An Investigation of Marine Taxa Referenced in Thesis Titles and Abstracts
as a Collection Development Tool

We evaluated titles and abstracts of 372 marine biology master's theses to identify the marine taxa researched by graduate students at our institution. Of 191 species investigated since 1976, the 15 most-researched species are regionally important and have each been researched at least five times. Fisher exact tests identified taxa demonstrating statistically-significant recent growth in research. A collection analysis of monographs about these species and taxa compared to four peer institutions highlighted strengths and weaknesses within our marine biology collection. This investigation demonstrates how taxonomic data in titles and abstracts can serve as a tool to guide biology collection development.

KEYWORDS: *collection management, peer comparison, marine taxa,
graduate theses, research trends*

Introduction

One of the challenges faced when making firm order acquisitions for a library collection is the allocation of scarce resources. Librarians often seek information relating to user needs in order to make fiscally-responsible choices. Direct requests made by library users for material are a significant indicator of the potential utility of a purchase. Additional evidence of potential value may be obtained from other sources to guide acquisition decisions.

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In memory of Sarah Smith-Gardner

At the Marine Resources Library (MRL) in Charleston, SC, the circulating collection of approximately 33,000 monographs serves the research needs of a diverse population. Students and faculty of the Graduate Program in Marine Biology (GPMB) of the College of Charleston (CofC), and research scientists of the South Carolina Department of Natural Resources (SCDNR) Marine Resources Division (MRD), the National Oceanic and Atmospheric Administration (NOAA) Charleston laboratories, and the National Institute of Standards and Technology (NIST) Charleston laboratory comprise the primary library user population. The MRL operates as a branch library of the College of Charleston, a public Sea Grant institution of higher education granting liberal arts and sciences bachelor's and master's degrees. The MRL collection development budget has been reduced by almost 80% in recent years, with anticipated regrowth in the future. New acquisitions, funded by CofC, are aimed primarily at meeting student and faculty information needs.

The current investigation seeks to guide the strategic acquisition of monographs, particularly in the zoology and botany areas of the MRL collection. Direct requests from faculty and students for specific material have been scarce in recent years, so master's theses were chosen as a potential source of taxonomic data to aid collection development. This study seeks to identify which species have been most researched by GPMB students and which taxa appear to be growth areas. A third objective is to assess the adequacy of the collection compared to peer libraries, in areas that are revealed to be of particular research interest.

Literature Review

Scholarly material has long been used as a source of data for collection management, both to guide acquisition decisions (Gross and Gross 1927) and to assess existing holdings (Smith 2003).

Dissertations and theses, by virtue of their comprehensive research at advanced (typically postgraduate) level, are often chosen as the source of data with which to undertake bibliometric research (Scalfani 2017).

Citation analysis has frequently been used to guide collection decisions. Citations may be interpreted as evidence of value in which a user-focused collection management strategy may be grounded (Barnett-Ellis and Tang 2016). Emphasis and design of past citation analysis studies vary widely (Hoffmann and Doucette 2012) including investigation of citation ages (Nabe and Imre 2008), subject category (Burright, Hahn, and Antonisse 2005), and correlation with user perceptions of collection adequacy (Rossmann 2013). Numerous citation studies have been undertaken in the biological and marine/atmospheric sciences (Zipp 1996; Kuruppu and Moore 2008; Nabe and Imre 2008; Miller 2011; Kimball et al. 2013; Timms 2018).

In contrast to the focus on resource use evidenced by citations, another aspect of the data analysis of theses and dissertations emphasizes the subject matter of the thesis itself. This may be investigated from various data points including title and assigned keywords (Caffarella 1999; Zong et al. 2013). The title of a scholarly work is a concise descriptor and may have one of several communicative purposes, including revealing the subject or captivating the attention of a target audience through its linguistic form (Crosby 2012; Soler 2007). Longitudinal analysis of titles in specific contexts has been used to evaluate the development of academic fields and research trends therein (Rodríguez and Moreira 1996; Scalfani 2017), or to describe research areas (Ko et al. 1994). The extent of analysis ranges from basic descriptive statistics to complex statistical analyses.

An abstract, when well prepared, is a rich and concise source of information about a scholarly work. Studies of abstracts often analyze their organization, adherence to abstracting

standards, and use of linguistic mechanisms (Cross and Oppenheim 2006; Stotesbury 2003; Anderson and Maclean 1997; Ebrahimi and Chan 2015). Abstracts, like titles, have also been employed to investigate trends in themes and research areas in a given field (Rotgans 2012). Synthesis of bibliometric data, including word analysis in titles, keywords, and abstracts, is another technique employed to identify current trends in a discipline (Zhang, Xie, and Ho 2010).

In the fields of fisheries, aquaculture, and ichthyology, a number of studies have been undertaken to identify trends and patterns or gaps in a body of research. Studies adopting a semantic approach have employed textual analysis to identify research topics and to investigate the interrelatedness of words. Syed and Weber (2018) identified topics and subtopics within the full text of fisheries modeling articles, using the Latent Dirichlet Allocation probabilistic model. Natale, Fiore, and Hofherr (2012) employed Latent Semantic Analysis on article titles and keywords, and Topic Modeling on article abstracts, titles, and keywords, to identify aquaculture research disciplines and methodologies. They independently evaluated references to species to facilitate topic-species analysis and to investigate methodologies and research disciplines by species.

Research has also been undertaken to identify knowledge gaps with regard to specific aquatic species. These studies, based upon species-specific searches in leading bibliographic databases, evaluated the research volume related to each species. Knowledge gaps were identified by comparing species-specific research output with other criteria such as fishery volume (Aksnes and Browman 2016), trade volume and conservation status (Cohen et al. 2017), and research topic (Nikolic et al. 2011). Broader studies, using similar techniques, documented all species identified within a collection of literature. One study recorded and analyzed species from article abstracts, with taxonomic families derived from Fishbase (<http://www.fishbase.org>),

and also considered conservation status (Azevedo, Mesquita, and Young 2010). A temporal analysis of the frequency of taxon references over two five-year periods demonstrated changes in the volume of research of species referenced in article titles (Jarić et al. 2012). Most studies investigated the research disciplines either assigned in databases or derived from textual analysis.

Hypotheses

Hypothesis 1: GPMB graduate students place most research emphasis on commercially and recreationally-important and endangered marine species of South Carolina.

Hypothesis 2: Growth areas of GPMB research are associated with recent concerns in South Carolina marine ecosystems (threatened and invasive species).

Hypothesis 3: The MRL monograph collection is strongest in relation to highly-researched recreationally and commercially-important species or their superior taxa, and weakest in recent growth areas of GPMB research.

Methods

A master list of published GPMB theses maintained at MRL was used as the basis for collating thesis data. Thesis titles, years, and abstracts published since 2007 were downloaded from ProQuest Dissertations and Theses Global (PQDT) database and exported into a Microsoft Excel spreadsheet. Theses older than 2008, and others that were not represented in PQDT online, were located in the MRL stacks. Titles and abstracts of print theses were scanned with Optical Character Recognition and added to the spreadsheet. Of 375 theses, one had never been received in print and was not available in PQDT. Two were checked out and were also not available online.

The titles and abstracts of the remaining 372 theses were evaluated for reference to species or other taxonomic ranks. Distinction was made between species as the focus of the study and species merely observed in relation to the primary focus of the study. For example, a study of several types of coral referenced numerous organisms observed interacting with the coral, but they were secondary to the focus of the study. Thus, the coral species were documented but the many secondary organisms were not. For each species or other taxonomic rank identified in a thesis, a new spreadsheet row was added. A total of 496 taxonomic entries were recorded across the 372 theses, resulting in 496 rows in which thesis and taxonomic data were synthesized.

Species were referenced in theses either by common name, scientific name, or by both names, and were recorded in the spreadsheet as referenced in the thesis. References to other taxonomic ranks or divisions were also recorded for each thesis. Once all taxonomic references had been identified, a process of correction and standardization was undertaken. All species and other taxonomic ranks were recorded with their current accepted scientific names, according to the World Register of Marine Species (WoRMS, <http://www.marinespecies.org/>). Errors and inconsistencies in spelling were corrected and common names for species were carefully evaluated to ensure the correct scientific name was chosen. For each entry, a chain of select superior taxonomic ranks (genus, family, order, class, and phylum) was documented with reference to WoRMS.

A Python (<https://www.python.org/>) script was written to read data from the spreadsheet and insert it into a PostgreSQL (PGSQL) relational database. A thesis table documents the title, abstract, and publication year of each thesis. Additional tables list occurrences of each taxonomic rank. A final table documents links between theses and taxonomic ranks for each spreadsheet

row (taxonomic rank referenced in the thesis and superior taxonomic ranks), referencing thesis identifiers and taxonomic rank identifiers.

Queries were run on the database to extract tables of data representing the number of occurrences of each taxon at each taxonomic rank. Data were extracted for each of five decades to facilitate longitudinal analysis. To analyze differences in the number of occurrences of each taxon over time, Fisher exact tests were run on the data for the two most recent decades to identify statistically-significant variation among taxa over time.

The taxa identified as statistically-significant growth areas were further investigated. Species from these taxa that were referenced in thesis titles and abstracts were compared to lists of conservation priority and invasive species of South Carolina (SCDNR 2014a; SCDNR 2014b; SCDNR 2014c; SERTC n.d.a.; SERTC n.d.b.; SERTC n.d.c.) and matches were documented.

MRL holdings of the most-researched taxa and taxa with statistically-significant growth in research interest were investigated using WorldCat queries by associated Library of Congress (LC) Call Numbers and Subject Headings. Call Numbers and Subject Headings for each taxon were determined using the *Library of Congress Classification* and *Library of Congress Subject Headings* on the Library of Congress Linked Data Service (<http://id.loc.gov/>). Classes, orders, and families were investigated, with species being considered too specific and some phyla being too broad in scope for meaningful Call Number and Subject Heading-based data to be obtained. In cases where Call Numbers or Subject Headings were not listed for a specific taxonomic rank, the nearest appropriate superior Call Number range or Subject Heading was chosen. Holdings of four peer libraries in the Southeastern United States with marine science collections at Virginia Institute of Marine Science, Skidaway Institute of Oceanography/University of Georgia, Marston Science Library/University of Florida, and Texas A&M University at Galveston were also

documented for each taxon using WorldCat. In cases where a marine science library did not use an OCLC Symbol distinct from its broader institution's library system, the symbol for the whole institution was used to define the scope of the search. MRL uses two OCLC symbols, reflecting its affiliation with the College of Charleston Libraries (SBM) and its status as a NOAA Regional Library (OAS). Both were used in this investigation. Queries were limited to non-juvenile, non-fiction material in the Book and Internet Resources categories. Ranks were established for each institution for each taxon, by number of items held. An overlap analysis was also run between MRL and the synthesized holdings of the peer group to identify the extent of material unique to MRL and common to both MRL and the peer group.

Results

The GPMB has grown since its genesis in the 1970s, with the number of theses produced consistently increasing over the decades. As the program has reached its current capacity with an intake of sixteen students per year, the 2010s are on track to match the thesis count for the 2000s. Overall, 191 species, from 178 genera, 143 families, 80 orders, 34 classes, and 17 phyla were identified from the 372 theses analyzed. While the number of theses produced per decade has increased, so has the diversity of taxa studied, as represented by Table 1.

Fifteen species were identified as the most-researched organisms (Number of referencing theses ≥ 5) during the study period and their common names and significance in South Carolina are documented in Table 2. Approximately 60% of these species are of importance to both commercial and recreational fisheries or aquaculture in the region.

Extrapolation of superior taxonomic ranks of the most-researched species and comparison to overall occurrences of these taxa at each rank across all theses, correlates with the

most-researched taxa at each rank (See Table 3). From the fifteen most-researched species, we have identified four phyla, six classes, eight orders, and 13 families representing 83.6%, 73.5%, 61.7%, and 45.7% respectively of all research at each taxonomic rank, across all theses. The lower portion of Table 3 presents several other taxa which were represented ten or more times across all theses. A significant order is the Carcharhiniformes (ground sharks) of the class Elasmobranchii (including sharks and rays). Notable phyla are the Cnidaria, which include the class Anthozoa (including anemones and corals), and Porifera, which include the class Demospongiae (sponges). The class Gastropoda includes whelks and limpets.

For collection management purposes, changes in species studied over time are of interest. In Table 4 we observe that the most consistent level of research has occurred with the Pacific white shrimp, with five theses per decade for the last three decades. This species, while not native to the East Coast, is the prominent species used in shrimp aquaculture. To account for variation in the number of theses published each decade, these data are also expressed as a percentage of total theses per decade for each species.

Notable growth in research interest has occurred with the bottlenose dolphin, Atlantic blue crab, and red drum. Species of developing research interest since the year 2000 are the black sea bass and the marine dinoflagellate *Karenia brevis*, which is associated with harmful algal blooms. *Karenia brevis*, however, has experienced a 50% reduction in research interest since its debut in the 2000s. Research of loggerhead sea turtles and diamondback terrapins also decreased since the 2000s. Other notable decreases in research have occurred with the daggerblade grass shrimp and mummichog since the 1990s. The Eastern oyster and hard clam were the most-researched species in the 1990s, but research was substantially reduced in the 2000s and exhibited a modest increase in the current decade.

Two-tailed Fisher exact tests for statistically-significant variation over the past two decades were conducted for each taxonomic rank. Table 5 demonstrates statistically-significant changes in research interest for a number of taxa. The only species showing a significant increase is *Fragilaria cylindrus*, a marine diatom. This is replicated through its superior taxonomic ranks. The orders Decapoda, including shrimp and crabs, and Carcharhiniformes, a large order of sharks, show statistically-significant growth. The class Echinoidea, which includes sea urchins, also demonstrates statistically-significant growth.

In appendices to South Carolina's 2015 Wildlife Action Plan (SCDNR 2014a; SCDNR 2014b; SCDNR 2014c), a total of 133 marine and diadromous species, including ten marine and estuarine plants, are listed as Species of Greatest Conservation Need. Of these, 19 are of highest priority, 14 of high priority, and 100 of moderate priority. GPMB students studied six (31.6%) highest-priority species with 31 total occurrences, eight (57.1%) high-priority species with 41 total occurrences, and 24 (24.0%) moderate-priority species with 70 total occurrences. Of these, however, just four species fall into growth areas of GPMB research interest (Table 6). Only one of these species, Atlantic blue crab, is of highest priority for conservation. The bonnethead shark, falls in the high-priority category for conservation. None of these four species are considered by SCDNR to be threatened (SCDNR n.d.c.).

The Southeast Regional Taxonomic Center identifies 142 invasive aquatic species in South Carolina (SERTC n.d.a.; SERTC n.d.b.; SERTC n.d.c.) These lists include both marine and freshwater species. GPMB students researched eight of these species, with 29 total occurrences. Of these, two invasive species, green porcelain crab and Pacific white shrimp, occur in a growth area of research interest (order: Decapoda). The Pacific white shrimp is further

distinguished both as an important species for South Carolina aquaculture and the second highest-researched species by GPMB students.

The investigation of holdings of MRL and four peer institutions for these most-researched and growth-area taxa demonstrates mixed results (Table 7). In terms of number of holdings, MRL is weakest at the class level, ranking fourth in one class and third in three classes. Conversely, MRL has more holdings than each of its peers in three orders and seven families. The taxa in which MRL is ranked fourth or fifth are associated with holdings in common with the peer group of less than 15%. Interestingly, overlaps of less than 25% were observed for two taxa where MRL is highest rated.

Discussion

Hypothesis 1: GPMB graduate students place most research emphasis on commercially and recreationally-important and endangered marine species of South Carolina.

As anticipated, the most-researched species, as determined by analysis of thesis titles and abstracts, are species of importance to South Carolina. Nine of these are harvested recreationally and/or commercially, including Pacific white shrimp, which are raised in aquaculture. Three other species are either protected, endangered, or of concern. Two species are of significance as indicators of estuarine ecosystem health.

The local significance of these most-cited species is not surprising. Many GPMB students work with CofC, SCDNR, and NOAA researchers who have long-term associations with the most-researched species. An individual student's thesis research may, therefore, be a relatively short-term project which contributes to a longer-term research program executed by professional researchers. From a practical standpoint, local marine species are the most readily accessible. It

is also much more feasible, both financially and logistically, to conduct research in conjunction with the ongoing work of institutions that are already investigating a particular species. For example, the expense of conducting multi-day offshore, or multiple single-day inshore, research cruises solely for the purpose of graduate student research may be prohibitive. As the GPMB has developed, SCDNR has increasingly provided funded-research opportunities suitable for thesis projects. This has served to guide students towards research associated with species of local significance.

Hypothesis 2: Growth areas of GPMB research are associated with recent concerns in South Carolina marine ecosystems (threatened and invasive species).

The only species, *Fragilaria cylindrus* (a sea ice diatom found in the Arctic and Antarctic), to demonstrate significant growth in research interest could not be much farther removed from South Carolina. However, studies of polar sea ice diatoms are important in understanding the effects of global warming and increased exposure to ultraviolet light that may translate to other regions. Growth was statistically significant because research on this species by GPMB students only began in the past six years.

Research in the order Decapoda demonstrated significant growth, although not due to significant growth in the research of any single species. In fact, interest in the daggerblade grass shrimp, a highly-researched species and moderate conservation priority in South Carolina, diminished. Notable, but not statistically-significant, growth is observed for the Atlantic blue crab even though it is the most-researched species in the current decade, included in seven theses. While not threatened, it is among the highest conservation priority species for SCDNR. Interest in other species of crab and shrimp appears to have contributed to the significant growth

of research observed in this order. None are threatened or conservation priority species in South Carolina. The green porcelain crab, researched in two theses, is classified as an invasive species.

Research on sharks (order: Carcharhiniformes) grew significantly. South Carolina waters contain a great diversity of sharks, many of which are protected from recreational harvest (SCDNR n.d.b.). The blacktip and bonnethead are of particular popularity within the recreational fishery. Both bonnethead and tiger sharks are of moderate conservation priority and are not listed as threatened in South Carolina. Growth of research in this order may reflect a growth in coastal shark studies conducted by SCDNR (SCDNR n.d.a.).

While the class Echinoidea (sea urchins) appears to demonstrate statistically-significant growth, it was noted that all four references to distinct Echinoidea species occurred in just one thesis. The statistical significance, therefore, is not considered noteworthy.

It is apparent that GPMB research growth areas are not necessarily closely related to threatened, conservation priority, or invasive species. It is important to note, however, that a lack of growth in research about a species considered important to South Carolina does not indicate a lack of research. Of the most-researched of these species, five (33%) have been studied by five or more GPMB students in the current decade and 10 (66%) were studied by three or more students in the same period. Therefore, at least some species of importance or concern may already be adequately represented in graduate student thesis research.

Hypothesis 3: The MRL monograph collection is strongest in relation to highly-researched recreationally and commercially-important species or their superior taxa, and weakest in recent growth areas of GPMB research.

MRL has unique possession of 25% or more of total monograph holdings of seven taxa compared to the peer group. Holdings relating to the families Moronidae (temperate basses), Sciaenidae (drums), and Serranidae (groupers and seabasses) all of the order Perciformes (perch-like fishes); Palaemonidae (shrimp), Penaeidae (Penaeid shrimp), and Portunidae (swimming crabs) all of the order Decapoda (ten-footed crustacea); and Veneridae (clams) appear to be particular numerical strengths of the MRL collection compared to peer institutions. These all relate to nine of the most-researched species, eight of which are of commercial/aquaculture or recreational importance in South Carolina.

In addition, MRL also ranks first by number of holdings in the classes Malacostraca and Actinopterygii (represented by the superclass Osteichthyes); the orders Decapoda, Perciformes, and “Sharks” (an LC Subject Heading); and the families Cheloniidae and Delphinidae.

Malacostraca is the superior class of the order Decapoda, of which four species are among the most-researched and of which three are of commercial/aquaculture and recreational importance in South Carolina. Osteichthyes (bony fishes) is the superior superclass of the orders Perciformes and Cyprinodontiformes, of which five species are among the most-researched and of which all four Perciformes are of commercial/aquaculture and recreational importance in South Carolina. Cheloniidae is a family of sea turtles, of which the endangered loggerhead sea turtle is the sixth most-researched species by GPMB students. The family Delphinidae includes the common bottlenose dolphin, the third most-researched species.

Overall, MRL ranks first in holdings count compared to its peers at the most-specific superior taxonomic levels within the Library of Congress Classification for six of the nine commercially and recreationally-important species most researched by GPMB students.

Similarly, MRL also ranks first in relation to three other highly-researched species. MRL ranks

second at four family ranks. In three of these cases, it is notable that total holdings among all the libraries are less than 20 distinct items and no more than five items separate first and second place. While MRL holdings for the order Cetartiodactyla (represented by Cetacea) rank third, the first-place rank of the more specific and highly-researched Delphinidae family somewhat alleviates this concern.

Of the statistically-significant growth areas, the MRL collection is strongest among its peers in the order of Decapoda, with unique possession of 23.7% of total holdings compared to the peer group. This order also represents four highly-researched species. The strength of the Decapoda collection is likely due to the ongoing level of research interest in specific commercial and recreational species like the white and Pacific white shrimp, and the Atlantic blue crab.

Conversely, MRL is weakest in the growth area classes of Bacillariophyceae and Echinoidea placing fourth and third respectively in numbers of holdings compared to peers. Bacillariophyceae represents the diatoms, an area of new research interest which should be monitored for evidence of ongoing research. For the reasons discussed for Hypothesis 2, Echinoidea are not considered a current priority area for collection development.

No holdings of the Call Number for the order Carcharhiniformes were found in WorldCat for MRL or its peers. However, the size of the MRL collection related to the broader Library of Congress Classification of “Sharks” ranks first among its peers. Even so, a potential opportunity exists for improvement, with particular emphasis on any material supporting the study of the Carcharhiniformes or other specific orders and families of sharks in which interest may develop.

Limitations

After the data were separated by decade and taxonomic rank into sets of distinct taxa, the resulting sample size for each taxon was small, particularly at the lower taxonomic ranks. This limited the scope of appropriate statistical tests for independence. The Fisher exact test was selected over the Chi-square test due to its appropriateness for small sample sizes.

One of the challenges associated with the investigation of holdings by a discreet Call Number range is the inconsistency with which Call Numbers may be applied to a given monograph. For example, no holdings were found in WorldCat for MRL or for any of its peers when searching by Call Number (QL638.94 .C37) for monographs about Carcharhiniformes. One book entitled *Sharks of the Order Carcharhiniformes* was found in 17 libraries worldwide with this Call Number. When a search for this monograph was conducted by title, 263 libraries were identified in one record with holdings of this title, including MRL and all four peer libraries. The Call Number associated with this record was QL638.9 (Sharks - General works), which encompasses significantly more shark species than those found within the order Carcharhiniformes. This suggests that peer comparison at broader Call Number descriptor levels may represent holdings more accurately, but at the expense of specificity within a subject area.

Similarly, the use of LC Subject Headings can also be somewhat arbitrary. For example, in the case of sharks, Subject Headings may be chosen for a given monograph at the taxonomic order or family, or with the broad heading “shark” representing the class. In the case described above, the Subject Headings chosen represent the order, but the Call Number used reflects general works about sharks. For this reason, a combination of Call Numbers and Subject Headings was used to conduct searches in WorldCat.

The investigation of graduate theses to gain awareness of highly-researched and growth areas among marine organisms is one useful tool for guiding collection development. However, this approach is retrospective inasmuch as it uses past activity to predict future research interest. It also represents only a part of the broader picture. Thesis work represents the culmination and focus of a graduate student's scholarly work. Monographs, however, are also of value as graduate students begin their studies and master the fundamentals of ichthyology and the study of marine invertebrates, for example. Therefore, a holistic collection development strategy should ideally be nimble enough to respond to the needs of existing students.

Ongoing collection management should consider the courses that graduate students are currently studying or being offered. Communication with teaching faculty can help identify the unique areas of focus or nuance that each professor emphasizes in teaching these courses. In addition, the timely acquisition of monographs for graduate students who have just defined their research proposals can help provide background material of value to them. The GPMB publicizes current graduate student thesis topics online, which serves as another useful guide for collection development (College of Charleston n.d.). Thus, the combination of current and retrospective information can provide input for short and longer-term collection strategies.

It is also important to recognize that the size of a collection is not necessarily an indicator of its quality. Holdings evaluated and compared with peers at broad taxonomic levels, such as class, may also include numerous lower taxa that are irrelevant for a specific context like marine science. This may give an impression of the superiority of a library collection at a university, which may support biology research more completely, when compared to that of a marine research station that is focused on marine biology. Additionally, material type, format, focus, and academic level are important to consider in relation to patron needs.

Furthermore, and of interest for further research, is the question of why students choose to research particular species. Some are of obvious direct importance to South Carolina's coastal economy, while others are of concern for other reasons. However, some species may be specifically chosen because of their distinct characteristics. Model species are chosen for reasons such as ease of survival or reproduction in laboratory conditions, similarity to other species of interest, or for their ability to survive in adverse conditions which enables investigation into responses to changes in the marine environment. It should also be acknowledged that the availability of funding for research, often related to the advisor's work, may be a significant factor in determining the focus of a student's research. Particularly well-funded researchers with ongoing projects may provide multiple research opportunities focused on a specific subject over time. This has been the case recently with *Fragilaria cylindrus*, resulting in its significance as a growth area.

Conclusion

We have confirmed that the most-researched species in GPMB student theses are of significance in South Carolina, particularly as target species of the commercial and recreational fisheries. Areas of growth in student thesis research, however, are not necessarily directly related to significant growth in research of species of particular local importance or concern. Some are observed to share the same superior taxa as species of significance, as is the case with Decapoda. This reflects investigation of other species within the taxon, such as invasive decapods. Analysis of monograph holdings compared to peers in research growth areas has identified strengths and weaknesses of the collection. Attention must be paid both to maintaining and developing these

areas as needed. Lastly, a more complete picture of research needs must be developed by assessing current and future courses and thesis proposals to proactively build the collection.

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Table 1. Growth in the number of theses and taxa studied by decade.

	1976-1979	1980s	1990s	2000s	2010-2018
<i>Number of theses</i>	8	37	80	136	111
Number of phyla	5	5	7	12	12
Number of classes	6	7	12	22	20
Number of orders	6	9	22	49	40
Number of families	6	23	43	75	61
Number of genera	6	24	42	101	70
Number of species	7	29	44	101	76

Table 2. Most-researched species, their common names, and their significance in South Carolina.

No. Theses	Scientific Name	Common Name	Species Significance (South Carolina)
16	<i>Crassostrea virginica</i>	Eastern oyster	Commercial/recreational fishery
15	<i>Penaeus vannamei</i>	Pacific white shrimp	Aquaculture/aquaculture research
14	<i>Tursiops truncatus</i>	Common bottlenose dolphin	Protected marine mammal
12	<i>Callinectes sapidus</i>	Atlantic blue crab	Commercial/recreational fishery
12	<i>Mercenaria mercenaria</i>	Hard clam	Commercial/recreational fishery
11	<i>Caretta caretta</i>	Loggerhead sea turtle	Endangered species
10	<i>Malaclemys terrapin</i>	Diamondback terrapin	Species of concern
10	<i>Sciaenops ocellatus</i>	Red drum	Recreational fishery
8	<i>Palaemon pugio</i>	Daggerblade grass shrimp	Model organism
8	<i>Penaeus setiferus</i>	White shrimp	Commercial/recreational fishery
7	<i>Cynoscion nebulosus</i>	Spotted seatrout	Recreational fishery
7	<i>Fundulus heteroclitus</i>	Mummichog	Model organism
7	<i>Karenia brevis</i>	<i>Karenia brevis</i>	Threat (Red Tide)
5	<i>Centropristis striata</i>	Black sea bass	Commercial/Recreational fishery
5	<i>Morone saxatilis</i>	Striped bass	Recreational fishery

Table 3. Taxonomic ranks of most-researched species with rank of occurrence [n] and percentage of rank occurrences across all theses.

Phylum	Class	Order	Family	Species
Arthropoda [2] 15.5%	Malacostraca [2] 15.1%	Decapoda [2] 12.8%	Palaemonidae [11-12] 2.1%	<i>Palaemon pugio</i>
			Portunidae [6-8] 2.8%	<i>Callinectes sapidus</i>
			Penaeidae [2] 6.2%	<i>Penaeus setiferus</i>
				<i>Penaeus vannamei</i>
Chordata [1] 53.0%	Actinopterygii [1] 34.2%	Cyprinodontiformes [6] 3.5%	Fundulidae [11-12] 2.1%	<i>Fundulus heteroclitus</i>
		Perciformes [1] 23.5%	Moronidae [15-17] 1.6%	<i>Morone saxatilis</i>
			Sciaenidae [1] 6.5%	<i>Cynoscion nebulosus</i>
				<i>Sciaenops ocellatus</i>
			Serranidae [3] 5.5%	<i>Centropristis striata</i>
	Mammalia [3] 7.5%	Cetartiodactyla [3] 7.2%	Delphinidae [4] 4.6%	<i>Tursiops truncatus</i>
	Reptilia [5] 5.7%	Testudines [4] 5.1%	Cheloniidae [6-8] 2.8%	<i>Caretta caretta</i>
			Emydidae [10] 2.3%	<i>Malaclemys terrapin</i>
Mollusca [3] 10.5%	Bivalvia [4] 7.1%	Ostreida [5] 4.0%	Ostreidae [5] 3.9%	<i>Crassostrea virginica</i>
		Venerida [7-8] 2.8%	Veneridae [6-8] 2.8%	<i>Mercenaria mercenaria</i>
Myzozoa [4] 4.6%	Dinophyceae [7] 3.9%	Gymnodiniales [7-8] 2.8%	Kareniceae [9] 2.5%	<i>Karenia brevis</i>
Other highest-ranked taxa (no. occurrences >=10) not represented in most-researched species				
Cnidaria [5] 3.2%	Anthozoa [8-9] 3.0%			
Porifera [6] 2.5%	Demospongiae [10] 2.3%			
Proteobacteria [7] 2.3%				
	Elasmobranchii [6] 4.6%	Carcharhiniformes [9] 2.3%		
	Gastropoda [8-9] 3.0%			

Table 4. Number and percentage of theses investigating top-researched species, by decade

Name	Common Name	1976-79		1980s		1990s		2000s		2010-18		Totals	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
<i>Crassostrea virginica</i>	Eastern oyster	0	0	0	0	8	10.0	3	2.2	5	4.5	16	4.3
<i>Penaeus vannamei</i>	Pacific white shrimp	0	0	0	0	5	6.3	5	3.7	5	4.5	15	4.0
<i>Tursiops truncatus</i>	Common bottlenose dolphin	0	0	0	0	2	2.5	6	4.4	6	5.4	14	3.8
<i>Callinectes sapidus</i>	Atlantic blue crab	0	0	2	5.4	1	1.3	2	1.5	7	6.3	12	3.2
<i>Mercenaria mercenaria</i>	Hard clam	0	0	3	8.1	6	7.5	1	0.7	2	1.8	12	3.2
<i>Caretta caretta</i>	Loggerhead sea turtle	0	0	0	0	2	2.5	6	4.4	3	2.7	11	3.0
<i>Malaclemys terrapin</i>	Diamondback terrapin	0	0	0	0	1	1.3	6	4.4	3	2.7	10	2.7
<i>Sciaenops ocellatus</i>	Red drum	0	0	1	2.7	2	2.5	2	1.5	5	4.5	10	2.7
<i>Palaemon pugio</i>	Daggerblade grass shrimp	1	12.5	0	0	4	5.0	3	2.2	0	0	8	2.2
<i>Penaeus setiferus</i>	White shrimp	0	0	2	5.4	2	2.5	1	0.7	3	2.7	8	2.2
<i>Cynoscion nebulosus</i>	Spotted seatrout	0	0	1	2.7	2	2.5	1	0.7	3	2.7	7	1.9
<i>Fundulus heteroclitus</i>	Mummichog	1	12.5	0	0	4	5.0	1	0.7	1	0.9	7	1.9
<i>Karenia brevis</i>	<i>Karenia brevis</i>	0	0	0	0	0	0	5	3.7	2	1.8	7	1.9
<i>Centropristis striata</i>	Black sea bass	0	0	0	0	0	0	3	2.2	2	1.8	5	1.3
<i>Morone saxatilis</i>	Striped bass	0	0	1	2.7	1	1.3	0	0	3	2.7	5	1.3

Table 5. Taxa with statistically-significant variation ($P < .05$, two-tailed Fisher exact test) in number of occurrences in theses between decades (2000s and 2010-2018).

Phylum	Class	Order	Family	Genus	Species
Ochrophyta <i>P=0.0019</i>	Bacillariophyceae <i>P=0.0092</i>	Fragilariales <i>P=0.0433</i>	Fragilariaceae <i>P=0.0439</i>	Fragilaria <i>P=0.0439</i>	<i>Fragilaria cylindrus</i> <i>P=0.0466</i>
Porifera <i>P=0.0011</i>	Demospongiae <i>P=0.0021</i>				
	Echinoidea <i>P=0.0446</i>				
	Mammalia <i>P=0.0417</i>	Cetartiodactyla <i>P=0.0345</i>			
		Anguilliformes <i>P=0.0167</i>	Muraenidae <i>P=0.0326</i>		
		Carcharhiniformes <i>P=0.0479</i>			
		Decapoda <i>P=0.0358</i>			
			Gorgoniidae <i>P=0.0326</i>	Leptogorgia <i>P=0.0326</i>	

bold type = increase, shaded box = decrease.

Table 6. Number of theses referencing South Carolina Species of Greatest Conservation Need found within statistically-significant growth taxa. Presented in order of Wildlife Action Plan (WAP) priority.

WAP Priority	Name	Common Name	Growth Taxon	No. Theses 2000s	No. Theses 2010-18
Highest	<i>Callinectes sapidus</i>	Atlantic blue crab	Decapoda	2	7
High	<i>Sphyrna tiburo</i>	Bonnethead shark	Carcharhiniformes	0	2
Moderate	<i>Galeocerdo cuvier</i>	Tiger shark	Carcharhiniformes	0	1
Moderate	<i>Palaemon pugio</i>	Daggerblade grass shrimp	Decapoda	3	0

WAP Priority status adapted from SCDNR 2014b.

“2015 State Wildlife Action Plan – Appendix 1-C: Marine Priority Species and Their Habitats.”

Accessed August 15, 2018. <http://dnr.sc.gov/swap/main/app1-c-marinehabitats.xlsx>.

Table 7. Number of holdings at MRL by superior taxa of most-researched species and taxa with statistically-significant growth in research interest (bold type), compared with four peer libraries using WorldCat queries by Library of Congress Subject Headings, Call Number, and OCLC ID.

Taxa (closest Library of Congress Classification)	Subject Heading/Call Number Search Logic (*wildcard)	No. Distinct Holdings (OCLC WorldCat)							Rank of SBM/OAS by No. Holdings	No. Holdings Unique to SBM/OAS ⁴ (1-2)	% of Total Unique to SBM/OAS (4/1)	No. Holdings Shared with Peers ⁵ (3-4)	% of Total Shared with Peers (5/1)
		SBM/OAS and Peers ¹	Peers ²	SBM/OAS ³	VIM	GUA	FUG	TAG					
CLASS													
Actinopterygii (Osteichthyes)	hl:Osteichthyes <i>OR</i> lc:QL637.9* <i>OR</i> lc:QL638.[A-Z]*	1,910	1,487	967	726	568	667	123	1	423	22.2%	544	28.5%
Bacillariophyceae (Diatoms)	hl:Diatoms <i>OR</i> lc:QK569.D54*	238	212	52	74	85	105	34	4	26	10.9%	26	10.9%
Bivalvia	hl:Bivalves <i>OR</i> (lc:QL430.6* <i>OR</i> lc:QL430.7*)	603	513	212	257	193	191	63	2	90	14.9%	122	20.2%
Dinophyceae (Dinoflagellates)	hl:Dinoflagellates <i>OR</i> lc:QK569.D56*	113	99	33	53	38	31	11	3	14	12.4%	19	16.8%
Echinoidea	hl:Sea urchins <i>OR</i> lc:QL384.E2*	144	131	42	37	47	84	20	3	13	9.0%	29	20.1%
Malacostraca	hl:Malacostraca <i>OR</i> lc:QL444.M3*	645	486	356	266	166	208	52	1	159	24.7%	197	30.5%
Mammalia (Marine Mammals, general and by region)	hl:Marine Mammals <i>OR</i> (lc:QL713.2* <i>OR</i> lc:QL713.35* <i>OR</i> lc:QL715* <i>OR</i> lc:QL717* <i>OR</i> lc:QL719* <i>OR</i> lc:QL72[0-9]* <i>OR</i> lc:QL73[0-6]*	1,315	1,139	396	85	554	810	173	3	176	13.4%	220	16.7%
ORDER													
Carcharhiniformes (Sharks) †	hl:Sharks <i>OR</i> (lc:QL638.9* <i>NOT</i> lc:QL638.97* <i>NOT</i> lc:QL638.99*)	362	293	162	123	129	141	36	1	69	19.1%	93	25.7%
Cetartiodactyla (Cetacea)	hl:Cetacea <i>OR</i> lc:QL737.C4*	596	500	249	107	258	295	104	3	96	16.1%	153	25.7%
Cyprinodontiformes	hl:Cyprinodontiformes <i>OR</i> lc:QL637.9.C95*	3	3	0	2	0	2	0	3-5	0	0.0%	0	0.0%
Decapoda	hl: Decapoda (Crustacea) <i>OR</i> (lc:QL444.M33* <i>NOT</i> lc:QL444.M338*)	561	428	301	234	138	175	55	1	133	23.7%	168	30.0%
Perciformes	hl:Perciformes <i>OR</i> lc:QL637.9.P46*	29	26	20	13	8	12	2	1	3	10.4%	17	58.6%
Testudines (Chelonia)	hl:Turtles <i>OR</i> lc:QL666.C5*	857	710	341	140	297	500	110	2	147	17.2%	194	22.6%

FAMILY													
Cheloniidae	hl:Cheloniidae OR lc:QL666.C536*	196	156	106	51	57	103	26	1	40	20.4%	66	33.7%
Delphinidae	hl:Delphinidae OR lc:QL737.C432*	135	103	72	25	56	57	31	1	32	23.7%	40	29.6%
Emydidae	hl:Emydidae OR lc:QL666.C547*	17	15	7	1	7	12	1	2-3	2	11.8%	5	29.4%
Moronidae	hl:Moronidae OR lc:QL638.M678*	7	5	4	5	0	1	0	2	2	28.6%	2	28.6%
Ostreidae	hl:Oysters OR lc:QL430.7.O9*	607	543	151	394	87	88	59	2	64	10.5%	87	14.3%
Palaemonidae	hl:Palaemonidae ††	12	6	8	3	4	4	1	1	6	50.0%	2	16.7%
Penaeidae	hl:Penaeidae ††	66	48	38	21	13	15	11	1	18	27.3%	20	30.3%
Portunidae	hl:Swimming crabs ††	8	6	4	5	1	1	0	2	2	25.0%	2	25.0%
Sciaenidae	hl:Sciaenidae OR (lc:QL638.S34* NOT lc:QL638.S347*)	124	81	66	60	16	17	9	1	43	34.7%	23	18.6%
Serranidae	hl:Serranidae OR (lc:QL638.S48* NOT lc:QL638.S483*)	81	52	55	37	14	18	3	1	29	35.8%	26	32.1%
Veneridae	hl:Veneridae OR lc:QL430.7.V5*	28	19	19	8	11	8	2	1	9	32.1%	10	35.7%

Marine Resources Library/College of Charleston (SBM/OAS). Overlap analysis counts and percentages calculated compared to peer group as a whole.

Peer libraries at: Virginia Institute of Marine Science (VIM), Skidaway Institute of Oceanography/University of Georgia (GUA),

Marston Science Library/University of Florida (FUG), and Texas A&M Galveston (TAG).

† Works about Carcharhiniformes were seldom represented by their Library of Congress Call Number, so the search was expanded to include all sharks.

†† Library of Congress Call Number used for these families is the same as for the order Decapoda, so was not searched.