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## GAS PRESIDENT'S COMMENTS AND REPORT FROM THE ACADEMY COUNCIL

Happy New Year! I hope all of your resolutions come true! Speaking of New Year's resolutions, I would like to state a couple of my Academy-related resolutions. Not to sound like a broken record, but we still need to focus our attention on membership numbers. The good news is that they are on the rise. However, I would love to see the rising trend continue. So, please continue sharing the concept of GAS with your colleagues & of course, your students. If you need some help, send these folks to the web site or a Council member for some great information.

We also need to put some thought into who will be replacing outgoing Council members. An especially urgent need is to replace Hubert as Treasurer (I thought this was a lifetime position!). Seriously, if you know of anyone that would be even remotely interested, please contact a Council member as soon as possible. Hubert has graciously offered to train & support the new Treasurer so that the transition is a smooth one for all involved. Of course, there are other positions available, so please don't be shy.

The Council is also planning the next annual meeting, which will be hosted by Gordon College on April 1-2, 2005. We are very excited about this year's line-up & hope you will plan on attending & will consider submitting a paper for presentation. Consider bringing students, as well! The Academy is allowed to invite the Saturday speaker to the meeting & we have a small amount of funding for an honorarium. If you know the name & contact information of an impressive local speaker, please let me know as soon as possible. To date, we have a couple of suggestions, but no firm commitments as of yet.

As usual, if you have ideas of projects that the council needs to address, I would like for you to contact me either by e-mail or by phone. My contact information has recently changed again, so please be sure to check out the Academy web site for updates. My new e-mail address is cinstokes@aol.com. I hope to see and/or hear from you soon! Have a wonderful 2005!

Cynthia S. Mayer, President



## NEWS FROM A.I.B.S.

From the American Institute of Biological Sciences (AIBS) Public Policy Report, January 18, 2005. All material from these reports for January, 2005 may be reproduced or forwarded. Go to http://www.aibs.org/.

### COURT: DISCLAIMERS MUST COME OUT OF COBB COUNTY TEXTBOOKS, BUT…

On 13 January 2005, United States District Judge Clarence Cooper issued a 44 page ruling in the case of Selman et al versus Cobb County School Board. Briefly, the case was brought by parents that objected to the Cobb County School Board's decision to place anti-evolution stickers in textbooks. In essence, the parents argued that the stickers are a violation of the U.S. Constitution's Establishment Clause, which prevents the government from intruding on religion. Judge Cooper's ruling found that the school board's actions are unconstitutional and ordered that: "1. Defendants shall immediately remove the Sticker from all science textbooks into which the Sticker has been placed 2.Defendants are permanently enjoined from disseminating the Sticker in any form." Finally, the Defendants were also ordered to pay plaintiff's court costs. According to an 18 January 2005 report in the Atlanta Journal Constitution, it seems that the Cobb County School Board has not yet enjoyed enough time in the national spotlight. Following Judge Cooper's ruling, the board met with its lawyer and promptly voted 4-2 to pursue an appeal of the federal court's ruling. Reportedly, the board members feel the court overstepped its bounds by ruling on a local school control issue. The board's attorney, who has pledged to pursue the appeal at no additional cost to the district, plans to file a motion on 18 January 2005, seeking a stay of the order to remove the stickers.

### IN THE STATES: EVOLUTION EDUCATION RELATED LEGISLATION SURFACES ACROSS THE COUNTRY

In January, members of state legislatures returned to their capitols and began introducing legislation that reflects their policy priorities. Not surprisingly given the increased public profile of evolution education, legislators in many states have introduced measures that would require disclaimers be placed in textbooks, require that intelligent design/creationism be taught along side evolution, or requiring that science teachers 'teach the controversy.' Before providing an update on some of the anti-evolution legislation, it is interesting to note that a Montana State Senator from Helena introduced a resolution that, if passed, would communicate to local school districts that there is a separation of church and state clause in the Constitution and that school districts should teach students only sound science. Not to be outdone, a newly elected member of the Montana House, State Representative Roger Koopman (R-Bozeman), announced his intent to introduce legislation (LC 1199) that would allow schools to teach intelligent design/creationism.

Back in Georgia, where a federal judge recently ruled that Cobb County's textbook disclaimers are unconstitutional, a member of the Georgia House of Representatives introduced House Bill 179. This legislation would require that "Whenever any theory of the origin of human beings or other living things is included in a course of study," evidence against evolution would also be included. When the Speaker of the Republican-controlled state House was asked about the measure, he simply noted that any member of the caucus can introduce any legislation they like. Georgia Citizens for Science Education and other organizations that support a strong K-12 science curriculum are not taking the measure lightly. Staying in the south, legislation introduced in the Mississippi State Senate (SB 2286) would require that classic creationism be taught in schools where evolution is taught. The South Carolina Senate will again be able to consider legislation (S 114) designed to provide anti-evolutionists with control over how textbooks dealing with evolution are approved and adopted by school districts. A similar measure was introduced in the last session.

Policy threats to a sound science education are not limited to southern states. As has been previously reported, Grantsburg, Wisconsin spent most of 2004 flirting with ways to introduce intelligent design/creationism into the science curriculum. Following a prolonged process in which local parents, educators, and university faculty and members of the clergy from across the state expressed strong opposition to the district's plans, in December 2004 the board adopted a resolution stating: "Students are expected to analyze, review, and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information. Students shall be able to explain the scientific strengths and weaknesses of evolutionary theory. This policy does not call for the teaching of creationism or intelligent design." While the policy is an improvement over earlier iterations, science education advocates remain concerned that evolution is the only area of science listed in the statement. Local evolution education supporters have pledged to remain vigilant.

The challenges in Dover, Pennsylvania are far from over. Following the school board's decision to approve the teaching of intelligent design/creationism, local parents in conjunction with national organizations filed a lawsuit against the school district. Meanwhile, the school district prepared a four-paragraph long disclaimer statement that high school biology teachers were to read to their classes prior to beginning a unit on evolution. In short, citing their obligation under the state's Code of Professional Conduct and their professional and "solemn responsibility to teach the truth" the district's biology teachers sent a letter to their administrators refusing to read the disclaimer statement. The statement was, however, read before each class by a school administrator.



**NEW IN BIOSCIENCE: "ENVIRONMENTAL SCIENCE SACRIFICED IN LATEST US BUDGET"**

The January 2005 Washington Watch column in BioScience explores how research funding for key environmental biology programs was cut in final FY 2005 spending bill passed by Congress. "In early December, President George Bush told Canadians that by 'relying on sound science and mutual goodwill, we can resolve issues.' One week later, he signed a budget for fiscal year 2005 that slashes funding for the federal programs providing the bulk of scientific knowledge on our environment. Together, the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) account for 52 percent of all federal spending on environmental science. NSF and NASA's environmental science programs were cut by more than $200 million in the most recent budget."

You may continue reading this article for free at:
http://www.aibs.org/washington-watch/washington_watch_2005_01.html

## ANNOUNCEMENT

### A Field Guide to GenBank and NCBI Molecular Biology Resources
### Thursday & Friday, October 27-28, 2005

Mercer University School of Medicine will be hosting a free training course for life sciences educators, scientists and researchers interested in searching molecular sequence databases. Instructors from the National Center for Biotechnology Information at the National Library of Medicine will be in Macon to teach "A Field Guide to GenBank and NCBI Molecular Biology Resources." The course consists of a three-hour lecture the morning of Thursday, October 27, and a two-hour computer workshop. Out-of-town attendees will be given priority for the hands-on sessions that afternoon while local participants may be scheduled for a session the next morning, Friday, October 28. Training is designed for educators, principal investigators, postdoctoral fellows, graduate and advanced undergraduate students, and others in the life sciences who work with biological sequence data. Additional information is available at: http://www.ncbi.nlm.nih.gov/Class/FieldGuide/FieldGuide.html.

Training is free, but pre-registration is required. Registration materials will be mailed in late summer, and posted on Mercer's Website. To be sure you receive notification and additional information, please send your name & address to:

Jan LaBeause, MLS, AHIP, Director
Medical Library & Peyton T. Anderson Learning Resources Center
Mercer University School of Medicine
1550 College St.
Macon, GA 31207-0001
Phone: 478-301-2519
Fax: 478-301-2051
Email: labeause_j@mercer.edu



Gordon College
UNIVERSITY SYSTEM OF GEORGIA


### 82nd Annual Meeting
### Georgia Academy of Science
Friday and Saturday, April 1 and 2, 2005
Gordon College
419 College Drive, Barnesville, Georgia

Gordon College, located in Barnesville, GA, is approximately 55 miles south of Atlanta and 35 miles northwest of Macon. Gordon is a two-year, residential college in the University System of Georgia with a deep and rich history. Founded as Male and Female Seminary in 1852, this was a pioneer school of its kind in Georgia. It was reorganized in 1872 as Gordon Institute, named for General John B. Gordon, famed Confederate soldier, Governor and Senator, who was a friend of Charles E. Lambdin, its first president. In 1927 this school became Gordon Military College, an accredited, non-sectarian, two-year college. Graduates have won distinction in many fields of endeavor.

With an enrollment of over 3,400 students and a student-to-teacher ratio of less than 25:1, students have excellent opportunities to become campus leaders. Gordon boasts solid academic programs in more than 60 programs of study, and all of the core curriculum classes are transferable to any of the schools in the University System of Georgia.

Lodging: Blocks of motel rooms have been reserved at the Country Hearth and the Sun Inn. Please make your reservations by Mar. 5.

| Local Motel List | 12 Miles Distant |
|---|---|
| Country Court Motel<br>2105 S Hwy 341<br>Barnesville, GA 30204<br>770-358-0487 | Super 8 Motel<br>436 Tift College Dr, Forsyth, GA 31029<br>478-994-5101 |
| Country Hearth Inn<br>648 S Hwy 341<br>Barnesville, GA 30204<br>770-358-0967 | Holiday Inn<br>480 Holiday Circle, Forsyth, GA 31029<br>478-994-5691 |
| Sun Inn<br>878 S Hwy 341<br>Barnesville, GA 30204<br>770-358-1700 | Hampton Inn<br>520 Holiday Circle, Forsyth, GA 31029<br>478-994-4757 |

**Papers:** Oral talks should be 12 minutes; the other 3 minutes are for questions and set-up. All rooms will have a computer, a computer projection device, an overhead projector and a slide projector; speakers need to bring their own slide carousels. All power point talks must be on a CD that should be loaded in the break times before the paper sessions. Microsoft PowerPoint 2003 will be available. Speakers must not use their own computers for presentations.

**Posters:** Posters must be mounted on pressboard or some other suitable material. Easels will be provided, or you may bring yours if you prefer.

**Registration:** A registration form follows.

**Questions?** These people can help.

| | | |
|---|---|---|
| Patti Lowery | Registration | 770-358-5126<br>pattil@gdn.edu |
| Richard Schmude, Jr. | All other matters | 770-358-0728<br>Schmude@gdn.edu |



**GEORGIA ACADEMY OF SCIENCE**
**PRE-REGISTRATION FOR THE 82ND ANNUAL MEETING**
**APRIL 1-2, 2005, GORDON COLLEGE**

Name: _____

MailingAddress: _____

Institution: _____ Section: _____

Phone: _____ Electronic mail: _____

| Pre-registration Fees: (includes food on Friday & Saturday) | | Amount enclosed |
|---|---|---|
| Non-members | | |
| Faculty (with 2005 membership)* | $95.00 | _____ |
| Student (with 2005 membership)* | $35.00 | _____ |
| Members | | |
| Faculty | $60.00 | _____ |
| Student | $30.00 | _____ |
| Late fee (postmarked on March 12 or later) | $10.00 | _____ |
| Donation to support Student Award | | _____ |
| Extra Meals (guests) | $18 per person | _____ |
| | TOTAL: | _____ |

* If paying for a 2005 membership, indicate whether renewal:____ or new membership:____
If it is a new membership, give member sponsor's (if any) name: _____

I will definitely attend: The Friday evening reception _____ the Saturday lunch _____

Check here if you require vegetarian meals. _____

* * * * * * * **CREDIT CARD INFORMATION** * * * * * * *

Name of cardholder: _____ Expiration date: _____

Billing address of cardholder: _____

Signature: _____

Card Number: _____ Visa_____MC_____

If paying by check, please make checks payable to Gordon College. Send this form with payment to: Patti Lowery, Dept. of Comm. Ed., Gordon College, 419 College Dr., Barnesville, GA 30204.

# AN EVALUATION OF THE UNIVERSITY OF FLORIDA 2003 ENVIRONMENTAL HEALTH PARTNERSHIP WORKSHOP

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## ABSTRACT

This study consisted of quantitative and qualitative methodologies to evaluate an Environmental Health Partnership (EHP) workshop for high school science teachers. A pre-test was given prior to the start of the workshop and a post-test was administered at the end. Teachers were asked to respond to questions on a written evaluation form in accordance to the goals of the workshop as a qualitative method of program evaluation. The study sample consisted of 18 teachers from Florida. There were 12 females and six males. All 18 teachers showed increases in their knowledge of superfund and environmental health issues. A majority of the teachers (a total of 13) were impressed with the program, had positive comments, and felt that the goals of the workshop were met. Only five teachers had suggestions for program improvement and felt that the goals of the workshop were not completely met. Overall, the 2003 Environmental Health Partnership workshop was successful.

***Key words:*** environmental education, teacher workshop, evaluation, Environmental Health Partnership (EHP), Environmental Protection Agency (EPA), National Institute of Environmental Health Services (NIEHS), Superfund.

## INTRODUCTION

The Environmental Health Partnership program is a national effort funded by the National Institute of Environmental Heath Sciences (NIEHS). The EPA Superfund Basic Research Program was designed to compliment the existing work by the United States Environmental Protection Agency in the effort to clean up hazardous sites. The Environmental Health Partnership takes place during June of each year. Outstanding science teachers are selected from across the state to partake in an intensive one-week residential program. These teachers are chosen based on having at least three years of science teaching experience, a letter of recommendation from a school administrator, the willingness to prepare and implement an action plan involving their school and community, and being from a county that has a Superfund site.



During this one intensive week in residence, the teachers work with researchers to analyze alligator eggs from contaminated sites (Ecotoxicology Project), use Western blots to identify the biomarker vitellogenin in minnows exposed to estrogen (Molecular Biomarkers Project), test the bioavailability of heavy metals (Environmental Engineering Project), observe toxin-induced damage in human tissue (HistoPathology Core), and sample local spring and runoff waters for contamination. In addition to laboratory and fieldwork, the teachers attend lectures on human and ecological risk assessment, Superfund site cleanup, waste management, and careers in public health and environmental sciences. A typical day would involve breakfast followed by a lecture, a tour of lab facilities, or maybe an activity, then lunch followed by another lecture, tour, or activity, then dinner followed by another lecture, tour, activity, or curriculum discussions.

## DESCRIPTION OF PROJECT ACTIVITIES

The following was taken from the University of Florida Center for Precollegiate Education and Training website 2003:

### *Sunday, June 15*

**Overview**

Dr. Mary Jo Koroly gave an overview of the week as well as some of the other UF CPET programs. Dr. Steve Roberts presented a lecture on the Superfund Basic Research Program (SBRP) at UF.

### *Monday, June 16*

**Risk Assessment**

Dr. Steve Roberts and Dr. Hugo Ochoa, both faculty at UF, presented material on Human and Ecological Risk Assessment. Dr. Aaron Hilliard, from the Florida Department of Environmental Protection, gave a 'front line' look at the cleanup of Superfund sites and the testing of areas around Jacksonville for contaminants such as lead.

**Blackworm lab**

Using *Lumbriculus variegatus,* (California blackworms) the participants performed an experiment they can use in their classrooms to introduce toxicology. The blackworms were exposed to various concentrations of different toxicants and the results were recorded and shared with the group.

**Ecotoxicology**

Dr. Gross with the USGS and UF Fisheries gave an overview of the Ecotoxicology Program, part of the SBRP. The teachers rotated through laboratories and had 'hands on' opportunities to work with mussels, fish, alligators, and alligator eggs.

**Best practice sharing**

The teachers started Best Practice Sharing sessions in which each teacher presented a novel or successful classroom activity or approach.

***Tuesday, June 17***

**Environmental Field Day**

Mr. Steve Everett, an Environmental Science teacher and Summer Program Assistant with UF CPET, led the teachers through North Central Florida's water, from a creek, to a sink, to a spring. The teachers collected water, soil, and benthic samples at each location.

**Water and Soil Testing**

Dr. Charles Lawrence, a CPET instructor, presented the teachers with an environmental classroom projects manual and CD-ROM he developed, and demonstrated some of the experiments so they could easily be reproduced at the schools. Using the samples they gathered during the day, the teachers were able to perform the experiments themselves. Ms. Leslie Leader, coordinator of the Alachua County Watershed Action Volunteers, helped the teachers with the identification of the macroinvertebrates they collected during the day.

***Wednesday, June 18***

**Vitellogenin Laboratory**

The teachers performed part one of a two-day experiment in biotechnology. Dr. Nancy Denslow's laboratory staff and students led an experiment utilizing vitellogenin as a biomarker in Fat Head Minnows exposed to estrogenic compounds. Dr. Denslow's graduate students presented research related to the experiment in short lectures and the undergraduate students discussed the concepts and techniques the teachers were learning.

***Thursday, June 19***

**Vitellogenin Laboratory**

The teachers attended Dr. Sheldon Schuster's lecture *Biotechnology and Gene Therapy* in conjunction with SSTP. The teachers completed the vitellogenin experiment by developing their Western blots and Comassie stained gels. Dr. Nancy Szabo presented a lecture about her research at the Analytical Toxicology Core Laboratory (ATCL) and the services the ATCL provides other scientists. Dr. Margaret James also spoke about the bioavailability of superfund chemicals and the research she is leading as part of the UF SBRP.

**Bioremediation and Environmental Engineering**

Dr. Angela Lindner and her graduate students introduced the teachers to bioremediation. The participants rotated through four lab stations, performing experiments they can use in their classrooms.



**Project WET; Best practice sharing**

Ms. Eileen Tramontana from St. John's River Water Management District demonstrated activities the teachers can do in their classrooms utilizing the Florida Project WET manual. The teachers completed the Best Practice Sharing sessions.

***Friday, June 20***

**Laboratory Rotations**

The teachers participated in laboratory rotations through Urban Development and Wildlife Conservation with Dr. Mark Hostetler, Pathobiology with Dr. Dan Brown, Wildlife Forensics with Ms. Ginger Clark, Analytical Toxicology Core with Dr. Nancy Szabo, and Histology/Pathology with Dr. Holly Kolenda-Roberts. Three groups of 6-7 teachers spent two hours at each laboratory, engaged in 'hands-on' and 'mind-on' research activities. They were also presented with different career-related applications of the research programs.

***Saturday, June 21***

**Action Plans**

The teachers presented the Action Plans that they will implement in their classrooms. The results of their action plans will be presented to the SBRP scientists, students and teachers from across the state at the Florida Junior Science, Engineering, and Humanities Symposium (JSEHS), hosted by UF CPET in February at UF. The participants also enjoyed a light lunch while visiting the UF CPET laboratory to view some of the classroom experiments in their manuals prepared by Dr. Lawrence." (1)

The teachers also receive many novel teaching materials to take back to their classrooms including a Manual of Laboratory Experiments in Environmental Pollution, Bioassy and Bioremediation, a Schema of the Superfund Program, tutorials on the Floridian Aquifer System, the Geology of Florida and its Ground Water, and a Field Manual on Water Quality and Biodiversity along with numerous CD-ROMs. Teachers created an "Action Plan" that describes a means to translate and transfer the Superfund/EHP experience to their classroom, school, and community. The teachers return to UF in February to share the results of their "Action Plans" at the Florida Junior Science Engineering and Humanities Symposium (JSEHS).

## EVALUATION MODEL

The evaluation of an educational program is important because it establishes the worth or value of the program (2). Evaluation and communication of results to stakeholders are keys to the success of any program (3). Stake's (4) Countenance Model provided the basis for the EHP evaluation because it focuses on describing and making judgments about a program.

Stake (4) provided a framework for evaluators to collect, organize, and interpret both qualitative and quantitative data. His model separates

descriptive from judgmental activities and determines whether they occur as antecedents (are prior evaluation conditions), transactions (occur during the implementation of the educational program), or outcomes (the results of the program). In Stake's (4) model, descriptive activities are subdivided into intended and observed. Judgmental activities are subdivided into standards used to make judgments and the actual judgments about the educational program being evaluated. Stake (4) recommended that evaluators study the relationships among program antecedents, transactions, and outcomes. His model is extremely useful for educational program evaluation. It provides broad insights regarding the successes and shortcomings of programs because it investigates links among all aspects of a program (5). The Stake model also helps researchers determine whether teaching and learning processes are followed as prescribed by guidelines or other standards (6).

Antecedents investigated included the demographic characteristics of the teachers involved and their score on the pretest. The transactions investigated included the teachers' comments about the day-to-day activities of the program, and the outcomes investigated in this study focused on the posttest scores of the teachers. Stake's (4) Countenance Model is a theoretical model and thus, there is no reliability data.

## METHODS

A quantitative pre-test was given to the teachers prior to the start of the Environmental Health Partnership (EHP) workshop (Sunday June 15, 2003) and a quantative and qualitative post-test was administered at the end (Saturday June 21, 2003). The number of questions each teacher answered correctly on the pre-test was compared to the number of questions each teacher answered correctly on the post-test to provide a means of quantitative evaluation. Teachers were also asked to respond to questions on a written evaluation form as a qualitative method of program evaluation. The qualitative evaluation was written based on the following stated goals of the EHP workshop.

The short-term goals of the Teacher/Research Public Health Partnership are to:

1. Give the teachers a feel for what environmental health science UF is doing
2. Provide information on various aspects of environmental health problems
3. Assist the teachers in developing enhanced programs for their schools
4. Establish lasting partnerships

The long-term goals of the Teacher/Research Public Health Partnership are to ensure that:

5. Southeastern Region high school teachers will be able to integrate current interdisciplinary research in Toxicology and Public Health in their home institutions to train students in the sciences, community health, preventive health, and/or allied health professionals in the health sciences.
6. The teachers will be able to interact with researchers engaged in NIEHS Superfund research.
7. The teachers will be able to explain the impact of the environment on the health of all Americans through methods that reflect the importance and role of contaminants in specific environments.
8. The teachers will be able to develop research resources, teaching strategies and community and public health agency collaborations to inform students, their families and communities about the toxicological effects in their communities.
9. The teachers will be able to collect data, participate in an environmental field study, use tools for environmental science analyses, and obtain instructional materials and community resource development strategies to use in their home institutions.
10. The teachers will be able to engage students and communities across the Southeastern Region in an exciting, interdisciplinary intervention in public health status by informing them of the state, local and community health issues, providing them with sufficient scientific knowledge to assess their community's health needs, devise strategies for prevention, education and amelioration of environmental hazard.
11. Teachers will be able to develop and assess continuing partnership goals and action at the Superfund regional meetings.



## STUDY SAMPLE

The study sample consisted of 18 teachers from all over Florida. There were 12 females and six males chosen based on having at least three years of science teaching experience, a letter of recommendation from a school administrator, the willingness to prepare and implement an action plan involving their school and community, and being from a county that has a Superfund site.

Seven teachers reported living in suburban areas, another seven in rural areas, and four in cities. A majority of the teachers were White (a total of 16) and two were Latin. They had a variety of educational backgrounds with the majority having a master's degree (a total of 11), five with a bachelor's degree, one with an educational specialist degree, and one with a doctorate. Combined, these teachers had over 135 years of teaching experience. Eight had over 12 years of teaching experience while seven had three to five years, two had nine to 11 years, and one had zero to two years.

## RESULTS

The results of the pre/post test indicate that all of the teachers gained knowledge from the EHP workshop. All 18 of the teachers did not perform well on the pretest, but dramatically increased their score on the posttest.

Therefore, the EHP workshop was successfully in increasing the teachers' knowledge of Superfund and environmental health topics, such as: risk assessment, bioremediation, biological oxygen demand, groundwater flow, biomarkers, estrogen mimics, and western blot and gas chromatography analyses.

The results of the written evaluations are discussed as they relate to each of the goals for the EHP workshop. For the first four evaluation questions, all 18 of the teachers felt that as a result of attending the EHP workshop, they now have an idea of what type of environmental health science research the University of Florida is doing, felt that the workshop provided them with information on various aspects of environmental health problems, and helped them to develop enhanced programs for their schools. In addition, all of the teachers agreed that they have begun to establish lasting partnerships with the EHP faculty.

A majority of the teachers (a total of 12) stated that they will be able to integrate current interdisciplinary research in Toxicology and Public Health in their home institutions to train students. One teacher responded concerning integration, "Some. I have limited background in biology. Definitely in my classroom tied to hydrology." Five did not respond to this question.

For the areas of community health, preventative health, and health sciences, teachers felt less comfortable with their ability to integrate current interdisciplinary research in Toxicology and Public Health in their home institutions to train students. A majority of the teachers (a total of 10) responded positively. One expressed concern in his/her ability to integrate the above topics in their schools. Seven did not respond.

A majority of the teachers (a total of 16) declared that they were able to interact with researchers engaged in NIEHS Superfund research, while two opined that their interaction with these researchers is limited. All of the teachers agreed that they will be able to explain the impact of the environment on the health of all Americans to their students in ways that reflect the importance and role of contaminants in specific environments.

A majority of the teachers (a total of 13) agreed that they will be able to develop research resources, while one disagreed, and four did not respond. All of the teachers who answered this question (a total of 14) said they will be able to develop teaching strategies.

A majority of the teachers (a total of 15) stated that they will be able to develop community and public health agency collaborations to inform students, their families and communities about toxicological effects in their community. One disagreed and two did not respond.

Fourteen teachers stated that they were able to collect data, participate in an environmental field study. Fifteen explained that they were able to use scientific tools for environmental science analyses.

Twelve teachers responded by saying that they were able to obtain instructional materials and community resource development strategies to use in their home institutions. Twelve of the teachers said yes, two no, one limited, and three gave no response to how they feel about their ability to engage students and communities in their area in an exciting, interdisciplinary intervention in public health status.



Fifteen teachers responded positively to their ability to engage students and communities across the Southeastern Region in an exciting, interdisciplinary intervention in public health status by informing them of the state, local and community health isues and providing them with sufficient scientific knowledge to asses their community's health needs. Seventeen of the teachers responded yes that they would be able to devise strategies for prevention, education and amelioration of environmental hazards. Twelve teachers responded in a positive manner, while four responded in a negative manner about their ability to develop and assess continuing partnership goals and action at the Superfund regional meetings.

## CONCLUSIONS

All 18 of the teachers felt that as a result of attending the EHP workshop, they now have an idea of what type of environmental health science research the University of Florida is doing, felt that the workshop provided them with information on various aspects of environmental health problems, and helped them to develop enhanced programs for their schools. In addition, all of the teachers agreed that they have begun to establish lasting partnerships with the EHP faculty, and will be able to explain the impact of the environment on the health of all Americans to their students in ways that reflect the importance and role of contaminants in specific environments.

The majority of the teachers (a total of 12) stated that they will be able to integrate current interdisciplinary research in Toxicology and Public Health in their home institutions to train students in science, but teachers feel less comfortable with their ability to train students in community health, preventive health, and the health sciences. Sixteen teachers feel they were able to interact with researchers engaged in NIEHS Superfund research. A majority of the teachers (a total of 13) agreed that they will be able to develop research resources, teaching strategies (a total of 14), and community and public health agency collaborations (a total 15) to inform students, their families and communities about toxicological effects in their community, while one did not, and two did not respond.

Fourteen teachers stated that they were able to collect data and participate in an environmental field study, while 15 teachers explained that they were able to use scientific tools for environmental science analyses, and only 12 felt they were able to obtain instructional materials and community resource development strategies to use in their home institutions. Twelve of the teachers said comfortable, two uncomfortable, one limited, and three gave no response to how they feel about their ability to engage students and communities in their area in an exciting, interdisciplinary intervention in public health status. Fifteen teachers answered positively about their ability to inform students and communities in the area about the state, local and

community health issues while providing them with sufficient scientific knowledge to assess their community's health needs. A majority of the teachers (a total of 17) responded yes that they will be able to devise strategies for prevention, education and amelioration of environmental hazards. Twelve teachers responded in a positive manner, while four responded in a negative manner about their ability to develop and assess continuing partnership goals and action at the Superfund regional meetings.

Overall, the 2003 Environmental Health Partnership workshop was successful. All 18 of the teachers increased their knowledge of superfund and environmental health issues. A majority of the teachers (a total of 13) were impressed with the program, had positive comments, and felt that the goals of the workshop were met. Only five teachers had suggestions for program improvement and felt that the goals of the workshop were not completely met. The main issues that the teachers had were that they would like to see more activities and/or labs that they can take home ready to go to do with their students. They expressed concern about some of the speakers "talking over their heads," which was due to a lack of sensitivity to the background knowledge of the teachers. Teachers were also discouraged by the lack of funding at their home institutions to be able to perform the labs and activities shown to them during the workshop. Therefore, it is suggested that the workshop aim to be more "teacher and student friendly" in the future. Maybe a way to do this is to involve more teachers and/or teacher educators in the planning process.

## LITERATURE CITED


1. University of Florida Center for Precollegiate Education and Training www.cpet.ufl.edu 2003.
2. O'Hearn GT: What is the purpose of evaluation? JEE 13: 1-3, 1982.
3. Bennett D: Evaluating environmental education in the context of a junior high school state studies program. JEE 13: 13-18, 1982.
4. Stake RE: The countenance of educational evaluation. Teachers College Record 68: 529, 1967.
5. Wood BB: Stake's countenance model: Evaluating an environmental education professional development course. JEE 32: 18-27, 2001.
6. Guba EG and Lincoln YS: "Effective Evaluation." San Francisco: Jossey-Bass, 1982.




# A REDESCRIPTION OF THE MATURE LARVA OF *THERMONECTUS BASILLARIS* (HARRIS) (COLEOPTERA: DYTISCIDAE: DYTISCINAE)


Keith Carroll
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E. H. Barman
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## ABSTRACT

Mature larvae collected from Georgia ephemeral habitats were cultured into the adult stage and identified and described as *Thermonectus basillaris*.The legs of *T. basillaris* have fewer spiniform sensilla than reported for *Acilius mediatus*, and it appears that its two large dorsal stemmata are more massive than those of *A. mediatus*. These morphological differences indicate that nektonic larvae of *T. basillaris* and *A. mediatus* may be exploiting different prey regimes.



***Key Words:*** Dytiscidae, *Thermonectus basillaris*, larva, *Acilius mediatus*, morphology, southeastern United States.


## INTRODUCTION

The New World genus *Thermonectus* Crotch, in the tribe Aciliini, is represented in the Southeast by relatively few species, with Turnbow and Smith (1) having only two species of record for Georgia, *T. basillaris* (Harris) and *T. ornaticollis* Aubé. McWilliams (2) synonymized *T. ornaticollis* as a junior synonym of *T. nigrofasciatus* (Aub ), assigning two subspecies, *T. n. nigrofasciatus* and *T. n. ornaticollis*. Larvae of Aciliini are usually characterized as nektonic predators of plankton. However, Wilson (3) reported observing larvae of *T. basillaris* and *T. n. ornaticollis* feeding on invertebrates (e.g., nymphs of *Notonecta*) on or near the water surface of small fishponds. Wilson's study also includes descriptions of mature larvae of *T. basillaris* and

*T. n. ornaticollis*, but his descriptions emphasize general larval appearance and lack the detailed analysis that are characteristic of more recent studies. Wilson's descriptions have been used for identification of these two species when they are the only representatives of the genus. However, Barman and Epler (4) reported that Wilson's descriptions have been erroneously interpreted and incorporated into keys (5; 6) so that larvae of both *T. basillaris* and *T. n. ornaticollis* are likely to be identified as *T. n. ornaticollis* in Georgia and elsewhere. The cranium of the mature larva of *T. basillaris* has been described, emphasizing mandibular morphology and internal cranial structures supporting extra oral digestion (7), but the restricted nature of this study limits its systematic value.

The objectives of this study are to redescribe the mature larvae of *Thermonectus basillaris* with an emphasis on leg chaetotaxy and to report a preliminary assessment of the ecological implications of selected morphological systems.

## MATERIALS AND METHODS

Mature larvae and exuviae of mature larvae examined in this study were from the aquatic Coleoptera fluid collection (70% glycerated alcohol) of Georgia College & State University. These larvae were collected in Talbot County, Georgia USA, on 9 and 14 May 1997 and identified as *Thermonectus basillaris* by culture into the adult stage.

Measurements were obtained from dismembered specimens with head lengths taken dorsally from the posterior margin along the coronal suture to the anterior margin of the frontoclypeus, excluding the posterodorsal notch and frontoclypeal sensilla. All other measurements were taken at the longest or the widest aspects. Anatomical assessments were of eight larvae unless noted otherwise. A modification of a descriptive system proposed by Wolfe and Roughley (8) was used to enumerate sensilla by position or origin on segments of body and appendages, permitting comparisons between closely related taxa (9).

### Larval Description

*General aspect*. – Body spindle-shaped, widest at or the near first abdominal segment (3), length (alcohol preserved specimens) about 16 mm excluding urogomphi; sclerotized areas pale yellowish-brown with irregular areas on head darker brown; broad lateral area of head below dorsal stemmata appearing much darker on some specimens.

*Head*. – Hyperprognathic, dorsoventral shape trapezoidal anterior to well-defined cervical region (7), cervical region delimited by a deep constriction and with prominent dorsal and ventral notches penetrating the entire length of the cervical region, occipital suture present, total length 1.86 - 1.98 mm ($\bar{x}$ = 1.92 ± 0.05 mm), width 1.30 - 1.46 mm ($\bar{x}$ = 1.37 ± 0.06 mm); coronal suture length 0.62 - 0.68 mm ($\bar{x}$ = 0.65 ± 0.02 mm); frontoclypeus, length 0.78 - 0.84 mm ($\bar{x}$ = 0.82 ± 0.02 mm), anterior margin with lamellae clypeales, adnasale well-developed; large rectangular sclerotized plate extending from between the adnasale and below the lamellae clypeales onto the cibarium; cranium largely glabrous, prominent sensilla of the head capsule included temporal spines, lamellae clypeales, and a group of spine-like sensilla ventral and anterior to cervical region; antenna four-segmented, total length 0.56 - 0.68 mm ($\bar{x}$ = 0.62 ± 0.05 mm) segments two and three with secondary segmentation, first segment 0.14 - 0.18 mm ($\bar{x}$ = 0.16 ± 0.02 mm), second segment 0.17 - 0.21 mm ($\bar{x}$ = 0.19 ± 0.02 mm), third segment 0.20 - 0.24 mm ($\bar{x}$ = 0.23 ± 0.01 mm), lacking accessory sensorial appendage, fourth segment 0.05 - 0.06 mm; two large anterodorsal stemmata each with a massive cellular sac (10) penetrating deeply into the cranial interior from beneath the corneal lens; remaining stemmata smaller with two lateral, one ventral, and one anterolateral near base of mandible, cellular sacs not visible externally; gular suture obscure; posterior tentorial pits visible mesoventrally.



*Mouth parts*. - Mandible falciform, mandibular channel partially closed medially, ventral edge serrated distally (7), mandibular abductor muscle with a dorsomedial origin (n = 1), proximal and lateral fringe of hair-like sensilla present; maxilla with galea long, robust and spur-like with ventral spines; stipes strongly arcuate, acute medially and distally beneath galea, medial edge strongly spinulous, spinulae larger medially on apex, apparent homologs of ancestral sensilla on ventral surface, prominent series of hair-like sensilla originating dorsolaterally, second dorsal series of hair-like sensilla terminating as a cluster near base of the palp, dorsomedial series becoming longer distally to terminate near base of galea, small scale like spinulae between dorsomedial and medial edge; maxillary palp three segmented, homologs of ancestral sensilla present; third segment, first segment 0.06 - 0.09 mm ($\bar{x}$ = 0.08 ± 0.01 mm), second segment 0.11 - 0.14 mm ($\bar{x}$ = 0.12 ± 0.01 mm), third segment 0.15 - 0.18 mm ($\bar{x}$ = 0.16 ± 0.01 mm) and secondarily segmented; labium rounded distally and protruding well beyond origins of palps, hair-like sensilla arising near base of each palp, small cone-like sensilla along distal rounded edge, ligula prominent with a shallow distal bifurcation with each short branch supporting a prominent sensillum, proximal segment of labial palp with lateral scale-like spinulae, first segment 0.21 - 0.27 mm ($\bar{x}$ = 0.25 ± 0.02 mm), second segment 0.18 - 0.20 mm ($\bar{x}$ = 0.18 ± 0.01 mm).

*Thorax*. – Pronotum elongate, laterally compressed anteriorly, prominent rectangular prosternal plate covering almost entire venter; thoracic nota glabrous; spiracles in pleural region under anterolateral margins of mesothoracic notum.

*Legs*. – (Fig. 1, Tables I and II) Range of respective lengths of pro-, meso-, and metalegs, excluding trochanters and claws, 3.0 to 3.3, 3.3 to 3.5, and 3.3 to 3.4 mm; coxal sutures absent; trochanters with 7 - 10 sensilla, secondary homolog of $TR_2$ not observed; anteroventral and posterodorsal natatory sensilla present on femur, tibia, and tarsus; tarsus with anteroventral series restricted to proximal half and posterodorsal series along the length of

the segment; tibia without ventral spinulae, tarsal ventral spinulae robust, present anteroventrally on distal half; posterior tarsal claw shorter than anterior and broadly spinous ventrally.

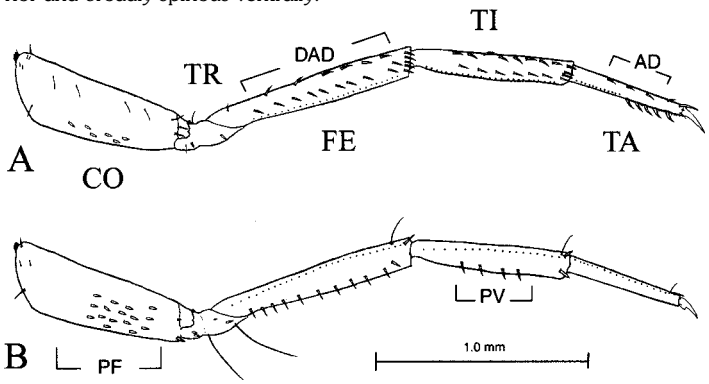


***Figure 1.*** Anterior (a) and posterior (b) views of the prothoracic appendage of *Thermonectus basillaris* (Harris). Abbreviations: AD, anterodorsal; co, coxa; DAD, dorsal anterodorsal; PF, posterior face; PV, posteroventral; fe, femur; TA, TARSUS ti, tibia; AND; TR, TROCHANTER.

***Table I.*** Measurements (N=8, unless noted otherwise; in mm) of Thoracic Appendage Segments of *Thermonectus basillaris* (Harris).

| Segment | Mean | Standard Deviation | Range |
|---|---|---|---|
| Procoxa | 0.87 | 0.07 | 0.80 - 0.96 |
| Mesocoxa | 0.96 | 0.04 | 0.90 - 1.05 |
| Metacoxa | 0.98 | 0.03 | 0.95 - 1.04 |
| Protrochanter | 0.41 | 0.04 | 0.36 - 0.48 |
| Mesotrochanter | 0.43 | 0.03 | 0.39 - 0.47 |
| Metatrochanter | 0.43 | 0.05 | 0.35 - 0.48 |
| Profemur | 1.09 | 0.06 | 1.01 - 1.20 |
| Mesofemur | 1.15 | 0.05 | 1.07 - 1.22 |
| Metafemur | 1.08 | 0.05 | 1.01 - 1.14 |
| Protibia[1] | 0.73 | 0.06 | 0.69 - 0.86 |
| Mesotibia | 0.79 | 0.08 | 0.69 - 0.93 |
| Metatibia | 0.77 | 0.02 | 0.75 - 0.81 |
| Protarsus[2] | 0.51 | 0.02 | 0.47 - 0.54 |
| Mesotarsus | 0.56 | 0.02 | 0.51 - 0.59 |
| Metatarsus | 0.57 | 0.02 | 0.54 - 0.60 |

[1] N=7; [2] N=6



***Table II.*** Sensillar distribution on legs of the mature larva of *Thermonectus basillaris* (Harris).

| Appendage | Location[1] | Coxa | Femur | Tibiae | Tarsus |
|---|---|---|---|---|---|
| | DAD | 3 - 6 | 6 - 9 | 8 - 9 | 5 - 7 |
| | AV | 3 - 7 | 9 - 13 | 4 - 8 | 0 |
| | ADi | 2 | 5 - 6 | 3 - 5 | 2 sm |
| Proleg | APr[2] | 6 | NA | NA | NA |
| | PD | 0 | 0 | 0 | 1 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 1 - 2 +1 hrl | 2 sm |
| | PV | NA | 10 - 14 | 3 - 7 | 0 |
| | PF | 8 - 17 | NA | NA | NA |
| | PPr[2] | 4 | NA | NA | NA |
| | DAD | 6 - 11 | 9 - 14 | 4 - 11 | 4 - 6 |
| | AV | 3 - 7 | 7 - 13 | 8 - 12 | 0 |
| | ADi | 2 | 5 - 6 | 3 - 5 | 2 sm |
| | APr[2] | 6 | NA | NA | NA |
| Mesoleg | PD | 0 | 0 | 0 | 1 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 1 - 2 +1hrl | 2 sm |
| | PV | NA | 11 - 14 | 4 - 5 | 0 |
| | PF | 5-16 | NA | NA | NA |
| | PPr[2] | 4 | NA | NA | NA |
| | DAD | 8 - 12 | 9 - 14 | 9 - 11 | 5 - 6 |
| | AV | 4 - 6 | 11 - 16 | 10 - 14 | 0 |
| | ADi | 2 | 6 - 8 | 4 - 6 | 2 sm |
| | APr[2] | 6 | NA | NA | NA |
| Metaleg | PD | 0 | 0 | 0 | 1 2 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 1 - 2 + 1 hrl | 2 sm |
| | PV | NA | 10 - 13 | 4 - 5 | 0 |
| | PF | 3 - 7 | NA | NA | NA |
| | PPr[2] | 4 | NA | NA | NA |

[1]Abbreviations: ADDi, anterodorsal distal; AF, anterior face; APr, anteroproximal; AV, anteroventral; AVDi, anteroventral distal; DAD, dorsal anterodorsal; hrl, hair-like; PD, posterodorsal; PF, posterior face; PPr, posterior proximal; PV, posteroventral; PDDi, posterodorsal distal; and PVDi, posteroventral distal.

[2]These data represent a composite enumeration

*Abdomen*. – Abdominal terga one - six extending onto ventrolateral areas, with lateral sclerotization increasingly progressively, segments seven and eight completely sclerotized; segment eight 1.88 - 2.14 mm ($\bar{x}$ = 2.01 mm, n=5); siphon length 0.21 - 0.40 mm ($\bar{x}$ = 0.28 mm, n = 5); segments one - six with ventrolateral spiracles, spiracles on segment seven below natatory sensilla; tergites one - six glabrous, non sclerotized areas of segments two-four with posteroventral hair-like sensilla; two -seven with a ventrolateral series of hair-like sensilla, segments seven and eight each with well-defined lateral series of hair-like natatory sensilla;

*Urogomphus*. - Single segmented, length 0.81 - 0.90 mm ($\bar{x}$ = 0.85 mm, n = 4) with 4 apical sensilla, 3 long hair-like prominent sensilla arising from the proximal third and one shorter sub distal spine-like sensillum near origin of urogomphus.

## DISCUSSION

The general shape (3) of the larva of *Thermonectus basillaris* and the distribution and morphology of sensilla on the larval legs are consistent with descriptions provided for other Aciliini larvae (e. g., 9, 11). Nilsson (9) reported that within the Dytiscinae primary sensillum $TR_2$ was present on trochanters of *Dytiscus*, *Hydaticus*, and *Cybister* but absent on *Eretes*, *Acillius*, and *Graphoderus*. Secondary homologs of $TR_2$ were not found on *T. basillaris*, although homologs of the remaining primary sensilla appear to be present. The homologs of the primary sensilla and the secondary sensilla are distributed in patterns on legs that appear similar to those of other Aciliini. However, there are fewer spines on the legs of *T. basillaris* than reported for *Acilius mediatus* (Say). As an example, the profemur of *T. basillaris* has 27 to 44 non-natatory sensilla (Table 3), contrasting significantly with the range of 56 to 75 sensilla that was reported for *A. mediatus* (11).

**Table III.** A comparison of the number of Sensilla and their patterns of distribution on legs of mature larvae of *Aculius mediatus* (SAY) and *Thermonectus basillaris* (Harris).

| Location[1] | *Acilius mediatus*[2] | *Thermonectus basillaris* |
|---|---|---|
| DAD | 10 - 15 | 4 - 9 |
| ADi | 7 - 9 | 4 - 6 |
| AV | 16 - 21 | 9 - 13 |
| PDi | 0 - 1 | 0 - 1 |
| PV | 23 - 29 | 10 - 15 |
| Total | 56 - 75 | 27 - 44 |

[1] Abbreviations are: ADi, anterior distal; AV, anterior ventral; DAD, dorsal anterodorsal; PDI, posterior distal; and PV, posterior ventral.
[2] Data taken from Sizer and Barman (11).



*Thermonectus basillaris* larvae have massive columnar cellular sacs beneath the four large dorsal lenticular cornea that are observable externally, as reported by Wilson (3). These structures penetrate almost to the venter of the cranial interior. Although the dorsal stemmata of *Acilius mediatus* are also large and penetrate deeply into the interior, they do not appear from the exterior to be as massive as those of *T. basillaris*. If this difference is confirmed by additional observations and comparisons, this would indicate that larvae of *A. mediatus* and *T. basillaris* have different sensory requirements associated with the dorsal stemmata. Wilson (3) reported observing *Thermonectus* larvae feeding on surface dwelling organisms. If the prey regimes of *Thermonectus* larvae include large numbers of these animals rather than the zooplankton diet attributed to the Aciliini (e.g., 12), morphological differences within some systems would be expected. Although additional observations are required, the massive dorsal stemmata and the apparent reduction in femoral chaetotaxy may be indications that *T. basillaris* and *A. mediatus* are feeding in different areas of the water column and exploiting different prey assemblages.

## ACKNOWLEDGEMENTS

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## REFERENCES

1. Turnbow R and Smith CL: An annotated checklist of the Hydradephaga (Coleoptera) of Georgia. J Ga Entomol Soc 18: 429-443, 1983.
2. McWilliams KL: A taxonomic revision of the North American species of the genus *Thermonectus* Dejean (Coleoptera: Dytiscidae). Ph.D. thesis, Indiana University, Bloomington, Indiana, 220 pp., 1968.
3. Wilson CB: Water beetles in relation to pondfish culture, with life histories of those found in fishponds at Fairport, Iowa. Bull Bur Fish, Wash 39: 231-345, 1923.
4. Barman EH and Epler JH: Errors in descriptions of larvae of *Thermonectus* Dejean (Coleoptera: Dytiscidae). Southeast Nat, in press.
5. Brigham WU: Aquatic Coleoptera. Pp. 10.1-10.136 *in* Brigham AR, WU Brigham and A Gnilka (eds.). Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, IL, 1982.

6. Epler JH: Identification manual for the water beetles of Florida (Coleoptera: Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Noteridae, Psephenidae, Ptilodactylidae, Scirtidae). Florida Dept Environ Protection, Tallahassee, FL. 257 pp., 1996.
7. Barman EH and Carroll K: Anterior cranial morphology of the mature larva of *Thermonectus basillaris* (Harris) (Coleoptera: Dytiscidae). Ga J Sci 60: 156-160, 2002.
8. Wolfe GW and Roughley RE: Description of the pupa and mature larvae of *Matus ovatus ovatus* Leech (Coleoptera: Dytiscidae) with a chaetotaxal analysis emphasizing mouth parts, legs, and urogomphus. Proc Acad Nat Sci Phil 137: 61-79, 1985.
9. Nilsson AN: A review of primary setae and pores on legs of larval Dytiscidae (Coleoptera). Can J Zool 66: 2283-2294, 1988.
10. Snodgrass RE: Principles of Insect Morphology. New York: McGraw-Hill, 667 pp; illus, 1935.
11. Sizer RL and Barman EH: Natural history of *Acilius mediatus* (Say) (Coleoptera: Dytiscidae: Aciliini) in central Georgia with a description of its mature larva. Ga J Sci 56: 165-174, 1998.
12. Galewski K: A study on morphobiotic adaptations of European species of the Dytiscidae (Coleoptera). Bull Entomol Pol 41: 488-702, 1971.



# A REDESCRIPTION OF THE MATURE LARVA OF *NEOPORUS CLYPEALIS* (SHARP) (COLEOPTERA: DYTISCIDAE)

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## ABSTRACT

Mature larvae of *Neoporus* were collected from lower Piedmont and upper Coastal Plain lotic habitats in Georgia. Specimens were cultured into the adult stage and identified as *N. clypealis*. The larval head is characterized by an extended frontoclypeus, a prominent reddish-brown dorsomedial W-shaped marking, and well-developed stemmata. Mesothoracic and lateral abdominal spiracles are absent. The presence of tarsal and tibial natatory sensilla and short secondary sensilla on the proximal urogomphal segment is consistent with the chaetotaxy of previously described *Neoporus* species.

***Key words:*** *Dytiscidae*, *Neoporus clypealis*, larva, morphology, southeastern United States.

## INTRODUCTION

The majority of species in the Nearctic genus *Neoporus* have ranges that either include or that are restricted to the southeastern United States (1). *Neoporus* is the most specious genus recorded in Georgia with at least 22 species reported from throughout the state, including the Piedmont and Coastal Plain Regions (2). Although *Neoporus* contains a large number of species, we have been able to find descriptions of immature stages of only nine species. Barman (3) observed oviposition by *N. undulatus* (Say) and provided brief descriptions of its egg, first, second, and third instars, and pupa. This study also included descriptions of the mature larva of *N. dimidiatus*

(Gemminger and Harold) (as *N. solitarius*; 4) and *N. clypealis* (Sharp). Matta and Peterson (5) gave brief descriptions of the mature larvae of *N. blanchardi* (Sherman), *N. carolinus* (Fall), *N. cimicoides* (Sharp), *N. lobatus* (Sharp), *N. shermani* (Fall), and *N. superioris* (Balfour-Browne) based on material collected in the southeast. Alarie (6) identified and described the first, second, and third instars of *N. undulatus* and the third instar of *N. carolinus*. The first instar of *N. undulatus* was included as a reference specimen in the chaetotaxal analyses of the hydroporine last abdominal segment and urogomphi (7) and legs (8). The chaetotaxal analysis of the head (9) included first instars of *N. tennetum* (Wolfe), N. *dimidiatus*, and *N. undulatus*.

Larvae of *N. clypealis* have been described previously (3), but this study lacks the chaetotaxal detail required by current and more modern nomenclatural standards. The purpose of our study is to redescribe the mature larvae of *N. clypealis* using chaetotaxal analytical techniques developed by Nilsson (10), Wolfe and Roughley (11), Alarie (6; 9), Alarie and Harper (7), and Alarie et al. (8).

## MATERIALS AND METHODS

The mature larvae examined in this study were collected in backwater areas of Champion Creek, (Baldwin County), Turkey Creek, (Wilkinson County), and from thick beds of aquatic vegetation in Canoochee Creek, (Emanuel County), Georgia U.S.A., (Fig. 1). The larvae were identified as *N. clypealis* after culture into the adult stage. This material was compared to preserved larvae (70 percent glycerated ethyl alcohol) of *N. undulatus* and *Hydroporus signatus* (Mannerheim) that had also been identified after culture into adults.

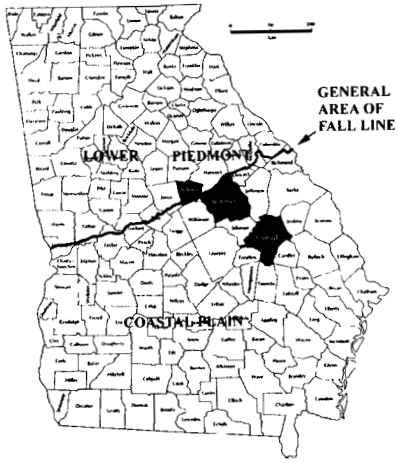


***Figure 1.*** County collection sites for the larva of *Neoporus clypealis* (Sharp).



Ten larvae were analyzed anatomically, unless noted otherwise. Measurements were obtained from dismembered specimens with head lengths taken dorsally from the posterior margin along the coronal suture to the anterior margin of the frontoclypeus and at the widest region of the cranium. Lengths of the coxa, trochanter, femur, tibia, and tarsus were taken at the longest aspect. Lengths of legs were determined by adding lengths of leg segments, excluding trochanters. A modification of a descriptive system proposed by Wolfe and Roughley (11) was used to enumerate sensilla by position and/or origin on body segments and appendages.

## LARVAL DESCRIPTION

*General aspect*. – Body widest at or the near base of first abdominal segment, length (alcohol preserved specimens) about 7.5 mm excluding urogomphi; sclerotized areas of body dark reddish-brown, light yellowish markings medially, and laterally on posterior third of pronotum, and anteriorly on the eighth abdominal segment. Head light yellowish brown with dark reddish brown W-shaped pattern on the frontoclypeus and epicranium (Fig. 2).

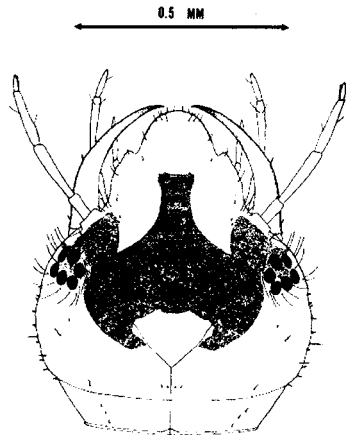


***Figure 2.*** Dorsal veiw of the cranium of *Neoporus clypealis* (Sharp).

*Head*. – Prognathic, pear-shaped dorsoventrally, defined cervical region absent, total length 1.01 – 1.15 mm ($\bar{x}$ = 1.10 ± 0.06 mm), width 0.80 – 0.91 mm ($\bar{x}$ = 0.87 ± 0.05 mm ) with a prominent occipital suture. Frontoclypeus, length 0.77-0.89 mm ($\bar{x}$ = 0.82 ± 0.05 mm), extended well beyond the origins of the mandibles to form a prominent frontoclypeal projection (nasale) with well-developed lateral serrated notches; venter of nasale extensively sclerotized, labrum not evident, coronal suture length 0.21 - 0.32 mm ($\bar{x}$ = 0.25 ± 0.04 mm); prominent ocular areas, each with six stemmatal

lenses arranged laterally in an elongate oval; gular sutures obscure; posterior tentorial pits visible meso-ventrally; prominent sensilla of the head capsule included temporal spines ranging from eight to ten, lamellae clypeales on anteroventral margin of nasale; antenna four-segmented, total length 0.53-0.62 mm ($\bar{x}$ = 0.58 ± 0.05 mm ), first segment 0.08 - 0.12 mm ($\bar{x}$ = 0.10 ± 0.02 mm), second segment 0.18 - 0.24 mm ($\bar{x}$ =0.21 ± 0.03 mm), third segment 0.19-0.22 mm ($\bar{x}$ = 0.21 ± 0.01 mm), accessory sensorial appendage present, fourth segment 0.05-0.07 mm ($\bar{x}$ =.06 ± 0.01);

*Mouth parts*. – (Fig. 3A) Mandibles slender, falcate, lacking medial teeth, directed dorsomedially to cross beneath anterior margin of the nasale, two small sensilla laterally, one proximal and one medial; maxilla with galea absent, maxillary cardo reduced with one sensillum, stipes short, fingerlike, medial surface without sensilla, two prominent ventral lateral sensilla; maxillary palps three segmented, first segment 0.21- 0.28 mm ($\bar{x}$ = 0.26 ± 0.02 mm), second segment 0.16-0.21 mm ($\bar{x}$ = 0.19 ± 0.02 mm) with a large distal pore and two distal hair-like sensilla, third segment 0.05-0.08 mm ($\bar{x}$ = 0.06 ± 0.01 mm) with a proximal hair-like sensillum; labium trapezoidal, narrowest posteriorly, separated from maxillary bases by two low but prominent protuberances, two small proximal spines and two hairlike distal spines at the base of each palp, first segment 0.18- 0.29 mm (0.24 ± 0.03 mm), second segment 0.18-0.24 mm ($\bar{x}$ = 0.21 ± 0.02 mm) with two ventral hair-like sensilla and two small distal spinulae.

*Thorax*. – Pronotum about one and a half times longer than mesonotum and metanotum, widest posteriorly, pronotal venter membranous; meso- and metanotum about equal in length; pronotum with long setae on the margins anteriorly, laterally, and posteriorly. Pronotum, mesonotum, and metanotum with irregularly distributed setae discally, forming fringe on the lateral and posterior margins. Spiracles absent on thorax.

*Legs*. - (Tables 1 and 2; Fig. 3). Coxal sutures present; ventral spinulae present on pro- and meso- tarsi and tibiae, absent on metathoracic leg; trochanter with six sensilla; simple and complex spines present, complex spines confined to the femoral and tibial segments, most numerous anteroventrally and distally, and on the metathoracic leg; posterior tarsal claw shorter than anterior claw, tarsal spines present.



***Table I.*** Measurements (N=10; in mm) of lengths of thoracic appendages of *Neoporus clypealis* (Sharp).

| Segment | Mean | Standard Deviation | Range |
|---|---|---|---|
| Procoxa | 0.53 | 0.04 | 0.48 - 0.60 |
| Mesocoxa | 0.55 | 0.07 | 0.41 - 0.66 |
| Metacoxa | 0.63 | 0.05 | 0.54 - 0.69 |
| Protrochanter | 0.16 | 0.01 | 0.12 - 0.20 |
| Mesotrochanter | 0.19 | 0.02 | 0.17 - 0.23 |
| Metatrochanter | 0.23 | 0.00 | 0.18 - 0.27 |
| Profemur | 0.51 | 0.04 | 0.45 - 0.57 |
| Mesofemur | 0.57 | 0.05 | 0.51 - 0.63 |
| Metafemur | 0.67 | 0.05 | 0.60 - 0.72 |
| Protibia | 0.24 | 0.04 | 0.18 - 0.30 |
| Mesotibia | 0.35 | 0.04 | 0.29 - 0.41 |
| Metatibia | 0.45 | 0.04 | 0.39 - 0.50 |
| Protarsus | 0.24 | 0.04 | 0.18 - 0.29 |
| Mesotarsus | 0.31 | 0.05 | 0.20 - 0.35 |
| Metatarsus | 0.45 | 0.04 | 0.39 - 0.50 |
| Proleg | 1.51 | 0.14 | 1.33 - 1.69 |
| Mesoleg | 1.77 | 0.12 | 1.63 - 2.03 |
| Metaleg | 2.20 | 0.15 | 2.01 - 2.39 |

***Table II.*** Sensillar distribution and patterns on legs of the mature larva of *Neoporus clypealis* (Sharp).

| Appendage | Location | Coxa | Femur | Tibiae | Tarsus |
|---|---|---|---|---|---|
| | DAD | NA | 5-8 | NA | NA |
| | AV | 1 - 4 | 7 - 13 | 1 - 4 | 0 |
| | AD | 4 - 6 | NA | 0 | 0 |
| Proleg | ADi | 2 | 2 - 3 | 2 - 3 | 1 + 2 sm |
| | APr | 6 | NA | NA | NA |
| | PD | 5 - 8 | 0 - 3 | 0 | 1 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 2 + 1 hrl | 2 sm |
| | PV | 0 - 2 | 5 - 8 | 2 - 4 | 0 |
| | PPr | 4 | NA | NA | NA |
| | NS | NA | NA | 5 - 8 | 1 - 5 |
| | DAD | NA | 3 - 10 | NA | NA |
| | AV | 1 - 4 | 4 - 14 | 4 - 6 | 4 - 7 |
| | AD | 4 - 8 | NA | 3 - 4 | 0 - 1 |
| | ADi | 2 | 2 - 3 | 2 - 3 | 1 + 2 sm |
| Mesoleg | APr | 6 | NA | NA | NA |
| | PD | 6 - 8 | 0 - 2 | 0 | 1 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 2 + 1 hrl | 2 sm |
| | PV | 0 - 4 | 7 - 11 | 4 - 5 | 0 |
| | PPr | 4 | NA | NA | NA |
| | NS | NA | NA | 9 - 14 | 8 - 13 |
| | DAD | NA | 7 - 12 | NA | NA |
| | AV | 2 - 6 | 11 - 15 | 5 - 7 | 6 - 10 |
| | AD | 6 - 8 | NA | 4 - 8 | 0 |
| | ADi | 2 | 3 - 4 | 2 - 3 | 1 + 2 sm |
| Metaleg | APr | 6 | NA | NA | NA |
| | PD | 4 - 12 | 0 - 2 | 0 | 1 + 1 hrl |
| | PDi | 2 | 1 + 1 hrl | 2 + 1 hrl | 1 + 1 sm |
| | PV | 2 - 4 | 7 - 11 | 4 - 6 | 0 |
| | PPr | 4 | NA | NA | NA |
| | NS | NA | NA | 11 - 16 | 11 - 15 |

Abbreviations employed include: DAD, dorsal anterodorsal; AV, anteroventral; AD, anterodorsal; ADi, anterodistal; APr, anteroproximal; PD, posterodorsal; PDi, posterodistal; PV, posteroventral; PPr, posterior proximal; NS, natatory sensilla.



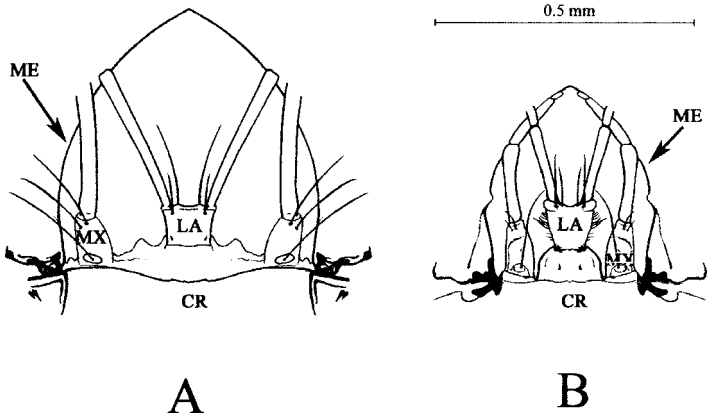


***Figure 3.*** Ventral views of the labia of (A) *Neoporus clypealis* (Sharp) and (B) *Hydroporus signatus* (Mannerheim). Abbreviations employed are: CR, cranium; LA, labium; MX, maxilla; and ME, medial edge of mandible.

*Abdomen*. – Segments 1 - 6 individually shorter than mesosternum, membranous ventrolaterally and ventrally, segments 7 and 8 completely sclerotized; segments 1 - 7 with sensillar series posteriorly and laterally, segment 8 with numerous sensilla distributed irregularly; spiracles absent on 1-7; segment 8 length 0.32 - 0.57 mm ($\bar{x}$ = 0.45 mm ± 0.07); siphon well-defined, length 0.12 - 0.20 mm ($\bar{x}$ = 0.16 ± 0.03 mm).

*Urogomphus*. - Two segmented; proximal segment length 0.92 - 1.11 mm ($\bar{x}$ = 1.01 ± 0.06 mm, n = 7) with 11 sensilla, including one small spine near origin and three long hair-like prominent sensilla arising distally; segment 2 subequal to proximal segment and hair-like with a hair-like sensillum arising distally.

## DISCUSSION

The mature larva of *Neoporus clypealis* has a distinct W-shaped dorsal head pattern (Fig. 2) similar to that of *N. carolinus* (5; 6). Both species have ranges that include Georgia (2). If this head pattern is restricted to *N. carolinus* and *N. clypealis*, the two species may be separated in Georgia by dramatic differences in the chaetotaxy of the proximal urogomphal segment. The number of sensilla observed on the proximal urogomphal segment on *N. clypealis* was eleven. In contrast, the number of sensilla on the proximal urogomphal segment of *N. carolinus* ranges from 20 - 29 (6).

The basal morphology of the labium of *Neoporus clypealis* and its relative proximity to the maxillae is significantly different from that of *Hydroporus signatus*. On *H. signatus*, the pre- and postmentum are well defined with

the base of the prementum proximate to the medial origins of the maxillae. The result is a relatively compact appearance of maxillae and labium when viewed ventrally (Fig. 3B). The prementum of *N. clypealis*, although shaped somewhat differently, is comparable to that of *H. signatus* in its relative size; however, the postmentum of *N. clypealis* has a very different morphology. If it is present on *N. clypealis*, the postmentum has a relatively wide base that is significantly greater than its height. As a result the distance between the base of the prementum and the medial surfaces of the stipes is almost twice the maximum width of the stipes (3A). The morphology of the mature larva of *N. undulatus* is similar to that of *N. clypealis*. This suggests that the relative positions of the labium and maxillae may provide a useful character for separation of *Hydroporus* and *Neoporus* larvae in Georgia. Additional sampling of larvae from both genera and further observations of positions of the labium and maxillae will help determine the utility of this character for delimiting *Hydroporus* and *Neoporus*.

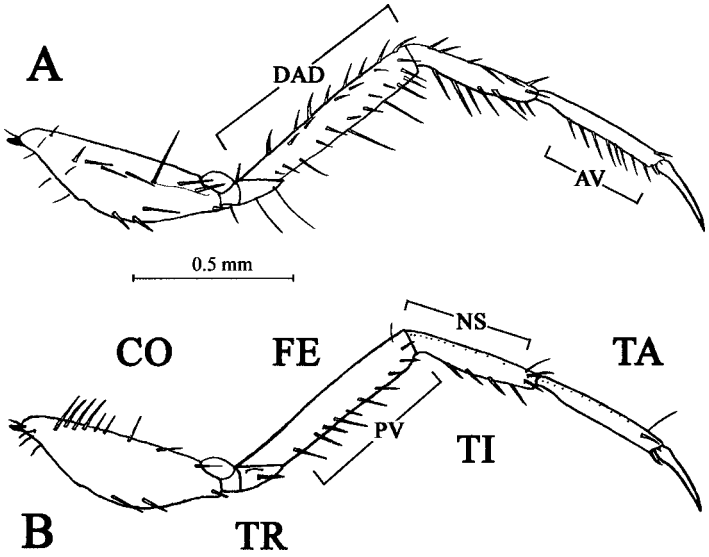


***Figure 4.*** Anterior (A) and posterior (B) views of the metathoracic appendage of *Neoporus clypealis* (Sharp). Abbreviations: ADDi, anterodorsal distal; AF, anterior face; APr, anteroproximal; AV, anteroventral; AVDi, anteroventral distal; DAD, dorsal anterodorsal; hrl, hair-like; PD, posterodorsal; PF, posterior face; PPr, posterior proximal; PV, posteroventral; PDDi, posterodorsal distal; and PVDi, posteroventral distal.



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**LITERATURE CITED**

1. Wolfe GW: A revision of the *Vittatipennis* species group of *Hydroporus* Clairville, subgenus *Neoporus* Guignot (Coleoptera: Dytiscidae). Trans Amer Ent Soc 110: 389-433, 1984.
2. Turnbow R and Smith CL: An annotated checklist of the Hydradephaga (Coleoptera) of Georgia. J Ga Entomol Soc 18: 429-443, 1983.
3. Barman EH: The biology and immature stages of selected species of Dytiscidae (Coleoptera) of central New York State. Cornell University. Ph. D. thesis, Ithaca N. Y. v + 207 p., 1972.
4. Larson DJ, Alarie Y and Roughley RE: Predaceous diving beetles (Coleoptera: Dytiscidae) of the Nearctic Region, with an emphasis on the fauna of Canada and Alaska. NRC Research Press, Ottawa, 982 pages, 2000.
5. Matta JF and Peterson DE: The larvae of six Nearctic *Hydroporus* of the subgenus *Neoporus* (Coleoptera: Dytiscidae). Proc Acad Nat Sci 137: 53-60, 1985.
6. Alarie Y: Description of larvae of 17 Nearctic species of *Hydroporus* Clairville (Coleoptera: Dytiscidae: Hydroporinae) with an analysis of their phylogenetic relationships.The Canad Entomol 123: 627-704, 1991.
7. Alarie Y and Harper PP: Primary setae and pores on the last abdominal segment and the urogomphi of larval Hydroporinae (Coleoptera: Adephaga: Dytiscidae), with notes on other dytiscid larvae. Canad J Zool 68: 368-374, 1990.
8. Alarie Y, Harper PP and Maire A: Primary setae and pores on legs of larvae of Nearctic Hydroporinae (Coleoptera: Dytiscidae). Quaest Entomol 26: 199-210, 1990.
9. Alarie Y: Primary setae and pores on the cephalic capsule and head appendages of larval Hydroporinae (Coleoptera: Dytiscidae: Hydroporinae). Canad J Zool 69: 2255-2265, 1991.
10. Nilsson AN: A review of primary setae and pores on legs of larval Dytiscidae (Coleoptera). Can J Zool 66: 2283-2294, 1988.
11. Wolfe GW and Roughley RE: Description of the pupa and mature larvae of *Matus ovatus ovatus* Leech (Coleoptera: Dytiscidae) with a chaetotaxal analysis emphasizing mouth parts, legs, and urogomphus. Proc Acad Nat Sci Phil 137: 61-79, 1985.

# PHOTOELECTRIC MAGNITUDE MEASUREMENTS OF THE LUNAR ECLIPSES ON MAY 16, 2003 AND OCT. 28, 2004

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## ABSTRACT

The Moon's brightness dropped by 10.73±0.07 and 10.61±0.15 magnitudes during the total lunar eclipses on May 16, 2003 and Oct. 28, 2004 respectively. These magnitude drops are close to the corresponding value for the Jan., 2000 total lunar eclipse and indicate that not much change in the transparency of the atmosphere has occurred in the last 4 years.

***Key words:*** total lunar eclipse, photometry.

## INTRODUCTION

A total lunar eclipse occurs when the moon moves into the darkest part of the Earth's shadow (called the umbra). The time when the Moon enters the umbra is called U2 and the time when the Moon begins leaving the umbra is called U3. The respective times for U2 and U3 for eclipse 1 in Universal Time were: 3:14 and 4:06 (1) and the corresponding times for eclipse 2 were: 2:23 and 3:45 (2). During a lunar eclipse, the moon does not become completely dark because the Earth's atmosphere bends a little light towards the Moon. The amount of light reaching the Moon depends on a variety of factors including the temperature, transparency and chemical composition of the atmosphere. In this paper, the brightness and color of the fully eclipsed moon is reported for two lunar eclipses: May 16, 2003 (eclipse 1) and Oct. 28, 2004 (eclipse 2).

## METHOD AND MATERIALS

An SSP-3 solid-state photometer along with a 0.03 meter f/4 telescope and a filter transformed to the Johnson V system were used in making all measurements. This equipment is described elsewhere (3,4). All magnitude measurements were corrected for both extinction and color transformation. For eclipse 1, alpha Bootes was the comparison star, while alpha-Lyrae was the comparison star for eclipse 2; star magnitudes are listed elsewhere (5).

When the moon was completely in the umbra, the full aperture was used; however, when only part of the moon was in the umbra, the aperture was reduced to about 0.0007 meters . The reduced aperture cut the brightness down by a factor of 2372 or 8.438 magnitudes. An aperture correction was applied to the measurements.

During eclipse 1, a WWV radio signal was used to record the time; these



times are accurate to 1 second. A GPS receiver clock which only gave hours and minutes was used for eclipse 2, the times are accurate to 1 minute. All measurements for the first eclipse were the average of 3 to 5 ten-second photometer readings. All measurements during the second eclipse were the average of 2 to 4 ten-second readings except those at 2:18 and 2:20 UT; in these two cases, 2 or 3 one-second readings were made.

## RESULTS

Table 1 lists the photometric magnitudes for eclipse 1. Most of the measurements were made between U2 and U3. Figure 1 illustrates the magnitude trend as a function of time. Clouds and haze prevented further measurements.

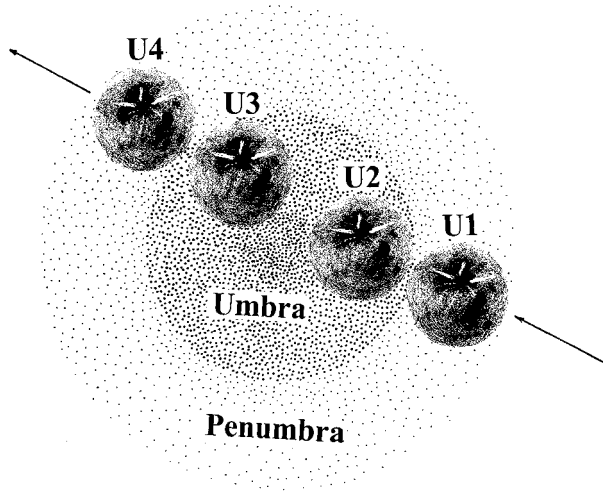


***Figure 1.*** The path of the Moon during eclipse 2. The point U1 is the time when the Moon begins entering the Earth's penumbra while U4 is the time when the moon completely exits the umbra. The points U2 and U3 are the first and last instant of time when the moon is completely inside of the Earth's umbra.

***Table I:*** Measured magnitudes of the Moon as it passed through the Umbra during the May 16, 2003 total lunar eclipse.

| Universal Time (hour:min:sec) | Magnitude |
|---|---|
| 3:11 | -4.24 |
| 3:12:46 | -3.84 |
| 3:20:31 | -3.07 |
| 3:25:11 | -2.83 |
| 3:27:06 | -2.74 |
| 3:36:21 | -2.56 |
| 3:44:31 | -2.51 |
| 3:48:11 | -2.57 |
| 3:51:01 | -2.65 |

Table II lists magnitude measurements during the Oct. 28, 2004 eclipse. The aperture was reduced to 0.0007 m for all measurements made before 2:18 UT and was increased to 0.030 meters afterwards. An appropriate correction was made to the measurements for the changing aperture.

***Table II:*** Measured magnitudes of the Moon as it passed into the Umbra during the Oct. 28, 2004 total lunar eclipse. All measurements were made with the V-filter.

| Universal Time (hour:min) | Magnitude |
|---|---|
| 1:28 | -11.74 |
| 1:37 | -11.38 |
| 1:40 | -11.23 |
| 1:42 | -11.05 |
| 1:46 | -10.81 |
| 1:55 | -10.08 |
| 2:02 | -9.17 |
| 2:04 | -8.93 |
| 2:07 | -8.54 |
| 2:09 | -8.10 |
| 2:11 | -7.76 |
| 2:18 | -5.83 |
| 2:20 | -5.05 |
| 2:23 | -4.17 |
| 2:25 | -4.12 |
| 2:44 | -3.01 |
| 2:47 | -2.91 |
| 2:50 | -2.77 |



## DISCUSSION

Figure 1 shows that the moon grew 1.26 magnitudes dimmer between the time it entered the umbra completely (U2) and mid-eclipse (midway between U2 and U3). The moon had a V-filter magnitude of -2.51 at 3:44:31 UT, which is close to the value predicted by Mallama (6) and to the value of -2.1 reported elsewhere (7). Had the moon not entered the Earth's shadow, it would have reached a magnitude of -13.24; this value includes a 0.35 magnitude brightening due to the opposition surge (8) and a V(1,0) value of 0.19, which is the average V(1,0) value for the waxing and waning phases (4). The total drop in the Moon's brightness as a result of the eclipse was 10.73±0.07 magnitudes, which corresponds to a factor of 19,600.

Figure 2 shows the magnitude measurements for eclipse 2. The Moon's magnitude dropped to -4.17 at U2 and fell to -2.77 at 2:50:30 UT. A haze may have moved in at 2:55 UT and so no further measurements were made.

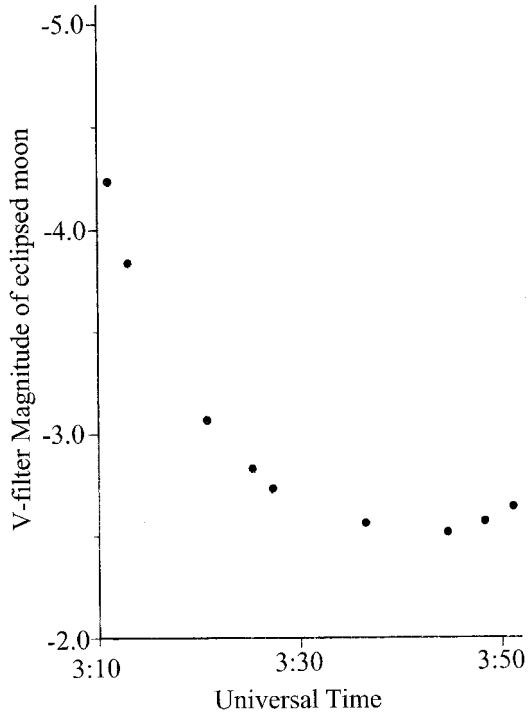


***Figure 2:*** Measured magnitudes of the entire moon as it moved into eclipse on May 16, 2003.

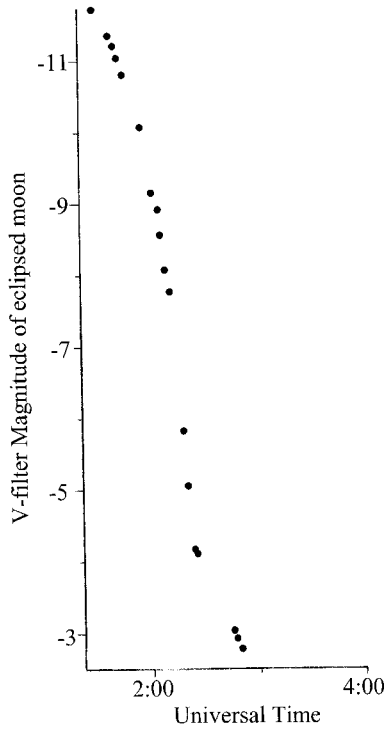


***Figure 3:*** Measured magnitudes of the entire moon as it moved into eclipse on Oct. 28, 2004.

A group of my students were given a description of the Danjon number which is numerical scale that rates the color of the Moon during a total lunar eclipse (7). A Danjon number of 0 means that the eclipsed Moon had a dark gray color whereas a Danjon number of 4 means that the eclipsed Moon had a bright copper-red or orange color. The average Danjon number reported by my students was 2.6 for eclipse 2.

There have not been many whole disc measurements of the brightness of the eclipsed moon. Schober and Schroll (9) carried out measurements using their eyes and a ball bearing and found that the Moon grew 10 magnitudes dimmer when it entered the umbra during the Aug. 6, 1971 total lunar eclipse. Schmude et al. (3) report a 10.74±0.20 magnitude drop for the Jan. 21, 2000 eclipse. The results for eclipses 1 and 2 are consistent with these earlier results.



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**REFERENCES**

1. Astronomical Almanac for the Year 2003. Washington DC US Govt. Printing Office, p. A81, 2002a.
2. Astronomical Almanac for the Year 2004. Washington DC US Govt. Printing Office, p. A85, 2002b.
3. Schmude RW Jr., Davies C and Hallsworth W: Wideband Photoelectric Photometry of the Jan. 20/21, 2000 Lunar Eclipse. IAPPP Communication 76: 75-83, 2000.
4. Schmude RW Jr.: Full-Disc Wideband Photoelectric Photometry of the Moon. Journal of the Royal Astronomical Society of Canada 95: 17-23, 2001.
5. Iriarte B, Johnson HL, Mitchell RI and Wisniewski WK: Five-Color Photometry of Bright Stars. Sky & Telescope 30: 21-31, 1965.
6. Mallama T: Private Communication.
7. MacRobert A: October's Ideal Lunar Eclipse. Sky & Telescope 108: 72-75, 2004.
8. Buratti, BJ, Hillier JK and Wang M: The Lunar Opposition Surge: Observations by Clementine. Icarus 124: 490-499, 1996.
9. Schober HJ and Schroll A: Photoelectric and Visual Observation of the Total Eclipse of the Moon of August 6, 1971. Icarus 20: 48-51, 1973.

# THE IMPACT OF OZONE ON THE SURVIVABILITY BRINE SHRIMP

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## ABSTRACT

Ozone ($O_3$) is a strong oxidizing agent that is routinely used as a disinfectant in water treatment for bacteria, viral infections, and algae. Brine shrimp are used in many aquaculture environments as fish food. Typically the brine shrimp eggs are hatched on site and fed to the fish stock after maturation. Brine shrimp are capable of transporting microbes into the fish stock. In order to eliminate the detrimental effects of infections from this process we ran a series of mortality tests by applying ozone to the brine shrimp. The time durations of ozone ranged from 5 minutes to 24 hours. A second set of experiments expose the brine shrimp directly with ozone over their life cycle (2 months). Our results demonstrate that ozone can be applied directly to the brine shrimp increasing their survivability.

***Key words:*** brine shrimp, ozone, aquaculture.

## INTRODUCTION

Ozone ($O_3$) is a strong oxidizing agent that is produced commercially by corona discharge systems from oxygen (1, 2). Ozone, which is a gas with a pungent odor, is widely used for different water treatment applications such as the reduction of color, degradation of organic pollutants, increase in dissolved oxygen levels and the oxidation of ammonia to nitrite and nitrate. In the gas phase, ozone can be lethal at high concentrations to humans and animals. When bubbled through water, the polar molecule has a maximum solubility in the 3-5 parts per million range, depending on water temperature and ionic strength.

Ozone is unstable and decomposes slowly (minutes) at ambient temperatures and rapidly (< 1 sec) at higher temperatures. Because of this instability, it must be manufactured on-site for industrial applications. Current ozone production is carried out by several techniques. One approach utilizes electrochemical techniques. These systems suffer from high electrical consumption and the cells produce chemicals that can be toxic or difficult to dispose.



The second general area involves the use of high-energy methods such as UV light, beta rays, and lasers to convert the oxygen to ozone but these means of converting oxygen to ozone have found no large-scale commercial application. The third general approach utilizes electrical discharges or plasmas. In this approach, pure oxygen or air in the gas phase is passed through an electric field generated by putting a high voltage across an anode and a cathode. These systems typically suffer from high electrical consumption and relatively low conversion efficiency (1-15%) of oxygen to ozone.

Like fluorine, chlorine, and hydrogen peroxide, ozone is a strong oxidizing agent.

$$O_2 + 4H_3O^+ + 4e^- \rightarrow 6H_2O \quad E^\circ = +1.23\ V \qquad [1]$$

$$Cl_2 + 2e^- \rightarrow 2Cl^- \quad E^\circ = +1.36\ V \qquad [2]$$

$$HClO + H_3O^+ + e^- \rightarrow 2H_2O + 1/2Cl_2\,(g) \quad E^\circ = +1.63\ V \qquad [3]$$

$$HClO_2 + 2H_3O^+ + 2e^- \rightarrow HClO + 2H_2O \quad E^\circ = +1.63\ V \qquad [4]$$

$$H_2O_2 + 2H_3O^+ + 2e^- \rightarrow 4H_2O \quad E^\circ = +1.77\ V \qquad [5]$$

$$O_3(g) + 2H^+ + 2e^- \rightarrow O_2(g) + H_2O \quad E^\circ = +2.07\ V \qquad [6]$$

$$F_2 + 2e^- \rightarrow 2F^- \quad E^\circ = +2.87\ V \qquad [7]$$

$$2H^+ + 2e^- \rightarrow H_2(g) \quad E^\circ = 0.0\ V \qquad [8]$$

Ozone has some well-known advantages over other strong oxidizing agents. For example, $HClO_2$ and HClO leave behind a chlorine-based residue and fluorine gas ($F_2$) is highly corrosive. The kinetics of ozone decomposing a variety of organic compounds have been measured (see Table I) and shown to be quite favorable compared to other strong oxidizing agents.

***Table I.*** Data that show the kinetics of reaction of ozone on certain organic compounds compared to other oxidizing agents. (11, 12)

| Compound | Chlorine | Permanganate | Ozone |
|---|---|---|---|
| Acetophenone | 26 days | 43 days | 25 minutes |
| Benzaldehyde | >3.2 days | 36 minutes | 28 minutes |
| Camphor | >3 days | >5.8 days | 12 minutes |
| p-nitrophenol | 2.1 hours | 1.1 days | 2 minutes |
| Borneol | 1.4 days | 7 days | 53 minutes |
| Methyl-m-toluate | >20 days | 22 days | 5.5 minutes |
| Diacetone-L-sorbose | 100 days | 14 days | 2.8 minutes |

The following thermodynamic considerations are fundamental to understanding the efficient and economic production of ozone from oxygen. First, the production of ozone from oxygen is an endothermic reaction:

$3O_2(g) \rightarrow 2O_3(g) \quad \Delta H = +286$ kJ/mol [9]

The discharge provides the energy needed to convert oxygen to ozone. Second, the decomposition of ozone to oxygen is thermodynamically favored:

$2O_3(g) \rightarrow 3O_2(g) \quad \Delta G = -326$ kJ/mol [10]

Lowering the temperature of the system can slow this decomposition. If the discharge energy is too low [Eq. 9], the formation of ozone from oxygen will not take place. If the discharge energy is not dissipated rapidly [Eq. 10] the decomposition of ozone will be accelerated.

Although ozone can be toxic to living organisms, if used correctly it can be a highly effective disinfectant in aquaculture systems (3). When applied to aquaculture systems it has the ability to eliminate harmful bacteria, deactivate viruses, remove color, and improve water quality (4). Ozone has been successfully demonstrated in closed loop aquaculture systems, such as fish hatcheries. The ability to eliminate nitrogenous wastes and bacteria produced by aquatic animals is a challenge that must be constantly met by the people that control the closed aquaculture systems (5, 6).

Studies have been conducted on the impact of ozone on different aquatic animals. One such experiment utilized shrimp to see if ozone had any effect on the shrimp pathogens *vibrio* and *Fusarium solani*. The results of the experiment showed that 99.9% of these organisms are killed when they are exposed to ozone for 5 minutes or less (7). Atlantic salmon were treated with 13g of ozone for one hour per day. Water clarity was maintained with the help of ozone. When the use of ozone was terminated there was an accumulation of humic compounds and there was a decrease in water quality. The ozone generator was accidentally left running for 15 hours and there were many fish mortalities observed (8). Other toxins that have been proven to be deactivated by ozone treatment are *Clostridium botulinum* (botulism) and *Gymnodinium breve* that is one of the red tide toxins (9). Ozone has also been used in another separate experiment to compare how fish and shrimp react to being exposed to ozone. The shrimp showed a higher tolerance to ozone than the fish due to their protective shell. Although the fish were not as tolerant as the shrimp were to the ozone, positive results were found from the use of ozone (10).

Brine shrimp are primarily used for food in many fish cultures. Brine shrimp can be a source of bacteria when introduced into these systems when they are used as fish food. Previous studies have shown that brine shrimp also benefit from the use of ozone in their environments (2). The purpose of this project is to see if ozone has any effect on the survival rate of brine shrimp over a period of 96 hours. This information is helpful because the data will provide the maximum amount of ozone brine shrimp can handle and still survive long enough to be used in other mediums such as nourishment for fish.



## EXPERIMENTAL

The first set of experiments consisted of separate hatchings of brine shrimp that were subjected to different amounts of ozone exposure (Table II, times from five minutes to six hours). Different quantities of brine shrimp were hatched in 2-liter bottles to measure any correlation between different densities of brine shrimp and their survival rates when exposed to varying time allotments of ozone in brackish water made from "Instant Ocean." The average salinity was 38ppt, the average pH was 8.64, and the average temperature was 21 degrees Celsius. The brine shrimp took approximately 24 hours to hatch. Once the brine shrimp hatched they were fed, and approximately 24 hours after they hatched they were exposed to ozone for the specific time duration. The different time amounts of ozone exposure were 5 minutes, 30 minutes, 1 hour, 3 hours, 6 hours, and 24 hours. The ozone was applied to the brine shrimp by attaching air stones to the ends of the plastic tubing that exited the ozone generator. The water was saturated with ozone which has an accepted concentration of 5 parts per million. The brine shrimp were then observed over 96 hours to measure mortality rates.

***Table II.*** Different quantities of brine shrimp eggs were allowed to hatch in 2-liters of water. Each container was then ozonated for a set amount of time (5 minutes, 30 minutes, etc.). The brine shrimp were then visually observed for 96 hours. Alive indicates some shrimp were observed. Dead indicates no living shrimp were observed.

| Shrimp in grams | 5 mins Ozone | 30 mins Ozone | 1 hr Ozone | 3 hrs Ozone | 6 hrs Ozone | 24 hrs Ozone |
|---|---|---|---|---|---|---|
| 0.15 | Alive | Alive | Alive | Alive | Dead | Dead |
| 0.3 | Alive | Alive | Alive | Alive | Alive | Dead |
| 0.45 | Alive | Alive | Alive | Alive | Alive | Dead |
| 0.6 | Alive | Alive | Alive | Alive | Dead | Dead |
| 0.75 | Alive | Alive | Alive | Alive | Dead | Dead |
| 0.9 | Alive | Alive | Alive | Alive | Dead | Dead |
| 1.05 | Alive | Alive | Alive | Alive | Dead | Dead |
| 1.2 | Alive | Alive | Alive | Alive | Dead | Dead |
| 1.35 | Alive | Alive | Alive | Alive | Dead | Dead |
| 1.5 | Alive | Alive | Alive | Alive | Dead | Dead |

In a second set of experiments, six 50-liter tanks were used to measure the periodic application of ozone and its impact on brine shrimp survival. Table III shows the dosages per week to each tank over an eight-week cycle. Typically marine organisms, such as shrimp, when living in an unfiltered environment will have high mortality rates due to the accumulation of

ammonia, bacterial infections derived from feces and discarded body armor due to molting, and viral infections. All tanks were continuously aerated (control and o-zone) throughout the 8-week experiment. The saturated levels of ozone in pure water (3-5 ppm) were achieved rapidly in small (<10 seconds) and large containers (<30 seconds). Attempting to measure the oxidizing agent concentration [$O_3$] in a system with a range of living organisms (i.e. diatoms, algae, shrimp), various suspended organic (i.e. undigested food) and inorganic matter (shrimps shells, ammonia, etc.) give inconsistent results. We assume it was at saturated levels for the duration of the ozonation.

***Table III.*** Tank #1 and 2 represent controls for the experiment (no ozone applied). Tanks #3-6 represent different levels of ozone application to the 50-liter solutions. The experiments were started on 1/6/03 and ended 2/26/03. Each tank was sampled ten times by removing 310 mL of water and counting the number of brine shrimp. (Tank #3 and 4, ozonated 3X per week each for 10 minutes; tanks #5 and 6, $O_3$ applied 1X per week, 10 minutes each)

| Dip # | Tank 1 # (No $O_3$) | Tank 2 # (No $O_3$) | Tank 3 # | Tank 4 # | Tank 5 # | Tank 6 # |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 5 | 4 | 6 |
| 2 | 0 | 0 | 1 | 5 | 6 | 13 |
| 3 | 0 | 0 | 0 | 5 | 4 | 9 |
| 4 | 0 | 0 | 2 | 8 | 3 | 11 |
| 5 | 0 | 0 | 1 | 7 | 3 | 12 |
| 6 | 0 | 0 | 2 | 6 | 4 | 12 |
| 7 | 0 | 0 | 1 | 3 | 7 | 3 |
| 8 | 0 | 0 | 1 | 2 | 3 | 7 |
| 9 | 1 | 0 | 1 | 5 | 8 | 13 |
| 10 | 0 | 0 | 5 | 3 | 4 | 8 |

## RESULTS AND DISCUSSION

Table II provides the average results of three sets of mortality tests. All results were recorded after 96 hours of observation. In trials #1-4 all shrimp remained alive after exposure to ozone. During the observation in trial #5, many of the shrimp showed a severe decrease in movement. The brine shrimp that received 24 hours of exposure to ozone were all found dead when the ozone was removed from the soda bottles. The soda bottles had the pH, DO, and ORP measured before and after receiving treatment with ozone. The use of ozone did not affect the long term levels of pH, DO, and ORP levels in any of the experiments. Once this set of results was completed, a series of grow outs were conducted to study the impact that ozone had on the long-term survival of the brine shrimp. Table III provides the results after the eight-week



grow-outs were complete. In these experiments there was a control in which brine shrimp were allowed to grow at a relatively high density (10 grams of eggs per 50 liters of solution) with only aeration. As the data set indicates, simple aeration was not enough to maintain a level of water quality needed for the shrimp to survive for the average duration of a brine shrimp life cycle. We found that over-ozonation (i.e. 7 times per week, 30 minutes each) quickly killed the shrimp. As the data demonstrate, ozonation for 1-3 times per week for duration of 10 minutes each increased the survival ability of the organisms.

## CONCLUSIONS

Past work in this lab with ozone has centered on fundamental and applied studies associated with its generation[11-13] as well as its potential applications in nanotechnology[14,15]. This work has given us opportunities to understand the potential of the environmental friendly (provided it is applied correctly) oxidizing agent in a number of chemical systems. Because of its favorable standard reduction potential (>2.0 V), it is easy to over use in many applications. In this application, if ozone is applied continuously, it will kill the shrimp rapidly. For this work, we found that ozonating between 1-3 times per week for 10-20 minutes per time increased the survivability of the shrimp when compared to the control. We did monitor parameters such as pH, DO, and salinity but found no correlation of these chemical parameters with survivability. The lack of ozone may have allowed ammonia levels to increase to toxic levels and/or bacterial and viral species that are harmful to the shrimp to multiply uncontrollably.

This work shows that applying ozone directly to brine shrimp can increase their survival rate if it is done in a controlled fashioned. Past work with ozone and shrimp has always applied ozone to the water off-line (i.e. a holding tank) and then returned the treated water to the runway. This adds complexity to the aquaculture process and increases the capital costs. All shrimp share a similar attribute in that their hard outer exoskeleton, composed of chitin, proteins, and some calcium carbonate, protects them from the oxidizing effects of ozone. Using ozone directly in a shrimp runway may be a method to increase the efficiency and lower the cost of raising shrimp in an aquaculture setting.

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## REFERENCES


1. Owsley D: Ozone for disinfecting rearing water. American Fisheries Society Symposium 10: 417-420, 1991.
2. Hochheimer J and Summerfelt S: Review of ozone processes and applications as an oxidizing agent in aquaculture. The Progressive Fish-Culturist 59: 94-105, 1997.
3. Theisen D, Stansell D and Woods LC: Disinfection of Nauplii of Artemia franciscana by ozonation. The Progressive Fish-Culturist 60: 149-151, 1998.
4. Singh S and Wheaton F: Ozone application in aquaculture. Aquaculture Magazine January/Feburuary: 58-63, 1999.
5. Summerfelt ST, Hankins JA, Weber AL and Durant MD: Ozonation of a recirculating rainbow trout culture system 1 II. Effects on microscreen filtration and water quality. Aquaculture 158: 57-67, 1997.
6. Suantika G et al: The use of ozone in a high density recircultaion system for rotifers. Aquaculture 201: 35-49, 2001.
7. Danald DA, Ure J and Lightner DV: Preliminary results of ozone disinfection of sea water containing the potential shrimp pathogens Vibrio species and Fusarium solani. Ozone: Science & Engineering 1: 329-334, 1980.
8. Williams RC, Hughes SG and Rumsey GL: Use of ozone in a water reuse system for salmonids. Progressive Fish-Culturist 44: 102-105, 1982.
9. Rosenthal H: Ozonation and sterilization. World Symposium on Aquaculture in Heated Effluents and Recirculation Systems May 28-30, 1980. 1: 219-274, 1981.
10. Reid B and Arnold C: Use of ozone for water treatment in recirculating-water raceway systems. Progressive Fish-Culturist 56: 47-50, 1994.
11. Manning TJ: Production of ozone in an electrical discharge using inert gases as catalysts. Ozone: Science & Engineering 22: 53-64, 2000.
12. Manning TJ and Hedden, J: Gas mixtures and ozone production in an electrical discharge. Ozone: Science & Engineering 23: 95-103, 2001.
13. Manning TJ: Apparatus and method for generating ozone. United States Patent #6,022,456
14. Manning TJ, Olsen K, Hardin L, Purcell J, Ayers TM, Duncan MA and Phillips D: Extensive ozonation of $C_{60}$: Degradation or polymerization? Submitted Ozone: Science and Engineering.
15. Manning TJ, Olsen K, Hardin L, Purcell J, Ayers TM, Duncan MA and Phillips D: Degradation of carbon nanotubes by ozone and nitric acid. Submitted Ozone: Science and Engineering.




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