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Article *in* Freshwater Crayfish · December 2015

DOI: 10.5869/fc.2015.v21-1.1

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Freshwater Crayfish 21(1):1–5, 2015
ISSN: 2076-4324 (Print), 2076-4332 (Online)
http://dx.doi.org/10.5869/fc.2015.v21-1.1

Astacology and Crayfish Conservation in the Southeastern United States: Past, Present and Future

Zachary J. Loughman [1] and James W. Fetzner Jr.[2]

[1] 2015 S.D.A.F.S. Crayfish Symposia Chair, Department of Natural Sciences and Mathematics, West Liberty University, West Liberty, WV 26003 USA.
*Corresponding Author.— *zloughman@westliberty.edu*

[2] IAA Managing Editor, Carnegie Museum of Natural History, Section of Invertebrate Zoology, 4400 Forbes Avenue, Pittsburgh, PA 15213-4080 USA.

A B S T R A C T

This paper summarizes the contributions from the symposium on freshwater crayfish held from January 29th thru February 1st in Savannah, Georgia. The symposium was hosted at the Spring meeting of the Southern Division of the American Fisheries Society. This symposium was the third such gathering of astacologists from the southeastern United States in the last six or so years. This symposium was attended by over 50 students, agency biologists and astacologists from across the central and southeastern United States. A total of 24 manuscript were received for consideration in this special meeting issue of Freshwater Crayfish, and of those, 19 contributions have made it into the present volume. Several of the manuscripts were postponed and so will appear in an upcoming issue of the journal. This issue has been dedicated to the memory of Dr. John E. Cooper, our mentor and astacological colleague from North Carolina who passed away earlier this year.

A R T I C L E I N F O

Article History:
Submitted: 20 DEC 2015
Accepted: 20 DEC 2015
Published Online: 31 DEC 2015
Published Print: 31 DEC 2015

Keywords:
astacology;
crayfish;
Savannah, GA;
southeastern US;
2015 symposium;

Contributing Author E-mail(s):
FetznerJ@CarnegieMNH.Org;

Few organisms are more familiar or representative of the lotic and lentic freshwater environments of the southeastern United States (SEUSA) than the freshwater crayfish. Crawfish, crawdads, mudbugs, crawcrabs, are all regional vernacular names used to describe these decapod crustaceans, which reach their highest global diversity in the Appalachian Mountains, Costal Plains, Piedmont, and Ozark Mountains of the southeastern United States (Taylor et al. 2007; Richman et al. 2015). Though quite familiar to the populace of the southeast, crayfish from this region have not received much focused attention by the broader scientific community, until just recently. Only now are we beginning to focus on discovering aspects of their biology, geographic distributions, and life histories in order to gather data to address the conservation issues that this diverse charismatic fauna face in the wake of current and future human-mediated environmental change. As outlined first in Taylor et al. (1996), followed by Taylor et al. (2007), and most recently in Richman et al. (2015), crayfish as a whole represent a group of animals with an unusually high imperilment rate, primarily the result of anthropogenic habitat degradation and human development. Naturally occurring high rates of endemism further compound this issue (Taylor et al. 1996; Taylor et al. 2007; Richman et al. 2015), thus creating an ecological situation primed for further declines. Conservation authorities at both the state and federal levels have been tasked with thwarting and reducing crayfish imperilment, but they need information on crayfish life histories, natural history, ecology, and even taxonomy in order to generate conservation strategies and to implement recovery plans. Often, this information is not available, thus further delaying actions that could help stem the tide of crayfish imperilment, ultimately limiting conservation planning for crayfish faunas at the local, regional (i.e., SEUSA), national or even global level. Fortunately, this situation is starting to change for the better as more and more scientists and their students become interested in astacology and begin to address this information shortfall.

Without question, the first and arguably most influential astacologist to work in the southeast was Horton H. Hobbs Jr. Hobbs indicated that his introduction and eventual life-long work with crayfish began as an undergraduate student, when he retained a few crayfish from the dissections he made during a Zoology laboratory class he was taking at the University of Florida, and brought them back to his dorm room for further study (Reed and Manning 1998). Those animals spawned both an interest and passion that led to his eventual description of over 70% of the crayfish fauna found in the SEUSA, as well as a revision of the family Cambaridae (Hobbs 1942), and naming of the majority of North American crayfish genera that we still recognize today.

The monograph that Hobbs produced on the crayfishes of Georgia (Hobbs 1981) is still to this day considered the gold standard of what a *Crayfishes of…* text should be. In addition to the pioneering work of Hobbs, a mix of additional historical and contemporary workers have contributed to our current understanding of SEUSA crayfish biology and taxonomy, including Hermann A. Hagen, Charles Girard, Walter Faxon, Arnold E. Ortmann, Edwin P. Creaser, Joseph F. Fitzpatrick Jr., Raymond F. Jezerinac, William H. Penn, Raymond W. Bouchard and John E. Cooper. They all contributed significantly to the vast body of work that current and future generations of astacologists use or will use as a starting point for their research, and hopefully those that follow will continue to build upon and augment that growing store of knowledge.

Back in January of 2008 in Wheeling, West Virginia, a symposium dedicated to the conservation, taxonomy, and ecology of SEUSA crayfish was held as part of the annual meeting of the Southern Division of the American Fisheries Society (SDAFS). This meeting represented the first time that astacologists working across the SEUSA met to present research findings specific to the region, discuss crayfish conservation issues, ponder taxonomic concerns, and network as a unified group of scientists and conservationists. In subsequent years, several additioanl SEUSA crayfish symposia have been held at other major meeting venues. These include 1) SDAFS in New Orleans, Louisiana in 2009, 2) the annual meeting of the Society for Freshwater Science in Louisville, Kentucky in 2012, and most recently 3) the SDAFS meeting in Savannah, Georgia in January 2015 (see Loughman 2015). Plans for another symposium at the 2016 SDAFS meeting are in the works. Both the 2008 (Loughman et al. 2010) and 2012 symposia (Helms et al. 2013) produced proceedings that resulted in over 30 publications; publications that have helped to fill knowledge gaps needed by crayfish conservation biologists tasked with generating conservation plans for SEUSA crayfish.

Keeping with the tradition established by the 2008 and 2012 symposia, the volume before you is the product of the 2015 SDAFS crayfish symposium. Articles found between these covers include descriptions and applications of field and molecular methods, new insights into cambarid crayfish ecology, life history and physiology, as well as new information on species distributions and survey results. In terms of methods, several manuscripts detail the use of genetics to aid in species identification (Cabe et al. 2015) and detection (Figiel and Bohn 2015), as well as critical reviews of the application of both morphology and genetics for species identification (Kessler et al. 2015). Taylor et al. (2015) detail a possible strategy for collecting crayfish in lotic bottomland habitats, where a disproportionate number of species are often difficult to adequately sample due to their propensity to burrow. Pit tag utilization to gain insight into ovigerous female habitat selection and use is the subject of Black et al. (2015). All of these papers add important tools to the tool chests of current and future astacologists.

As more studies accumulate, we are starting to understand the ecology and natural history of crayfish from the SEUSA and this understanding is leading to the general observation that crayfish communities are composed of species that occupy multiple trophic levels and very diverse niches. For example, Herleth-King et al. (2015) contribute to this body of knowledge by demonstrating that two syntopic headwater species, *Orconectes meeki meeki* and *Orconectes williamsi*, preferred and segregated themselves into different in-stream habitats in two Missouri streams. Determining the ecological parameters associated with the biology of SEUSA primary burrowing crayfish is a specific research priority for several current astacologists, and the contribution by Keller et al. (2015) that appears herein, adds to this growing dataset. *Cambarus harti* is a narrow endemic burrowing species limited to the Flint and Chattahoochee drainage of SE Georgia. Keller et al. (2015) investigated soil and hydrologic factors associated with the presence or absence of the species at sites within its restricted global distribution. Crayfish physiology is an often overlooked area of study, at least in the usual crayfish research journal outlets. However, Meade et al. (2015) examined the physiological stress of *Cambarus latimanus* in relation to temperature, and this may be of particular interest to astacologists trying to understand how a rise in stream temperatures may affect cambarid crayfish physiology, especially as humans continue to affect the global climate.

Crayfish trophic position and feeding habits were the subject of three contributions to this volume. McClain (2015) determined that *Procambarus clarkii* excavate potential forage from the benthos of wetlands and thus do not simply feed on the forage present on the surface. Fagundo and Loughman (2015) determined the summer and autumn feeding habits of female *Cambarus chasmodactylus* in a West Virginia stream. They found that female *C. chasmodactylus* feed as generalists during most of their annual period of activity, but convert to feeding specialists (on gastropods) just prior to and following oviposition. Trophic dynamics and cascades were detailed for omnivorous epigean species by Ludlam et al. (2015), who determined that crayfish density has an overall impact on consumers at lower trophic levels. Each of these manuscripts contributes another small piece to the ever growing crayfish ecology puzzle.

Moore et al. (2013) determined that the majority of North American crayfish lack detailed life history studies. Thus, any action taken by conservation officials is severely limited by this deficiency of basic biological information, making life history studies one of the most important contributions that researchers can presently make. In fact, such studies are the current focus of many SEUSA astacologists. Three data deficient species receive their first critical life history analysis due to work contained in this volume, two of which are narrow endemics restricted to one or two watersheds. *Cambarus parrishi* is an epigean species limited to the streams of western North Carolina and the Hiwassee basin of north Georgia. Davis et al. (2015) determined the annual life history, time of oviposition, and seasonal form change for this possibly imperiled species. Roberson et al. (2015) investigated *Cambarus truncatus*, a narrow endemic primary burrowing species limited to the Oconee Basin in Georgia. They determined the number of eggs per female, male form state, seasonal female glair state, and size cohorts, all of which represent the first critical review of this species biology. Noss and Simon (2015) present the first critical review of *Orconectes ronaldi* meristic and allometric growth across sexes and age groups, and present a model for future analysis of this type of data. Moore et al.'s (2013) call to action prompted Stoeckel et

al. (2015) to both review and propose possible strategies for future crayfish life history studies in the SEUSA. Specifically, Stoeckel et al. (2015) investigated the minimum capture number needed for various age groups to successfully complete a crayfish life history study in the SEUSA.

All of these aforementioned papers contribute to our overall understanding of SEUSA crayfish, and they all bring a critical missing component to bear on crayfish conservation issues within the region. One of the other critical components necessary for the conservation process are detailed field surveys and inventories, which help us to understand which species occur where, and can also allow for estimates of population density. To that end, Adams et al. (2015) detail the results of a biotic inventory of Sipsey Fork Drainage in Mississippi, with an emphasis on species occurrences in drainages impoundments. Adams et al. (2015) employed a pragmatic approach to gathering temporal data and occurrence records by investigating the stomach contents of fish collected both during and prior to their survey. Their results indicated that two species, *Orconectes lancifer* and *Orconectes* (cf.) *ronaldi,* were likely introduced into the drainage after 1990. Invasive species (especially other crayfish) can negatively affect and cause the decline of native crayfish species found throughout the SEUSA. Cobble et al. (2015) determined that *Procambarus acutissimus* has been eliminated from nine of the ten pools in their study area by the introduced *P. clarkii,* where the former species was once the only crayfish species found at that site a few years prior.

Eversole and Foltz present the combined results of field surveys and 3900+ databased museum records for South Carolina crayfish, and produced the first comprehensive review of the state's crayfish fauna to date. Eversole and Foltz (2015), along with recent efforts by both Keith Crandall and Henry Robinson in Arkansas (e.g., Ainscough et al. 2013), Chris Taylor and Guenter Schuster in Kentucky (Taylor and Schuster 2004), Chris Taylor, Guenter Schuster, Stuart McGregor and colleagues in Alabama (Smith et al. 2011), Chris Skelton and colleagues in Georgia (Skelton 2010), Jay Kilian and colleagues in Maryland (Kilian et al. 2010), Susan Adams and colleagues in Mississippi (Adams and Henderson. 2015), Bob DiStefano and colleagues in Missouri (DiStefano et al. 2015), the efforts of the late John Cooper in North Carolina (Cooper 2010), Dan Johnson in Texas (Johnson 2010), Zac Loughman and Stuart Welsh in West Virginia (Loughman and Welsh 2013) and Virginia, where Roger Thoma sampled the majority of the state (Thoma 2014), and Zac Loughman has surveyed the James and Roanoke River systems (Loughman 2013) have all helped to document the SEUSA crayfish fauna. The combined collective effort and data assembled by these surveys represent an incredible amount of field work, thousands of individual collections, and tens of thousands of specimens, resulting in the most comprehensive understanding of North American crayfish distributions to date, and have also led to the description of many previously unknown species.

Data is being gathered and accumulated on the crayfish of the SEUSA at a faster rate today than ever before. Paramount to the continued success of this effort will be our ability to stimulate the curiosity and passion for crayfish in the next generation. Whether our next round of budding astacologists will come as a reuslt of a left-over crayfish carcass from a zoology dissection lab or an innocent question on crayfish from an interested child, we all need to help foster an interest in our favorite organisms so that the next generation can carry the work forward. Currently, astacologists have many amazing technologies for studying crayfish right at their fingertips, something that Hobbs and company could only have dreamed about. Effectively, this volume serves as an important milestone for the future study of SEUSA crayfish, with over 70% of the articles having students, both undergraduate and graduate, as co-authors. One of these young men and women may be the future generation's Hobbs, Cooper, or Fitzpatrick; we can only hope. To that end, during the preparation of this volume, a giant and driving force behind SEUSA astacology, Dr. John Cooper, passed. A memorial paper to Cooper (Fetzner, 2015) is contained in this volume, and both the Managing Editor (JWF) and the Symposium Chair (ZJL) felt that it was only fitting to dedicate this volume and the papers it contins to his memory. This one's for you, John.

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