History of the biodiversity and limno-ecological studies on Lake Taal with notes on the current state of Philippine limnology

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Scientists have studied Lake Taal for its diverse flora and fauna, active volcanism and unique limnological features. In this paper, we track the development of scientific interest based on available literature which may help determine the current needs and future prospects for more in-depth research. The early part of the 20th century became the starting point of limno-ecological and biodiversity research in Lake Taal. Other significant researches such as the BFAR, PCAMRD, FISHSTRAT and Akvaplan-niva projects have been able to compile additional information on the lake. Unfortunately, many other aspects have remained unstudied while some completed projects remain unpublished or have become "gray literature". The lack of funding, long-term monitoring and the publication culture among local scientists have hampered the further growth of research on the lake. This scenario calls for the revival of limnology which can develop scientific knowledge on Philippine lakes.

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Submitted: August 12, 2010
Revised: December 9, 2010
Accepted: December 15, 2010
Published: January 10, 2011
Editor-in-charge: Eduardo A. Padlan

KEYWORDS

Tropical limnology, Caldera lakes, Eutrophication, Aquaculture

INTRODUCTION

Philippine limnology is inconsistent and fragmentary compared to other more established branches of biology that are being funded in the Philippines. The two subject areas usually prioritized and which comprise the bulk of Philippine lake studies are: 1) aquaculture and fisheries, and 2) pollution and eutrophication. Studies on resource utilization for food through aquaculture and fisheries help provide cheaper sources of nutrition for the growing Filipino population. However, the increased demand on resources by aquaculture, urbanization and industrialization of shore ecosystems led to misuse and thus necessitated monitoring the effects of pollution and eutrophication. Limno-ecological and biodiversity studies were left out in the process. After the pioneering works of European and American scientists on Philippine lakes in the 1930s and 1970s, very few dedicated Filipino scientists continued the study of Philippine freshwater ecosystems.

The Philippines is home to 59-70 lakes covering approximately 200,000 ha nationwide (Davies et al. 1990, Guerrero III 2001, Mutia 2001). They are important natural resources, yet little is known about their basic features. This is true even for Lake Taal (Figure 1), home to the lowest active volcano and the only freshwater sardinella in the world. There is still a need for further research and strict implementation of conservation strategies (Ong et al. 2002) for its flora and fauna.

This paper presents available information on the limnology and biodiversity of Lake Taal obtained from “gray literature” cited in peer-reviewed publications and the few peer-reviewed journal articles available online (11 ISI indexed biology papers over the past 30 years; see http://apps.isiknowledge.com). We review the development of limno-ecological and biodiversity studies from the colonial period to the present day and discuss how much local and foreign scientists contributed to current knowledge on this ecosystem.

Colonial Period: the age of exploration (1500s – 1940s)

Spanish and American explorers, missionaries and scientists were the first to document the lake with maps, e.g., Murillo Velarde’s map, drawn from exploratory expeditions since Juan de Salcedo’s expedition in 1570. These accounts described the lake to have salty or brackish water where sharks, tunas, snakes and other organisms abound and where the active Taal Volcano Island is found (Buñag 1934, Hargrove 1986, Hargrove 1991).

The Americans started exploring the islands shortly after their victory over the Spanish. Pratt (1916) published a paper on Philippine lakes with a lengthy discussion on Lake Taal. Herre (1927) reported four new fish species including the freshwater sardinella, *Sardinella tawilis* (*Harengula tawilis* Herre 1927). The only Filipino scientist to have published papers on Lake Taal during this period was D.V. Villadolid, who enumerated 101 fish species belonging to 32 families and the fishing gears used by the locals to catch them (Villadolid 1932a, Villadolid 1932b, Villadolid 1937). The Wallacea expedition meanwhile provided accounts on the origin, morphometry, hydrology and biodiversity of Philippine lakes (Brehm 1939, Hauer 1941, Kiefer 1939, Woltereck et al. 1941), which included first records of some species new to science such as *Alona pseudoanodonta* Brehm, *Diaptomus insulanus* Wright and its synonym *D. sensibilis* Kiefer, *D. vexillifer* Brehm, *Mesocyclops hyalinus* Kiefer, *Pseudodiaptomus brehmi* Kiefer, *Tropodiaptomus giganotviger* Brehm, *T. prasinus* Brehm, and *Thermocyclops woltereckii* Kiefer.

Focus on fisheries and volcanism (1950s – 1970s)

The granting of Philippine independence from the United States in 1946 ushered the beginning of Filipino-led researches in limnology, which however, resulted in only a limited number of publications. The volcanic eruptions between 1965 and 1976 prompted regular monitoring of the lake’s chemical parameters (SiO_2, pH, Na:K ratio, C̃l1, and SO_4) by the Commission on Volcanology (forerunner of the Philippine Institute of Volcanology and Seismology or PHIVOLCS). Zooplankton composition was updated as part of an effort to study the zooplankton of Southeast Asian lakes where several new records were documented for Lake Taal (Ueno 1966). The Bureau of Fisheries and Aquatic Resources (BFAR) conducted research from 1972 to 1975. A report on the *Sardinella tawilis* fisheries and a paper on a hydrological survey of the lake were published based on this study, which provided information on thermocline depth and vertical mixing of water layers (Castillo et al. 1975, Castillo and Gonzales 1976).

The Local Water Utilities Administration (LWUA) then collected data from various sources (e.g., Bureau of Public Works, Weather Bureau, and Commission on Volcanology) to study the feasibility of exporting water from Lake Taal to Saudi Arabia. They also analyzed water samples from the surface and at 43 m depth in four stations around the lake. Their report suggested that water from Lake Taal was unsuitable for irrigation of most

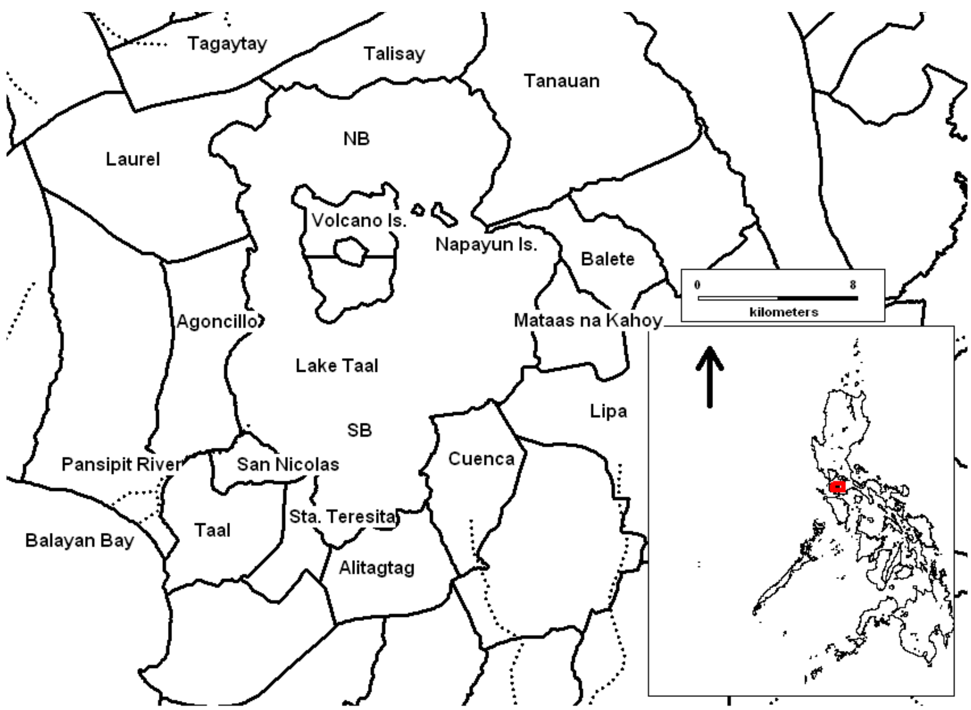

Figure 1. Map of Lake Taal including the lake-side towns in the surrounding watershed. Insert map shows its location in Luzon Is.

crops because it posed a medium alkali and sodium hazard and was deemed below export standards (LWUA 1978).

Limnological surveys in a changing environment (1980s – 1990s)

Food security for the rapidly increasing Filipino population and the meanwhile improving technologies in breeding of introduced continental species such as the Nile tilapia (*Oreochromis* spp.) made aquaculture a highly potential business investment. An aquaculture pilot project in 1975 (Aypa et al. 2008) in Lake Taal led to further hydrological surveys measuring physical, chemical and biological parameters in the early 1980s to assess the potential of fish cage culture (Aquino and Nielsen 1983). This, together with other studies by BFAR and the Southeast Asian Fisheries Development Center (SEAFDEC) confirmed the suitability of lakes such as Laguna de Bay, Taal, Sampaloc, Buhi and Sebu for aquaculture which would become a lucrative business, notably in Lake Taal, by the 1990s.

Scientific interest on Lake Taal in the 1980s born out of this aquaculture potential shifted to assessing the state of ecosystem health as the unregulated proliferation of fish cage culture began to take its toll. At the beginning, these researches pointed to more ideal conditions in the lake. A project funded by the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) and the University of the Philippines Los Baños (UPLB) studied basic limnological characteristics where the lake was classified as oligotrophic with low primary productivity due to nitrogen limitation in spite of its high phosphorus content. Additional data on physical and chemical characteristics such as thermocline depth, hardness, chloride, pH, conductivity and dissolved oxygen were also presented (UPLBF 1997, Zafaralla 1992a, Zafaralla 1992b, Zafaralla 1995). Other significant findings from this study include the identification of 126 species of phytoplankton from the lake (Zafaralla 1992b, Zafaralla and Orozco 1989).

Other biological studies have also been published during this period. A report on the occurrence of eight positive snakebite victims which included one fatality by the endemic *Hydrophis semperi* was published in 1985 (Watt and Theakston 1985). The book series "Guide to Philippine Flora and Fauna" contained a chapter on freshwater zooplankton where Mamaril Sr. added Lake Taal to the list of localities he sampled in the most comprehensive freshwater zooplankton survey in the country (Mamaril Sr. 1986). Ichthyological studies include an update on the species composition of migratory and littoral fishes (Mercene and Alzona 1990, Pagulayan et al. 1997) while a report published in 1991 discussed several important aspects on the biology of *S. tawilis* (Aypa et al. 1991). In 1998, a new cladoceran species (*Diaphanosoma tropicum*) was described based on samples collected from Lake Taal (Korovchinsky 1998). Other studies on phytoplankton, zoobenthos and aquatic macrophyte species richness and the biology of important fish species have also been conducted from 1995 to 2001. A majority of these have been done by students and faculty from the Institute of Biology of the University of the Philippines in Diliman (IB–UPD) where some have been published or presented (Bleher 1996, Cukingan and Pagulayan 1995-1996, Cukingan and Pagulayan 2001, Lopez et al. 2001, Pagulayan and Espiritu 2001).

By the 1990s the unregulated proliferation of aquaculture prompted the government to establish regulations on lake use

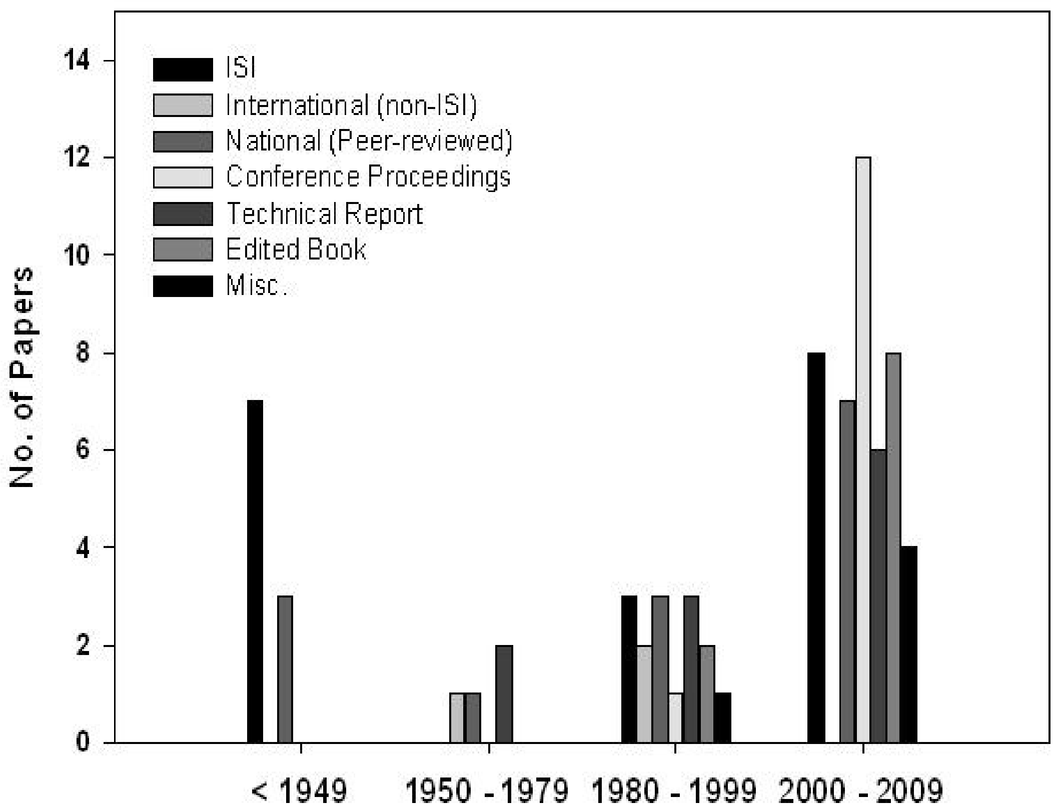

Figure 2. Limno-ecology and Biology papers on Lake Taal (miscellaneous papers include publications by scientists in newsletters or found in conference book of abstracts not classified as proceedings).

and management. The Tagaytay-Taal Integrated Master Plan of the Presidential Commission in 1994 included the creation of a fish sanctuary on the western side of Taal Volcano Island (PCTT 1994). Unfortunately, improper enforcement of this Plan favored the proliferation of fish cages in the sanctuary. Fish cage production concentrated on the northern and western areas of the lake rose from 36% in 1993 to 96% in 1998 (Datinguinoo 2005). Management efforts continued with the inclusion of Lake Taal in the EU-funded FISHSTRAT Project (1998-2003) together with other Asian lakes and reservoirs when scientists and their local counterparts (from IB–UPD and PCAMRD) studied the fisheries, phyto- and zooplankton components of the lake. This project conducted the first hydroacoustic survey in the lake and concluded that *S. tawilis*, inhabiting surface water layers, was the biggest contributor to the Lake's pelagic fish biomass (Frouzova et al. 2008, Schiemer et al. 2008), while copepods comprise the most dominant zooplankton followed by rotifers and cladocerans with three copepod and four cladoceran species inhabiting depths to 80 m (Amarasinghe et al. 2008, Perez et al. 2008). Significant findings on the phytoplankton of the lake include the identification and quantification of 44 phytoplankton species (Rott et al. 2008) including the bloom forming *Ceratium furcoides* and the endemic T*hallasiosira visurgis*. The FISHSTRAT project comprises the largest published compilation of limnological research on Lake Taal to date.

Altered state and the need to rehabilitate (2000 – present)

The 21st Century's first decade saw Lake Taal with fish kills, decline in water quality, and introduction of alien species linked with the under-regulated proliferation of aquaculture. One of the major findings of the FISHSTRAT Project included the increase in nutrient levels in the Lake which is now categorized as meso- to eutrophic (Perez et al. 2008).

Consequently, this period accounts for the highest number of ISI indexed papers on Lake Taal published by local scientists (Figures 2 and 3). Ramos (2002) published a paper on the origins and geological features of Lake Taal and discussed the presence of underwater craters and thermal vents in several areas of the lake's south basin. Vista et al. (2006) showed how aquaculture (fish cages producing 15,268 metric tons of fish equivalent to 52% of the country's total fish cage production) contributed heavily to nutrient loading to the lake. It highlighted the role of aquaculture in the decline of water quality in the lake due to eutrophication. Three studies on the endemic *Sardinella tawilis* have also been published - Samonte et al. (2000, 2009) suggested the existence of two *S. tawilis* subpopulations in the lake and determined its relationship with marine *Sardinella* while Papa et al. (2008) studied its zooplankton diet and found a preference for calanoid copepods. Other international publications include those of Quilang et al. (2007, 2008) on the comparison of morphometric and meristic characters of silver perch (*Leiopotherapon plumbeus*) populations from Lake Taal, Laguna de Bay and Sampaloc Lake. They found that *L. plumbeus* populations from Lakes Taal and Sampaloc shared more characteristics than the Laguna de Bay population. Meanwhile, a review on freshwater turtle species in the Philippines listed three species inhabiting Lake Taal (Diesmos et al. 2008).

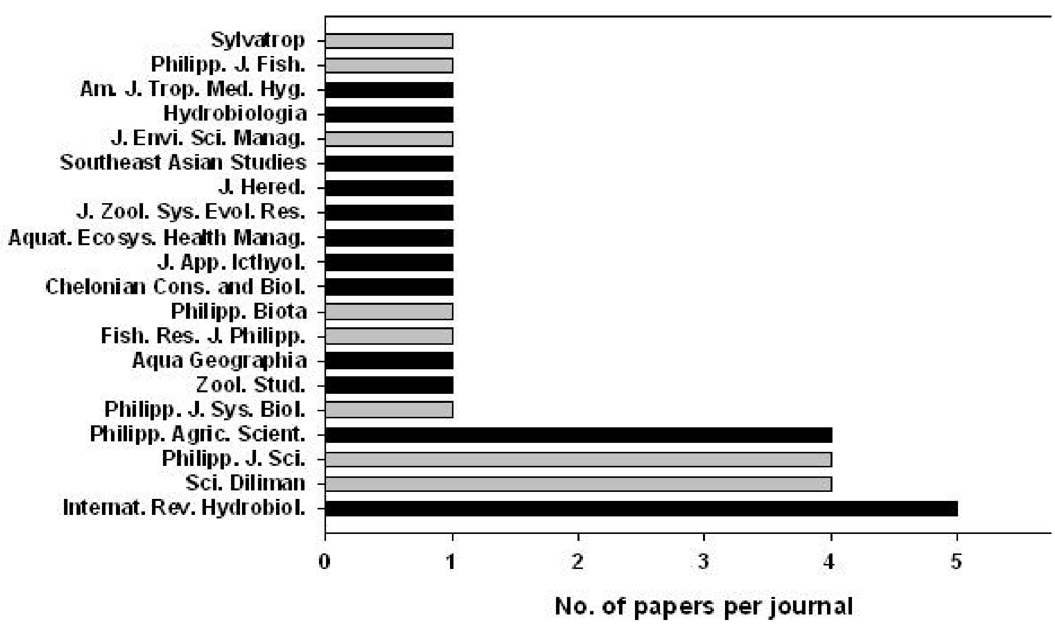

Figure 3. The number of papers on Lake Taal published in national (gray bars) and international (black bars) Limnology or Biology journals.

Other significant publications appeared in national journals, proceedings, or terminal reports. The proceedings of a national seminar-workshop on the conservation of Philippine lakes in relation to fisheries and aquaculture impacts included papers on zooplankton, benthos, fish and ectoparasite diversity in the lake (Alcañices et al. 2001, Araullo 2001, Lopez 2001, Lopez et al. 2001, Mamaril Sr. 2001a, Mamaril Sr. 2001b, Mutia 2001). A project funded by the North England Zoological Society and Flora and Fauna International on *Hydrophis semperi* (Taal sea snake) and *S. tawilis* where their biology, exploitation and conservation were discussed has been published as a technical report and a magazine article (Diesmos et al. 2004, Lagda et al. 2003). The ectoparasitic isopod *Corallana grandiventra* which has caused mortality among cage-cultured tilapia has been the subject of several investigations. Initial publications identified the isopod as *Alitropus typus* (Del Mundo et al. 1996, Kawit and Rosana 2002, Lopez 2001, Rosana and Salisi 2000) which was later corrected after thorough morphological and DNA analysis (Adorador et al. 2006). The introduced species *Parachromis managuensis* (Jaguar guapote) has been studied for its potential threat to native fish species (Rosana et al. 2006). From 2007 to 2008, three journal articles and one report were published based on the Akvaplan-niva project on risk assessment of aquaculture areas in the Philippines (2005 – 2006) conducted in Bolinao, Pangasinan and Lake Taal representing marine and freshwater aquaculture sites, respectively. For the first time, physico-chemical data were measured using a CTD probe to develop vertical profiles of dissolved oxygen, pH, temperature, salinity and chlorophyll-a. This project concluded with a recommendation of the adoption of several strategies to minimize the negative effects of aquaculture without sacrificing the rather important aquaculture yields (Legovic et al. 2008, Palerud et al. 2008, White and San Diego-McGlone 2008, White et al. 2007). A paper on the use of the *Danio rerio* embryo toxicity assay showed increased mortality of *D. rerio* embryos exposed to sediments from fish cage areas in Lake Taal indicating poor sediment conditions (Hallare et al. 2009). The most recent publication on Lake Taal dealt with a socio-psychological study based on the knowledge of Taal residents on *S. tawilis* where its value to local culture and economy was discussed (Siy 2010). Most, if not all of these studies have dealt with the mitigation of problems related to the deterioration of water quality from eutrophication or threats to native flora and fauna such as overfishing, increased fish mortality and the invasion of introduced species.

The way forward

If we would base scientific progress in terms of number of ISI publications, we can say that very little has been made for limno-ecological and biodiversity studies in Lake Taal (Figure 2). The eight ISI papers from 2000-2009 surpassed the output of the Wallacea expedition by one publication only. Given the technological advancements in limnology as well as the increase in the available resources and literature since the 1930s,

Table 1. Available data on physico-chemical variables measured in previous limnological surveys in Lake Taal.

Year / s	Parameter (units)	Value	Reference	Notes
1992	Trophic State	Oligotrophic	Zafaralla 1992	
2008		Meso-Eutrophic	Perez et al. 2008	
1974-75	Temperature (°C)	Min - 26.4 (Feb) Max - 31.4 (May)	Castillo and Gonzales 1976	
1973-74		Mean - 28.74		
1974-75		Mean - 28.99		
1989		Max – 34	Zafaralla et al. 1990	SW Station (Sep)
1981	Hardness (ppm)	Max – 237	PHIVOLCS unpubl.	Pira-piraso Is. (Sep)
1984		Min - 6.1		Pira-piraso Is. (Oct)
1992		200-300	Zafaralla 1992	Moderate
	Nitrogen	Low		
	Choride	High		
	Phosphorous	high		
1975	pH	7.5-9.0	Castillo et al. 1975	
1983		8.3-9.1	Aquino and Nielsen 1983	
1990		7.3-9.6	Davies et al. 1990	
		5.5-8.5	Zafaralla 1990	two stations in the southwestern bay
1992		7.43	Zafaralla 1992	generally alkaline
1981-90		6.9-8.9	PHIVOLCS unpubl.	neutral to slightly alkaline
1978	Conductivity (µS cm^{-1})	1850	LWUA 1978	
1990		1000-1400	Davies et al. 1990	
1998		1600-1700	Perez et al. 2008	
1990	Salinity (‰)	0.5-3	Zafaralla et al. 1990	
1976	Chlorinity (%)	0.42-0.52	Castillo and Gonzales 1976	generally freshwater
1976	DO (ppm)	0m - 6.38-6.49; 50m - < 2; 100m - < 1	Castillo and Gonzales 1976	(<2.0 mg L^{-1} at 50 m and <1.0 mg L^{-1} at 100 m
1983		0m - 12; 15m - 1	Aquino and Nielsen 1983	Northern basin - negative heterograde
		15-22m - 2.7; > 22m - 3		

Table 2. Provisional species list of flora and fauna in Lake Taal

Fish[1] (n=63)	Phytoplankton[2] (n=45)	Zooplankton[3] (n=39)
Ambassis buruensis	*Actinocyclus normani*	*Biapertura pseudoverrucosa*
Ambassis gymnocephalus	*Aphanothece minutissima*	*Bosmina fatalis*
Ambassis miops	*Carteria sp.*	*Bosmina longirostris*
Ambassis urotaenia	*Ceratium furcoides*	*Brachionus angularis*
Anguilla marmorata	*Chlamydomonas sp.*	*Brachionus calyciflorus*
Apogon hyalosoma	*Chroococcus disperses*	*Brachionus diversicornis*
Apogon thermalis	*Closterium acutum var. variabile*	*Brachionus falcatus*
Atherinomorus balabacensis	*Coelastrum indicum*	*Brachionus forficula*
Atherinomorus endrachtensis	*Coenococcus cf. fotti*	*Brachionus havanaensis*
Awaous ocellaris	*Cosmarium cf. regnelli*	*Brachionus plicatilis*
Caranx ignobilis	*Cosmarium depressum*	*Brachionus quadridentatus*
Caranx sexfasciatus	*Crucigeniella pulchra*	*Brachionus urceolaris*
Carassius auratus auratus	*Crucigeniella saguei*	*Ceriodaphnia cornuta*
Channa striata	*Cryptomonas marssoni*	*Chydorus barroisi*
Chanos chanos	*Cyanodictyon imperfectum*	*Chydorus ventricosus*
Clarias batrachus	*Cyanothece sp.*	*Diaphanosoma sarsi*
Clarias macrocephalus	*Cyclotella cf. comensis*	*Dunhevedia crassa*
Gambusia affinis	*Cyclotella cf. meneghiniana*	*Ectocyclops pharelatus*
Gerres filamentosus	*Cylindrospermopsis raciborski*	*Eucyclops serrulatus*
Glossogobius celebius	*Dictyosphaerium tetrachotomum var fallax*	*Hexarthra fennica*
Glossogobius giuris	*Elakatothrix acuta*	*Hexarthra intermedia*
Gnatholepis volcanus	*Eucapsis parallelepipedon*	*Ilyocryptus spinifer*
Gobiopterus stellatus	*Eudorina sp.*	*Keratella procurva*
Hippichthys heptagonus	*Golenkinia radiate*	*Keratella tropica*
Hypophthalmichthys nobilis	*Kirchneriella sp.*	*Keratella valga valga*
Hyporhamphus quoyi	*Lagerheimia citriformis*	*Latinopsis australis*
Kuhlia marginata	*Merismopedia punctata*	*Lecane luna*
Labeo rohita	*Monoraphidium contortum*	*Lecane patella*
Leiognathus equulus	*Mougeotia sp.*	*Lecane ungulate*
Leiopotherapon plumbeus	*Oocystis marsoni*	*Mesocyclops cf. thermocyclopoides*
Liza melinoptera	*Oscillatoria sp.*	*Mesocyclops leuckarti*
Liza subviridis	*Pediastrum tetras*	*Microcyclops varicans*
Lutjanus argentimaculatus	*Planktolyngbya limnetica*	*Moinodaphnia macleayi*
Megalops cyprinoides	*Rhodomonas minuta*	*Pompholyx complanata*
Mionorus bombonensis	*Rhodomonas sp.*	*Simocephalus vetulus*
Nomorhamphus vivipara	*Scenedesmus communis*	*Testudinella patina*
Oligolepis acutipennis	*Scenedesmus spinosus*	*Thermocyclops crassus*
Omobranchus ferox	*Selenodictyum brasiliense*	*Trichocerca dixon-nuttali*
Ophieleotris aporos	*Sphaerodinium sp.*	*Tripleuchlanis plicata*
Oreochromis niloticus niloticus	*Staurastrum pingue*	
Oxyurichthys microlepis	*Tetraedron regulare*	
Pandaka pygmaea	*Tetrastrum staurogeniaeforme*	
Parachromis managuensis	*Tetrastrum triangulare*	
Paraplagusia bilineata	*Thallasiosira visurgis*	
Poecilia reticulate	*Thallasiosira weissflogi*	
Poecilia sphenops		
Pomacentrus tripunctatus		
Psammogobius biocellatus		
Pseudogobius javanicus		
Pseudogobius poicilosoma		
Puntius hemictenus		
Redigobius bikolanus		
Redigobius roemeri		
Rhinogobius flavoventris		
Sardinella tawilis		
Scatophagus argus		
Sillago sihama		
Strongylura leiura		
Terapon jarbua		
Toxotes jaculatrix		
Trichogaster pectoralis		
Zenarchopterus buffonis		
Zenarchopterus dispar		

scientific output remains extremely low. However, if we add the number of papers that have come out in other publication types as well as the authors' affiliations, we can say that there have been more local scientists interested in studying the lake, albeit, their lack of output in mainstream literature curtails proper recognition by the international scientific community. The number of publications in international (19) and national (14) journals would seem to indicate better efforts to internationalize Lake Taal research (Figure 3). However, most of the international publications have been authored by foreign scientists; this includes papers that have appeared in reputable limnology journals such as the International Review of Hydrobiology and Hydrobiologia which have only discussed Lake Taal in passing. No ecosystem-wide studies on the lake may be found in international journals and only those that have focused on individual species (*S. tawilis and L. plumbeus*) have been published by Filipino scientists in the Journal of Heredity, Journal of Applied Ichthyology and Zoological Studies.

The progress of scientific research in Lake Taal plotted in Figure 2 shows that biodiversity studies focused on enumeration of different fish, phytoplankton and zooplankton species where some have data on abundance, biomass and distribution. The utilization of diversity indices and sampling regimes that may be considered representative of the entire lake or its watershed is yet to be conducted. Updates on the status of important species such as *H. semperi, S. tawilis and C. ignobilis* are lacking, more so

Table 2. continued.

Other Invertebrates[4] (n = 13)	Aquatic Macrophytes[5] (n=5)	Reptiles[6] (n=4)
Ampullaria luzonica	*Eichhornia crassipes*	*Chrysemys picta*
Ciridinia gracilostris	*Hydrilla verticellata*	*Hydrophis semperi*
Corallana grandiventra	*Paspalum sp.*	*Pelodiscus sinensis*
Corbicula manilensis	*Potamogeton blognus*	*Trachemys scripta*
Macrobrachium sp.	*Vallisneria gigantean*	
Melania blatta		
Melanoides costellaris		
Parathelpussa sp.		
Radix auricularia		
Solottelina elongate		
Spongilla carterii		
Terebia granifera		
Vivipara angularis		

References:
[1] FISHBASE - Froese and Pauly 2010
[2] Rott et al. 2008
[3] Ueno 1966; Mamaril 2001
[4] Perez et al. 2008
[5] Cukingan and Pagulayan, 1996; Lopez et al. 2001; Adorador et al. 2006; Perez et al. 2008
[6] Diesmos et al., 2004; Diesmos et al., 2008

with other taxa that are not considered economically important or threatened. Physical and chemical data on the lake are still limited. The lack of readily available and easy to use sampling equipment that utilizes current technology has hampered regular monitoring. Many of these variables have been measured for surface waters only (Zafaralla, pers. comm.). Given the depth of Lake Taal, these measurements would be inadequate for a comprehensive analysis of limnological conditions. Most researchers also rely heavily on local fishing boats for sample collections; these outrigger boats are not capable of withstanding the unpredictable wind and high waves in some portions of the lake. Internationally-funded research such as FISHSTRAT and Akvaplan-niva were able to compile the most comprehensive data because of adequate resources. However, since these projects have ended, none of the local institutions have sufficient funds or equipment to conduct regular follow-ups.

The year 2009 saw the implementation of the new Taal Volcano Protected Landscape Management Plan (TVPLMP) which calls for a more comprehensive zoning of the lake, including the designation of a new fish sanctuary, more defined areas where fish cages may be allowed and stricter enforcement of laws pertaining to zoning, use of proper fish net size and gear and watershed management (TVPL-PAMB 2009). This was a response to the growing clamor to rehabilitate the lake for the benefit of all stakeholders. The TVPLMP was based on past researches, consultations with scientists, stakeholders and recommendations by policy makers and consultancy groups. An immediate concern from the scientific standpoint however, is a need to re-assess the status of the entire ecosystem. Updating the inventory of fish fauna and detecting threats to fish abundance and diversity are needed. In-depth taxonomic studies based on recent literature while using novel techniques may also yield interesting results among common and inconspicuous species. This is because the unique limnological features of Lake Taal may have influenced behavior, reproduction and over-all ecology that have not yet been investigated.

The information presented in this paper has only unearthed limited knowledge needed to completely understand Lake Taal. Since the available data were not part of a routine limnological survey, this would not be very useful for long-term time-series data analysis. Regular monitoring may unravel the extent of aquaculture impact, introduction of invasive species, parasitism and fish disease. The benefits of weekly or bi-monthly routine sampling of physical, chemical and biological parameters may not be immediate, but were proven useful in monitoring other lakes for anthropogenic and climate impacts (Adrian et al. 2009). Immediate implementation would ensure that in 20 years, scientists will be able to answer more questions on the limnology of the lake and its response to past and present conditions. Sound scientific knowledge would prevent speculative generalizations on the characteristics of the lake. Publication of results in peer-reviewed journals is also encouraged among researchers. Although the last decade has seen the most number of ISI publications on Lake Taal since the Wallacea Expedition, output from local scientists can still be improved. We need a change in attitude especially among those who do not publish their research findings on Lake Taal and other Philippine lakes.

Lake Taal may be considered as part of the minority of lakes since in terms of origin and location, tropical volcanic lakes only comprise 1% of the total number of lakes worldwide (Lewis Jr. 2000). Thus, studying Lake Taal (as well as other Philippine lakes and lakes of similar origin) is important since the knowledge which can be gained from these ecosystems will contribute to a better understanding of lakes from this part of the world. Freshwater fishery is a prime source of food for inland communities in the Philippines as well as its neighboring countries. Knowledge on the status and needs for protecting these ecosystems from misuse and degradation may help ensure the survival of the people who depend on it. We need a revival of limnology in the Philippines since the very survival of lakes and the communities that depend on them rely on policies generated by a scientific approach to studying lakes.

ACKNOWLEDGEMENT

The first author would like to thank the German Academic Exchange Service (DAAD), Tonolli Fund of the International Society of Limnology (SIL), the Commission on Higher Education (CHED) and the University of Santo Tomas (UST) for funding support.

CONTRIBUTION OF INDIVIDUAL AUTHORS

Both authors contributed equally to the development of the concept, gathered literature and wrote several versions of the manuscript.

CONFLICT OF INTEREST:

None

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