. lanceolata* is a valid species, but because presently it cannot be satisfactorily defined, assignment to any given jeopardy rank (as has been done in some other reports) is premature. It need hardly be added that nothing unequivocal about the biology of this animal can be added. Fortunately, isoenzyme analysis of populations of southeastern *Elliptio*, currently being conducted by G. M. Davis and myself, promises soon to subtract from this area of misunderstanding. Apparently employing a taxonomically restricted concept of the Yellow Lance, Stansbery (1971) had been first to accord it a jeopardy rank, but Heard (1975a) subsequently interpreted the species as belonging to his category "not rare and endangered, although at least once listed as so". A *lanceolata*-complex member, *E. angustata* (Lea), was thought "rare and endangered" in South Carolina by the Nature Conservancy (1975).

GROUP III

The third group of mussels of special concern includes two taxa that are locally plentiful, but have been encountered only sporadically in South Carolina during recent years. It is probable, however, that further study will show that neither deserves a higher jeopardy rank in the State.

"Lampsilis" radiata splendida

The Red Mucket belongs to a morphologically varied complex of mussels that is geographically more far flung than any other in the Nearctic region (see Clarke, 1973). Johnson's (1970) concept of a subspecies "*L. r. splendida*" within the complex may well prove valid. Taxonomic subdivision of the *radiata* — complex remains a bewildering challenge, and its correct generic placement is little less so. On

*(Johnson (1970) and Webb (1942) published competent figures of typical shells of the Yellow Lance.)

the strength of my experience of Atlantic drainage populations from Maine through Georgia, I have elsewhere (Fuller, 1977) queried whether this group should be referred to *Lampsilis* at all. Subsequent investigations in the western Gulf drainage and upper Mississippi basin have provided evidence that on its periphery this complex includes morphs that so closely approximate or exhibit the soft-tissue characters of true *Lampsilis* that my placing this nominal subspecies' genus in quotation marks for the purposes of this report may prove unwarranted.

In spite of these nomenclatural difficulties, the Red Mucket's place in the jeopardy context is somewhat more clear. I found this animal in the Wateree River in 1966, and K. E. Wright (personal communication) did so in Lake Marion in 1976. Both these records represent living populations from the Santee-Cooper basin. In addition, for the last decade and more I have found "*Lampsilis*" *radiata splendida* plentiful in the middle Savannah River. The small number of these recent records is the only reason for considering this taxon as of special concern, and the health of these populations is such that future surveillance of the South Carolina naiad fauna will probably obviate this Mucket's being a problem to this or later Symposia. The Red Mucket ranges north from the Altamaha basin of Georgia into an as yet indeterminate river system where it finally blends into "*L.*" *r. radiata* (Gmelin), the at least nominal subspecies of the northern Atlantic drainage. Johnson (1970) is the best source for identification, and Fuller's (1977) representation of the Waccamaw Mucket is informative. Webb's (1942) illustrations are of limited service. His figure of *L. radiata* is of an atypical, probably make shell, but his *L. splendida* is a good representation of "*L.*" *r. splendida* females in the Altamaha and Savannah basins. Among the biological curiosities surrounding this taxon is the rather high frequency in which it harbors the Mussel Leech, *Placobdella montifera* Moore, and/or its close relatives (see Curry and Vidrine, 1976; Fuller, 1974c; Klemm, 1977; and Sawyer and Shelly, 1976).

Lampsilis cariosa

Unlike the previous mussel, the Yellow Mucket is an unequivocal *Lampsilis*, and, like the Red Mucket, it is admitted to special concern because of few known populations in South Carolina. These are restricted to the middle Savannah River, where the species is plentiful, as it is in Clark Hill Lake (R. H. Harvey, personal communication), the impoundment just

above Augusta. This species' adaptability to the artificial lacustrine habitat suggests that not even the proposed impoundments farther upstream (see Squeight, 1976) should thwart it. Accordingly, it is reasonably anticipated that the Yellow Mucket will prove to be not in jeopardy in the State and that additional populations will be discovered in South Carolina basins other than the Savannah. *L. cariosa* tolerates a broad variety of habitats and favors stable sands and muddy sands in larger bodies of water, apparently with little regard for waves and current. Aids in identification include Burch (1973, 1975), Clarke and Berg (1959), Emerson and Jacobson (1976), Fuller (1971), Johnson (1970), and Ortmann (1919). Webb's (1942) figure of *L. cariosa* is vague. A closely related species, *L. dolabraeformis* (Lea), traditionally considered endemic to the Altamaha basin of Georgia, has been imputed to the Savannah River and considered "rare and endangered" in South Carolina (Nature Conservancy, 1975).

GROUP IV

The fourth and last group of mussels of special concern consists of a lone species that is very rare, but currently enjoys effective protection. Were that protection removed, however, this animal might at once experience great danger.

***Elliptio* sp. of Fuller (1971, 1972, 1974b)**

I discovered this species, as yet undescribed, during 1971 in Mill Creek, an upland tributary of Upper Three Runs Creek, a Savannah River confluent in Aiken County, South Carolina, and mistakenly referred it to Johnson's (1970) concept of *Elliptio icterina* (Conrad). These misconceptions (Fuller, 1971, 1972) were reversed in a later publication (Fuller, 1974b), but this species' place among its congeners remains as mysterious as its rarity is certain. Luckily, Mill Creek and the only known population of this *Elliptio* are confined to a remote portion of the Savannah River Plant of the Energy Research and Development Administration and are thus almost perfectly preserved from human intervention for the foreseeable future. In this sense, no fresh-water mussel in South Carolina is more safe. However, should the SRP watersheds pass from ERDA control, even to any governmental agency, this unique population could be in grave danger. The decision by a parks service to bridge Mill Creek for the

pleasure of the avocational terrestrial investigator could terminate the Fat Spike as we know it. The vernacular sobriquet reflects the breadth of this species' marsupium and the consequent subcylindrical aspect of its shell. Mill Creek is a small, shallow, sand-bottom, moderate-gradient stream; these data are the limit of the known habitat of this *Elliptio*. The only aid to identification of the Fat Spike is Fuller (1971), however unsatisfactory. The Nature Conservancy (1975) has considered this species (as "*Elliptio* ref. *icterina*") "rare and endangered" in South Carolina. This decision was based in large measure on my written testimony, whose emphasis has shifted slightly in the present report.

SUMMARY

Seventeen taxa are of concern to this report and to South Carolina. Two of these fresh-water mussels are thought endangered in the State and the nation; two, threatened in the State and endangered nationally; and the balance of 13, of special concern. Novel vernacular names are introduced for some of them.

Cited causes of jeopardy and concern are municipal (including industrial and probably some agrarian) wastes, habitat destruction and alteration (largely by impoundment), and the impact of the Asiatic Clam. Their roles are most clear in the Savannah River, whose basin furnishes most of the data for this report. Others in South Carolina are far less well known, and all require much additional study before the State's naiad fauna can be considered adequately understood, ecologically and before the bar. Furtherance of such surveillance offers even the inexperienced investigator plentiful opportunity for adding valuably to knowledge and ultimately to overall environmental quality.

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ABUNDANCE, DISTRIBUTION, AND STATUS OF THE FISHES OF THE CAROLINA SANDHILLS NATIONAL WILDLIFE REFUGE, CHESTERFIELD COUNTY, SOUTH CAROLINA

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INTRODUCTION

The Bureau of Sport Fisheries and Wildlife has established more than 300 national wildlife refuges for management of waterfowl, large mammals, and certain endangered species. Carolina Sandhills National Wildlife Refuge was established in 1939 as a wildlife demonstration area (USDI, Fish and Wildlife Service 1968). All management practices and developments are designed to improve wildlife habitat, with emphasis placed on increasing the value of the refuge to waterfowl. Although the major emphasis of the refuge has been protection and management of birds and mammals, it also serves as a sanctuary for many other forms of life, including aquatic biota.

Very little information is available concerning the fishes of the sandhills region in South Carolina, and no detailed studies have been conducted previously on the refuge. Welsh (1916) reported on fishes collected during a canoe journey in the Lumber, Pee Dee, and Waccamaw drainages from Pinebluff, North Carolina to Georgetown, South Carolina, and Carolina Power and Light (1976) has surveyed the fishes of Lake Robinson and Black Creek south of the refuge. This study was initiated to provide distributional data on fishes of the sandhills region and to formulate management recommendations for protecting threatened species of economic or ecological interest on the refuge.

DESCRIPTION OF THE STUDY AREA

The Carolina Sandhills National Wildlife Refuge consists of 46,000 acres (18,600 ha) in a wide band of sandhills along the fall line between the Coastal Plain and Piedmont Plateau in Chesterfield County, South Carolina. Elevation ranges from 250 to 500 feet (75 to 150 m) above sea level. The soil is predominantly sand with occasional red clay outcroppings. Before 1939, most of the land was cleared or burned over, but it is now predominantly pine and scrub oak forest with scattered areas cultivated for wildlife management.

The eastern portion of the refuge drains into Black Creek and its tributaries (Fig. 1). The water is clear but stained brown or black due to organic acids. The larger creeks have steep banks, deep channels, and moderate flows. Aquatic macrophytes are generally abundant and submerged trees and debris are common. The banks are heavily vegetated and briar thickets abound. Tributary streams are similar except they are usually shallower and flows are swifter. Many small impoundments have been constructed on the tributaries. The impoundments have clear dark water and support extensive beds of macrophytes.

The western portion of the refuge drains into the Lynches River and its tributaries. Tributaries of the Lynches River are similar to those of Black Creek except they are swifter. The Lynches River originates