The History of Freshwater Research in the Philippines with Notes on its Origins in the University of Santo Tomas and Present-Day Contributions

Rey Donne S. Papa and Jonathan Carlo A. Briones

ABSTRACT

The study of freshwater ecosystems in the country has long had the reputation of being fragmentary and inconsistent, especially when compared to its marine counterparts. Other scientists have in fact noted that many studies that have been conducted on Philippine freshwaters have not gone beyond the “age of exploration”, which resulted to it being poorly represented in the scientific literature. This scenario has been consistent for both lotic and lentic habitats, even for those considered as major river and lake ecosystems, including those found in key biodiversity or known protected areas. This has gone on for decades in spite of the obvious need for invigorated and scientifically-driven approaches to study and manage freshwater ecosystems throughout the country, especially since freshwater ecosystems, including its flora and fauna, are under increasing threat from both natural and man-made environmental stressors, including intensive aquaculture, leading to eutrophication, the introduction of non-native species, as well as climate change. This is further aggravated by the low number of experts in various fields of basic and applied freshwater biology including taxonomists, limnologists, restoration ecologists etc. to deal with various problems and challenges in the Philippine setting. This paper presents the background, history and origins of freshwater biology research in the Philippines and the contributions of the University of Santo Tomas from 2002 to present.

KEYWORDS:
Wallacea Expedition
Tropical Lakes
History of Science
Freshwater Zooplankton
Invasive species
Limnology

INTRODUCTION

The University of Santo Tomas, being the oldest existing institution of higher learning in the Philippines, has had a significant role in the development of science in the country (Papa, 2013). In the fields of natural history and biology its Museum of Arts and Science served as the earliest known, scientifically-catalogued repository of Philippine fauna collected from the 1800’s through the efforts of Rev. Fr. Casto de Elera, OP - second director of the UST Museum. The publication of a three-volume book on the fauna of the Philippines by Fr. de Elera provided one of the earliest scientifically-catalogued repositories of Philippine fauna collected from the 1800’s through the efforts of Rev. Fr. Casto de Elera, OP - second director of the UST Museum. The publication of a three-volume book on the fauna of the Philippines by Fr. de Elera provided one of the earliest accounts of Philippine biodiversity (De Elera, 1895). Though not as popular as contributions to other fields of science (such as chemistry, pharmacy and medicine), Thomasian alumni have also conducted freshwater biology research during the latter part of the 19th century. Two notable alumni who studied freshwater ecosystems to some extent are Anacleto del Rosario and Antonio Luna, who, in their capacity as scientists of the Laboratorio Municipal de la Ciudad de Manila, separately conducted biological and chemical studies of water from the Pasig River and medicinal mineral springs in Luzon (Reyes, 2014). Line drawings of microscopic specimens observed by Anacleto del Rosario from the Pasig River clearly depicts several species of bacteria, microalgae (phytoplankton), rotifers and protozoans. These line drawings, which now form part of the collections of the Archives of the University of Santo Tomas (AUST), may be considered as some of the earliest documentation of freshwater biodiversity in the country (Papa, 2015). Both del Rosario and Luna studied Pharmacy in the university. Del Rosario finished his licence and doctorate in Pharmacy in UST where he was also later appointed Professor of Pharmacy while Luna began his pharmacy studies in Santo Tomas but finished his doctorate degree in the Universidad Central de Madrid and took post-doctoral training in the Pasteur Institute (Paris, France) prior to serving the Laboratorio Municipal. Luna, of course, later became more well known for his role as a general in the Philippine revolutionary army (Papa,
2013). Though technically graduates of pharmacy, these individuals performed scientific duties other than those done by pharmacists as we know today; this was due to the lack of any other related science course being offered in the country. Del Rosario is credited as the “Father of Philippine Laboratory Science” and the first Filipino chemist, while Luna, after his and post-doctoral training, was regarded as the first published bacteriologist in the country (Papa, 2013).

This paper outlines the development and the significant contributions of the University of Santo Tomas, particularly its Research Center for the Natural and Applied Sciences, to the field of freshwater biology and taxonomy during the past twelve years, where it has conducted research projects within the general realm of freshwater biology. This has led to the group receiving funding and awards from national and international award / grant-giving bodies and the publication of no less than 30 peer-reviewed papers. This is especially significant since prior to this, the university’s research agenda did not even include biodiversity and ecology priority areas. Difficulties that have also evolved due to the location of the university in the heart of Manila did not hinder its development. Through the efforts of its faculty and students, freshwater scientists from the University of Santo Tomas have been able to continue and build on the legacy began by its illustrious alumni - Anacleto del Rosario and Antonio Luna.

AGE OF EXPLORATION

Though such pioneering studies on the biology and chemistry of Philippine freshwaters have been contributed by scientists who, at one point in their careers had been associated with Santo Tomas, these never got the same attention as those from German naturalist Feodor Jagor, who has written descriptions of Philippine lakes he had visited during his expeditions, as documented in his book “Travels in the Philippines” (1875), which also included collections of its flora and fauna (Buñag, 1934). Towards the end of the 19th Century, another major publication that included listings and descriptions of freshwater ecosystems came in the form of Jose Montero y Vidal’s “El Archipielago Filipino” (1896 & 1909) (Vidal, 1909).

The end of the Spanish colonization of the Philippine archipelago and the start of the American regime opened up more opportunities for other scientists to study Philippine freshwater ecosystems. In 1916, Wallace Pratt published a paper entitled “Philippine Lakes”, in the Philippine Journal of Science, which may be considered as the first listing of Philippine lakes published in a scientific journal (Pratt, 1916). His involvement with lake research came courtesy of his appointment in the Division of Mines in the Philippine Bureau of Science. Prior to this, several geological studies by US government scientists had also included some notes on major freshwater ecosystems in the country as part of the US government’s effort to document the natural resources of their newly acquired colony (Pratt, 1916). Another notable publication by Pratt documented the impacts of the 1911 eruption of Taal Volcano, which also noted the eruption’s impacts on Lake Bombo, now more popularly known as Lake Taal (Pratt, 1911).

GOLDEN AGE

German developmental zoologist Richard Woltereck of the University of Leipzig led the most comprehensive biodiversity survey of major lake ecosystems in the country when he headed the U.S. Rockefeller Foundation-funded Wallacea (Wolterek-Tressler) Expedition in March 1932, which formed part of sixteen-month attempt to study ecologically-distinct Southeast Asian lakes. For the longest time, this had been considered as the most comprehensive documentation of freshwater flora and fauna in the country with descriptions of limnological characteristics for many of the lakes they had visited. This expedition resulted to several landmark publications in journals such as the Internationale Revue der Gesamten Hydrobiologie und Hydrogeographie and Zoologischer Anzeiger (Woltereck et al. , 1941). As for studies on freshwater fishes, the American Albert William T. Herre (Director of the Fisheries Division in the Philippine Bureau of Science), contributed the most significant scientific information through his 216 publications written over the span of his entire career, which included novel descriptions of many freshwater fishes native or endemic to the country (Herre, 1953).

Even though scientific literature on Philippine freshwaters during this time was dominated by foreign authors, there were two Filipinos who contributed to the development of freshwater biology in the country. The first Filipino to have published papers on the topic is considered the “Dean of Philippine Fisheries” - Deogracias V. Villadolid, who taught at the University of the Philippines Los Baños (now the University of the Philippines Los Baños) after finishing his Ph.D. in Stanford University. His earliest works included papers on the fisheries of Lake Taal and Laguna de Bay, as well as Pansipit River (Villadolid and Del Rosario, 1930; Villadolid, 1932a, b, c; Villadolid, 1937). He later became director of the Bureau of Fisheries where he was instrumental to the introduction of tilapia aquaculture in the Philippines by the 1950’s. He was also influential to the establishment of the UP College of Agriculture Limnological Research and Aquatic Resources Management Center, which was established through the proclamation of American Governor General Henry Stimson in 1928 upon the initiative of Leopoldo Uichanco (Dean of the UP College of
Agriculture) and Albert William T. Herre (Labatos, unpublished). The other Filipino to have made a significant contribution to the study of Philippine freshwater ecosystems was Daniel M. Buñag, also of the University of the Philippines College of Agriculture, who wrote "A supplement to our knowledge of two Philippine lakes" (Buñag, 1934) and co-authored "Die Seen und Inseln der "Wallacea"-Zwischenregion und ihre endemische Tierwelt. Zweiter Teil: Inseln und Seen der Philippinen" with R. Woltereck and W. Tressler (Woltereck et al., 1941). The achievements during the early part of the 20th Century in freshwater biology may very well be considered as its “Golden Age”, when the scientific community was introduced to the unique characteristics and biodiversity of freshwater habitats in the Philippines.

**FILIPINIZATION**

Sadly, the events of the Second World War halted any major developments. The subsequent granting of Philippine independence in 1946, failed to revive interest in studying freshwater ecosystems in the country to similar levels it had prior to the start of the war. The focus of most Filipino researchers shifted to the utilization of freshwater resources for food, out of necessity, which led to the introduction of aquaculture in many Philippine lakes. Throughout the 1950’s to the 1960’s, efforts to study freshwater bodies as ecosystems have almost been relegated to the sidelines, and were not in the same level before the war. As a result, novel scientific information on Philippine freshwater ecosystems in the form of peer-reviewed publications, went down significantly during this time (Papa and Mamaril Sr., 2011). The succeeding three decades (1970’s to 1990’s) saw slight improvement, which resulted to several international and national publications. This was due to the increased international exposure of some Filipinos who had been given the chance to undergo further training in foreign laboratories. Significant outputs included papers on the limnology and plankton ecology of Lakes Mainit and Lanao by the American limnologist William Lewis Jr. (Lewis Jr., 1973b; Lewis Jr., 1973a, 1974; Lewis Jr., 1975, 1979; Babin et al., 2005), updates on the taxonomy of Philippine freshwater zooplankton by Augustus C. Mamaril (who studied under the renowned zooplankton taxonomist, C. H. Fernando of the University of Waterloo) (Mamaril Sr. and Fernando, 1978; Lai et al., 1979; Mamaril Sr., 1986), phytoplankton by Macrina Tamayo-Zafaralla and Milagrosa Martinez-Goss (Martinez, 1978; Zafaralla and Orozco, 1989; Zafaralla, 1990; Zafaralla et al., 1990; Zafaralla, 1998), littoral fishes and gastropods in Lake Taal by Roberto C. Pagulayan (Pagulayan and Remigio, 1992/3; Cukingan and Pagulayan, 1995-1996; Pagulayan et al., 1997), as well as a textbook / laboratory manual on limnology designed for the Philippine setting by Ruben Umaly and Ma. Lourdes Cuvin (Umay and Cuvin, 1988). The studies conducted by Rafael D. Guerrero III on tilapia sex reversal are also considered among the most significant outputs on applied researches in freshwater biology in the country (Lee-Chua, 2000). Later, as director of the Philippine Council for Aquatic and Marine Research and Development, he published several papers on the conservation and proper utilization of lake resources (Guerrero III, 1991; Guerrero III, 2001, 2002). Of the studies mentioned above, the works of William Lewis in Lakes Mainit and Lanao were some of the first detailed observations on the limnology and ecology of tropical lakes that have been published in journals such as Limnology and Oceanography, Ecological Monographs and the International Review of Hydrobiology.

The Southeast Asian Fisheries Development Center (SEAFDEC), particularly its Binangonan Freshwater Station in Laguna de Bay, also published important research papers on freshwater organisms, though many papers have dealt with aquaculture applications, others focused on the occurrence of harmful algal blooms, particularly in Laguna de Bay (Baldia et al., 1986; Platon, 2001; Baldia et al., 2003; Baldia et al., 2007). By the 1990’s, the freshwater biology studies in the Philippines began to look into the negative impacts of intensive and irresponsible aquaculture in the Philippines. Results generated during this time have noted significant reductions in the water quality of lakes such as Laguna de Bay, Lake Sampaloc and Lake Taal. This has prompted the development of laws and policies related to lake zoning, the determination of the carrying capacity of lakes, and routine water quality monitoring (Pantastico et al., 1986; Santiago et al., 1989; Zafaralla et al., 1989; Zafaralla et al., 1992; Santiago and Arcilla, 1993; Pctt, 1994; Lasco and Espaldon, 2005; Baldia et al., 2007; Schiemer et al., 2008; TVPL-PAMB, 2009). However, the combined detrimental effects of intensive aquaculture and the problems that arose from a ballooning human population who settled previously unoccupied lakeshore or riverside areas have contributed to the rapid decline of freshwater ecosystems, particularly those near urban areas and in water-bodies throughout the Metropolis. This problem was compounded by the practice of majority of Filipino freshwater scientists to either not publish or merely being contented with publications in gray literature. This has been previously noted for studies in Philippine marine ecosystems (Lacanilao, 1997), and Lake Taal from the 1960’s to the 1990’s (Papa and Mamaril Sr., 2011), but was also the case for the other freshwater ecosystems that had been studied.

Since the start of Filipino involvement in this scientific field, biologists from the University of the Philippines and / the Bureau of Fisheries and Aquatic Resources / the Southeast Asian Fisheries Development Center / Laguna Lake Development Authority have been at the forefront, trying to
sustain the fledgling field of freshwater science in the country, which, when compared to other more popular fields of specialization in the natural and applied sciences, had received far little attention, students and funding. Many of these researches have been funded by the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) locally and internationally by funding agencies such as the SOGREA (Société Grenobloise d'Etudes et d’Applications Hydrauliques) and the Danish International Development Agency (DANIDA). Much attention has been focused on studying Laguna de Bay, making it the most widely studied Philippine lake, to date.

**Freshwater Biology in Santo Tomas 1: Birthing Pains**

It was against this backdrop that, after the pioneering efforts of del Rosario and Luna more than a century before, that UST scientists began to make contributions to freshwater biology. No doubt, through the influence of professors from the University of the Philippines, but similarly from scientists affiliated with other local and international institutes and universities, who had the chance to interact and influence a new breed of eager-to-learn Thomasian biologists. These individuals saw the need to increase awareness and scientific knowledge on a vital, yet understudied component of our environment. The efforts come during a time when freshwater resources in the country are faced with numerous threats and challenges, from both man-made and natural causes, that are being aggravated by a changing climate.

The initial exposure of Thomasians to the field of freshwater biology was due to the influence of faculty members of the Graduate School, as the undergraduate program in the College of Science did not have a freshwater biology course. These faculty members were usually part-timers with regular teaching or research appointments in other universities or government research institutions. During the 1970’s and 1980’s, Dr. Ruben Umaly of UP Diliman, author of the laboratory and field guide in limnology (National Bookstore, 1988), taught genetics and radiation biology in the UST Graduate School. Several theses conducted by UST graduate students in the 1970’s also dealt with freshwater biology. This included the bio-ecology of the freshwater gastropod *Idiopoma angularis* in Laguna de Bay (Castro, 1977) as well as a survey of monogenean parasites of fishes in Laguna de Bay (Guzman, 1974). By the 1990’s, the graduate course in Freshwater Biology had been taught by Dr. Abercio V. Rotor, a former student of Dr. Villadolid, who also taught Advanced Ecology and several botany courses. He was later joined by Dr. Roberto C. Pagulayan, who taught genetics and ecology from the late 1990’s to the early 2000’s. Though freshwater biology was regularly taught in the Graduate School, there had been no significant development in the publication of freshwater biology researches being conducted by the university. This may be due to the fact that none of those who taught freshwater biology and other related biology courses were actually affiliated with the Research Center for the Natural Sciences – the university unit devoted to the conduct of research projects in the sciences.

All this changed when in 2002, Dr. Susana F. Baldia, who was formerly affiliated with the SEAFDEC Binangonan Freshwater Station, joined the graduate faculty in Santo Tomas, where she taught courses in Freshwater Biology, Advanced Ecology and Phycology. Apart from teaching in the Graduate School, she also conducted researches on freshwater phytoplankton in the UST Research Center for the Natural Sciences (RCNS), where she pioneered research on freshwater organisms and later began to teach in the undergraduate level as well. She was later joined by Alicia Ely J. Pagulayan, a faculty member of the College of Science, who conducted research on the developmental biology of the Lake Taal endemic freshwater sardine, *Sardinella tawilis*. In 2006, the author (R.D.S. Papa) also joined the UST-RCNS after completing his M.Sc. thesis under the supervision of Dr. R.C. Pagulayan and A.E.J. Pagulayan where he worked on the zooplankton diet of the *Sardinella tawilis* in Lake Taal. His RCNS research project focused on ecological studies on freshwater zooplankton from different lakes which he was doing simultaneously with his academic requirements for his Ph.D. These developments in the university have opened opportunities for undergraduate and eventually graduate students to conduct freshwater biology researches in at least three fields: phytoplankton, zooplankton and fish development.

Lake Taal became the initial focus of UST researchers, which proved to be an enduring and fruitful endeavor. The initial studies conducted by A.E.J. Pagulayan and R.D.S. Papa for their master’s theses were followed by several undergraduate theses. In 2006, a study by undergraduate students of R.D.S. Papa and molecular biologist J.R. Castillo on the morphological and molecular identification of the ectoparasitic isopod *Corallana grandiventra* (locally known as *timud*) was published in The Philippine BIOTA Journal, making it the first published paper on Lake Taal fauna based on an undergraduate thesis from the university (Adorador *et al.*, 2006). This paper was able to correct the previous misidentification of the Lake Taal isopod which appeared in several reports by the local Bureau of Fisheries and Aquatic Resources office. Two years later, the first ISI publication based on a UST Graduate School master’s thesis in freshwater biology came out in the journal Zoological Studies. The study documented the feeding ecology of the *Sardinella tawilis* in Lake Taal (Papa *et al.*, 2008a). Apart from these major developments, active participation of
Thomasian researchers in national and international conferences and training seminars “introduced” UST’s efforts to undertake research projects on freshwater biology to the scientific community.

**FRESHWATER BIOLOGY IN SANTO TOMAS 2: MILESTONES**

The developments from the years 2002 to 2008 laid the foundations for the increased number of research staff and students from the University of Santo Tomas involved in freshwater biology research. In 2011, the increased number of students engaged in freshwater researches led to the formation of the Zooplankton Ecology, Systematics and Limnology research group in the Research Center for the Natural and Applied Sciences. Popularly known through its acronym ZESL, the group conducted research projects which involved graduate and undergraduate students, and many of these were under the framework of national and international collaborative research projects. International collaborations opened up venues for students to learn specific aspects of freshwater biology researches that they would not have otherwise been given the opportunity to learn given the limitations in the country. Foreign collaborators have been invited to deliver lectures, conduct training seminars and also teach graduate-level courses. More importantly, students were given the opportunity to conduct part of their researches in foreign laboratories located in institutions such as the National Taiwan University (Taiwan), Jinan University (China), Polish Academy of Science (Poland), Kyoto University (Japan), National Institute for Agronomy Research (France), University of Shiga Prefecture (Japan), and National University of Singapore (Singapore). This led to the increased number of quality publications in freshwater biology produced by the University of Santo Tomas, and also enabled it to apply for grants to support its researches. The following sections highlight the major outputs of the research group.

**Zooplankton Systematics**

Perhaps, the most significant contributions of the university are in the field of freshwater zooplankton systematics. There had been very few publications that had come out on Philippine freshwater zooplankton to build up on the work of A. C. Mamaril from the 1970’s to the 1990’s (Tuyor and Segers, 1999; Tuyor and Baay, 2001). The advances in the taxonomy and systematics of freshwater zooplankton worldwide, together with the changes that have occurred in terms of the utilization of freshwater resources makes it necessary to conduct a re-evaluation of the state of freshwater zooplankton diversity. In order to do this, faculty and students from the University of Santo Tomas conducted sampling expeditions to different parts of the country to 1)
revisit former sampling localities where zooplankton have been previously recorded and 2) collect samples from areas where no previous records have existed. Figure 1 shows the extent of sampling areas where zooplankton had been collected from different parts of the country. During the first two years of the ZESL, a research project entitled “Establishing a Zooplankton Reference Collection in the University of Santo Tomas” was approved and funded by the RCNAS, in order to come up with an organized system of managing specimens and data gathered from the different expeditions. The protocols established as a result of this project were benchmarked from foreign institutions with established zooplankton reference collections, and were modified to suit the local situation (Figure 2).

An updated species list and distribution map for microcrustacean zooplankton is given in Figure 3. This includes several new locality and new species records for the Philippines and one new species. Among the significant discoveries was the discovery of the presence of a Neotropical species *Arctodiaptomus dorsalis* (Calanoida: Diaptomidae) in Philippine lake and river ecosystems (Papa et al., 2012a; Metillo et al., 2014; Rizo et al., 2015). The occurrence of this species was discovered by accident, as the original intention of the study was to try to increase the number of known calanoid copepod species known from the Philippines. Instead, it led to the discovery of the presence of this non-indigenous zooplankton species in the Philippines. Unfortunately, previously recorded calanoid copepods were not found in sites where *A. dorsalis* had been recorded. This confirms that *A. dorsalis* is highly invasive, and can displace species previously inhabiting the ecosystem. Among the species that were displaced by *A. dorsalis* are the endemic *Tropodiaptomus gigantoviger* in Lake Lanao, the native *T. vicinus* in Lake Buhi and the endemic *Pseudodiaptomus brehmi* in Lake Naujan. This is especially significant for calanoid copepods, as there is usually just one calanoid copepod present for any given ecosystem. Notes on the mode of dispersal and its successful invasion are available in Papa et al. (2012) (Papa et al., 2012a). In another group of copepods, the Order Cyclopoida, however, there have been no documented invasive species among the species identified from samples collected from 22 lakes found in 5 major islands throughout the country (Papa and Holynska, 2013). In fact, a new species, *Mesocyclops augusti* Papa and Holynska, 2013 was described from samples collected from Lake Siloton (Mindanao Is.). The same paper also contains a redescription of the endemic *Mesocyclops microlasius* Kiefer 1981, where recent expeditions revealed it was also present in Lake Paay (Luzon Is.), making it the northernmost limit of its distribution, to date. A total of 11 taxa of cyclopoid copepods were also identified from all the samples collected from all 22 lakes, including *Thermocyclops taihokuensis* (Harada, 1931), a new Philippine record.

The other major contribution to freshwater zooplankton systematics dealt with the taxonomy and distribution of freshwater water fleas (Branchiopoda: Cladocera) in the Philippines. The paper by Pascual et al. (Pascual et al., 2014), was able to identify a total of 16 species from four cladoceran families (Bosminidae, Moinidae, Sididae, Chydroridae) which were collected from 86 freshwater ecosystems found in six islands throughout the country. The 16 species which were identified is extremely low compared to the 56 species previously recorded throughout the country, but included 78 new locality records. The study was also able to note that most of the 56 species previously recorded from the country have now been relegated as synonyms, or have been misidentified.

The major findings from all three studies (calanoid, cyclopoid and cladoceran taxonomy and distribution) were done using the standard methods used in zooplankton sampling, processing and analysis that had been developed in the university. This has enabled students and researchers to utilize previously collected samples for taxonomic analysis that has reduced the need to conduct repetitive sampling expeditions, unless otherwise needed. As such, more efforts have been put into sampling sites where no previous samples have been collected. At present, the University of Santo Tomas is the only institution with a Zooplankton Reference Collection in the Philippines.
In terms of freshwater ecology, most efforts have been site-specific, but ensured that sampling efforts were conducted for an adequate period of time. The first published studies on freshwater ecology from the university were based on undergraduate theses, that have been conducted in Lake Paoay (Aquino et al., 2008) and the Pasig River (Lazo et al., 2009). Though the study in Lake Paoay originally focused on zooplankton community dynamics, the discovery of a six-month continuous bloom of the colonial green algae, Botryococcus braunii led to a follow-up study that looked at the negative impacts of the bloom to the zooplankton community (Papa et al., 2008b). Since B. braunii is known to produce lipids, further studies by students of Dr. S. Baldia led to several publications that dealt with the optimization of culture conditions of B. braunii isolates from Lake Paoay to explore the possibility of using it for bio-fuel research, as well as a year-long sampling of phytoplankton in Lake Paoay to look at the other phytoplankton species in the area (Villaroman et al., 2010; Baldia et al., 2011).

From 2008 to 2014, most papers published on freshwater ecology that came from UST had been conducted in Lake Taal. These studies, which focused on 1) feeding ecology of the Sardinella tawilis (Papa et al., 2008a), 2) the spatio-temporal variability and diel vertical migration in freshwater
In 2011, Dr. Flor Lacanilao, former SEAFDEC Director and retired professor of marine science in the University of the Philippines - Diliman made a survey of institutions with published researches on Laguna de Bay, Lake Taal and Bolinao (Pangasinan), which were among the most studied aquatic ecosystems in the country. His results showed that UST had the most number of published papers (ISI-indexed) on Lake Taal, followed closely by the University of the Philippines – Los Baños (Lacanilao, unpublished).

Another lake ecosystem that had been the focus of studies by faculty and students of UST is Lake Sampaloc, which is among many small lakes in the Philippines that have been tapped as an economic resource, most notably as a pioneer site for aquaculture in the 1970’s (Santiago et al., 2001). By the late 1980’s, however, floating cages for tilapia culture in the lake expanded from 0.06 to 0.33 km$^2$ of its total surface area, with at most 6,000 t of fish feeds used in the lake annually (Santiago and Arcilla, 1993). The resulting increase in allochthonous organic matter caused the worst occurrences of mass fish kills in Lake Sampaloc in the early 1990’s, resulting in revenue loss and the risk of lake faunal extinction. These events prompted the revision of aquaculture and integrated water resources management plans in the lake which resulted to the reduction of the allowable cage area to only 0.12 km$^2$ which is approximately 10 % of the lake surface area (Cariño, 2003). These new provisions were geared towards lake rehabilitation and the protection of local stakeholders thru responsible aquaculture practices. However, just recently, Global Nature Fund (GNF) proclaimed Lake Sampaloc as the “Threatened Lake of the Year 2014”. GNF cited the local government’s difficulty in implementing the imposed regulations due to inadequacy of

Table 1. List of parasites obtained from different host fishes and sampling locality

<table>
<thead>
<tr>
<th>Classification</th>
<th>Species</th>
<th>Host</th>
<th>Locality</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>ACANTHOCEPHALA</td>
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<tr>
<td>Polymorphida</td>
<td>Bolbosoma sp.</td>
<td>Oreochromis niloticus</td>
<td>Lake Taal</td>
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<tr>
<td>Neoechinorhynchida</td>
<td>Neoechinorhynchus quinghaisiens</td>
<td>Carassius gibelio</td>
<td>Lake Sampaloc</td>
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<td></td>
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<td>Hypopthalmichthys nobilis</td>
<td>Laguna de Bay</td>
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<td></td>
<td></td>
<td>Oreochromis niloticus</td>
<td>Lake Sampaloc, Laguna de bay</td>
<td>All acanthocephalans listed herein are first records in the Philippines (Briones et al. in press)</td>
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<tr>
<td></td>
<td>Echinorhynchida</td>
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<td></td>
<td>Rhadinorhynchus ganapatti</td>
<td>Katsuwonis pelamis</td>
<td>Batangas Sea</td>
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<td>ARTHROPODA</td>
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<tr>
<td>Isopoda</td>
<td>Corallana grandiventra</td>
<td>Oreochromis niloticus</td>
<td>Lake Taal</td>
<td>Among the pioneering studies which confirmed the presence of Corallana in Lake Taal (Adorador et al. 2006)</td>
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<tr>
<td>Copepoda</td>
<td>Lernaea sp.</td>
<td>Oreochromis niloticus</td>
<td>Lake Taal</td>
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<tr>
<td>PLATYHELMINTHES</td>
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<tr>
<td>Strigeidida</td>
<td>Clinostomum sp.</td>
<td>Clarias batrachus</td>
<td>Lake Taal</td>
<td>All platyhelminth parasites listed herein are among the few published works on fish parasites in Lake Taal (Cauyan et al. 2013)</td>
</tr>
<tr>
<td>Azygiida</td>
<td>Euclinostomum sp.</td>
<td>Clarias batrachus</td>
<td>Lake Taal</td>
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<tr>
<td></td>
<td>Enleptus sp.</td>
<td>Glossogobius giuris</td>
<td>Lake Taal</td>
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<tr>
<td>Plagiorchiida</td>
<td>Oriantocreadium sp.</td>
<td>Clarias batrachus</td>
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<td>Opegaster sp.</td>
<td>Glossogobius giuris</td>
<td>Lake Taal</td>
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</table>
manpower and funding, and highlighted the continuing degradation of the Lake Sampaloc ecosystem. This issue has raised concerns regarding the current status and potential threats to Lake Sampaloc’s biodiversity (Fund, 2014). However, to date, most of the published research done in the lake has been related only to aquaculture implications (Santiago and Arcilla, 1993; Tan et al., 1995; Santiago et al., 2001; Carino, 2003) with only a handful of studies on the lake’s actual biota (Quilang et al., 2007; Santos et al., 2010). As a result, there is a gap on what is currently known regarding the lake’s biodiversity. Establishment of baseline information regarding the various biota of Lake Sampaloc is therefore needed. Thomasian scientists have conducted biodiversity surveys in many small lakes, and have placed particular focus on the zooplankton, zoobenthos, and nekton of Lake Sampaloc during their rapid surveys during 2012-2014. A highlight to their work is the first attempt at the official listing of fish (Briones et al., 2016) and benthos from the lake. These findings have helped elucidate the present dominance of many introduced biota from these lakes.

The contribution of Thomasian freshwater biologists was not confined to local ecosystems. Through collaborative agreements with scientists from the National Taiwan University and Kyoto University, a Thomasian was able to lead the analysis of the long-term changes in the diet of the endemic goby Gymnogobius isaza in Lake Biwa. This was done by analyzing the stomachs of archived specimens kept in Kyoto University that had been collected over the span of 40 years (Briones et al., 2012).

**Fish Parasites**

The Philippines has a rich history in fish parasite-related research, many of which have pioneered the knowledge in parasite biodiversity in tropical Asia. The monograph *Digenean Trematodes of Philippine Fishes* (Velasquez, 1975) is considered the first comprehensive monograph in this region. Likewise, the extensive records of helminths of Philippine animals by Tubangui (Tubangui, 1933) together with other recent records, have contributed a great bulk in the fish health literature in Southeast Asia by the end of the 20th century. However, notwithstanding the great deal of research already accomplished, a huge gap is still unknown for Philippine fish parasite biodiversity in general.

In the Philippines, studies on parasite hosts have been inclined towards aquaculture and aquarium fishes. This trend, unsurprisingly, is focused on detecting epizootics and avoiding the negative impact of parasites in commercial fisheries. Such an approach primarily employed parasite surveys from laboratory-based fish enclosures and fish market areas, making it difficult to infer specific locality records for parasites in Philippine inland waters. Arthur and Lumanlan-Mayo (Arthur and Lumanlan-Mayo, 1997) organized local reports into the *Checklist of the parasites of fishes of the Philippines*, which remains the most extensive reference for Philippine fish parasites to date. The report compiled records of fish parasites in the Philippines, and amounted to 201 parasite species from 190 species of fish host examined. *FishBase* records (viewed November 2015) estimate a total of 3282 fish species in the Philippines to date. Given that many parasites are potentially host-specific, we can only infer that there still remains a great deal of taxonomic and basic survey work before the parasites of Philippine fishes have been thoroughly documented.

Biodiversity-driven parasite research is still in the exploratory stage in the Philippine setting. The initiatives of students and faculty of the University of Santo Tomas to lessen this gap has been to focus on basic parasite survey work with implications to the systematics, biodiversity, and ecology of freshwater fish parasites in the Philippines. Highlights to their work are first reports of Acanthocephala from Philippine fish: namely *Neoechinorhynchus quinghaiensis*, *Rhadinorhynchus ganapatti*, and *Bolbosoma* sp. These three new records encompass a third of all the known species of acanthocephalan parasites associated with Philippine fishes (Briones et al., 2015). Also, pioneering surveys on the

<table>
<thead>
<tr>
<th>Classification</th>
<th>Species</th>
<th>Occurrence</th>
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<tbody>
<tr>
<td>CYPRINIFORMES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>Carassius gibelio</td>
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</tr>
<tr>
<td></td>
<td>Hypophthalmichthys nobilis</td>
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</tr>
<tr>
<td>PERCIFORMES</td>
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</tr>
<tr>
<td></td>
<td>Parachromis managuensis</td>
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</tr>
<tr>
<td></td>
<td>Giuris margaritacea</td>
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</tr>
<tr>
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<td>Glossogobius aureus</td>
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</tr>
<tr>
<td></td>
<td>Leiopotherapon plumbeus</td>
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<td></td>
<td>Oreochromis mossambicus</td>
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<tr>
<td></td>
<td>Cichlosoma Amphilopus</td>
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</tr>
<tr>
<td></td>
<td>Paraneetroplus</td>
<td>non-native</td>
</tr>
</tbody>
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Table 2. The occurrence records (non-native, native and endemic) of the different host fishes where the parasites have been obtained.
platyhelminth parasites of fish from Lake Taal have assessed initial measures of parasite burden which may aid in explaining possible routes of infection and showing possible effects on fish overall health (Cauyan et al., 2013). This is in addition to taxonomic work on parasitic isopods that have elucidated the presence of Corallana grandiventra in Lake Taal and in the country (Tables 1 and 2).

CONCLUSIONS AND FUTURE PROSPECTS

This paper is the first attempt to consolidate the history of freshwater biology research in the Philippines, and shows its major developments and achievements. Furthermore, it highlights the growth of the discipline in the University of Santo Tomas - an institution whose alumni played a role during the beginnings of the discipline, but was not able to sustain its visibility in the field until the developments of the last decade. This was made possible through the synergistic approach between key players – faculty researchers, graduate and undergraduate students, national and international collaborators. This has led to the increased output via peer-reviewed publications, and helped usher in grants from both national and international funding agencies. At present, Thomasian researchers are involved in more research projects in freshwater biology. It is hoped that this will be sustained, and would lead to an improvement of scientifically-derived knowledge of freshwater ecosystems in the country.

ACKNOWLEDGEMENTS

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