INLAND WATERS
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EDITORIAL

A century of scholarship archived in the Verhandlungen, Mitteilungen, and Inland Waters: publications of the International Society of Limnology

ABSTRACT
Over the past century, the International Society of Limnology (SIL) has supported 3 noteworthy publications that document the discoveries of our predecessors and contemporaries. There are 30 volumes of the Verhandlungen (Proceedings, 1922–2010), which archive findings presented at SIL Congresses. The 25 volumes of the Mitteilungen (Communications, 1953–1996) include focal papers and collections on specific topics. Inland Waters (2011 and ongoing) is the peer-reviewed, scholarly outlet for original papers within the framework of SIL. We commemorate our 100-year history with an abridged content review of SIL publications and republish 15 articles (spanning 1953–2022) to illustrate the scope of past contributions and current directions of the Society.

KEYWORDS
eutrophication; climate change; Inland Waters; lakes; International Society of Limnology; Mitteilungen; primary productivity; running waters; SIL; Verhandlungen

Introduction

The founding of the International Society of Limnology (SIL) has been detailed by Rodhe (1974a, 1975) and its early history summarized by Elster (1974). Over the past century, the Society has supported 3 noteworthy publications that document the limnological discoveries of our predecessors and contemporaries. There are 30 volumes of the Verhandlungen (Proceedings, 1922–2010; Jones 2010; https://www.tandfonline.com/loi/tinw19), containing 7785 manuscripts, which archive findings presented at SIL Congresses. The 25 volumes of the Mitteilungen (Communications, 1953–1996; https://www.tandfonline.com/loi/tinw18) include 278 contributions, some quite lengthy; it began with dedicated articles on analytical and field techniques, then broadened to include collections on important topics. A Jubilee Symposium (Mitteilungen, Vol. 20) provides a synopsis of the first 50 years of SIL scholarship (Rodhe 1974b). Inland Waters (2011 and ongoing, https://www.tandfonline.com/loi/tinw20) is the peer-reviewed, scholarly outlet for original papers within the framework of SIL and currently includes over 500 publications.

This curated collection commemorates our 100-year history with an abridged content review of inland water resources drawn from the global range of SIL publications. In addition, 15 articles spanning 1953–2022 are republished to further illustrate the scope of past contributions and current directions of the Society (these articles are highlighted in bold in the text and reference list).

Content review

Regional limnology and lake types – SIL founders, A. Thienemann (1922) and E. Naumann (1922, 1924), had joint interest in regional limnology and characterization of lake types, with both themes continuing throughout the SIL collection (Magnuson and Kratz 2000). Examples are lake features in Spain (Margalef 1958), Central America and Mexico (Deevey 1953, Jones et al. 1993, López 2000), Brazil (Tundisi et al. 1991), Argentina (Oliver 1953, Quiros 1991, Zagarese et al. 2000), India (Gopal 1994), Bangladesh (Khondker 1994), Sri Lanka (Costa 1994), Malaysia (Ho 1994), Indonesia (Nontji 1994), Thailand (Campbell and Parnrong 2000, Jones et al. 2000), China (Chang 2002), Africa (Hecky and Bugenyi 1992, Ntakimazi 1992), former Soviet Union (Winberg 1972), Australia (Pearson 1994), lakes located at high altitude (Pennak 1958, Löffler 1964, 1969, Zutshi 1991), Alaska (O'Brien 1975, La Perriere and Jones 2002), and the sub-Antarctic (Grobbelaar and Smith 2009).

Characterization of lake types across a continuum of conditions began with studies of *Chironomus* by Thienemann (1922) and continued with emphases on littoral fauna (Macan 1953), sediment composition (Hansen 1961), production and consumption (Elster 1958), structure and dynamics (Margalef 1964), circulation patterns (Walker and Likens 1975), bacteria (Aizaki 1985), salinity (Williams 1996), and macrophyte communities (Free et al. 2005). Lake properties in Italy (Tartari et al. 2006) and Denmark are described with consideration of the European Union Water

Framework Directive (Søndergaard et al. 2020). Individual lakes can show alternate stable states characterized by vegetation and clarity or a turbid, phytoplankton-dominated phase (Jacoby et al. 2001).

Primary productivity – Globally, lake primary productivity is regulated by irradiance, temperature, ice cover, mixing depth, and nutrients (Lewis 2011). Studies have identified patterns with morphometry (Rawson 1953), periodicity of phytoplankton (Lund 1964), self-regulation of the light climate (Talling 1971), latitude (Kalff 1991), and nutrient abatement (Ahlgren 1978). Highest rates are measured in light-limited, non-photoinhibited lakes with elevated nutrients and phytoplankton (Staehr et al. 2016). Evaluation of food webs in subarctic lakes during winter suggested mixotrophic (autotrophy and heterotrophy) growth of picoplankton and nanoplankton (**Rodhe 1953**), and recent data show under-ice respiration rates can switch the annual carbon cycle of an oligotrophic lake to heterotrophy (Brentrup et al. 2021). Primary productivity has increased steadily in Lake Tahoe (Goldman 1993), and decadal changes have occurred in Lake Victoria, particularly in near-shore areas (**Mugiddle 1993**). Quantification of littoral benthic productivity (littoral greening) in lake food webs has expanded the scope of study beyond the traditional pelagic viewpoint (**Vander Zanden and Vadeboncoeur 2020**). The land–water interface is one of the most metabolically active and productive zones within aquatic ecosystems (Wetzel 1964, 1990) and is a reflection of the watershed (Likens 1984).

Phytoplankton – The growth and seasonal succession of phytoplankton in freshwaters are well characterized in SIL manuscripts (Round 1971, Reynolds 1988, Talling 2002), providing a basis for identifying phytoplankton associations across energy and resource gradients (**Reynolds 1996**). The abundance of picocyanobacteria varies in temperate lakes, with small cells dominating the productivity of oligotrophic systems (Pick 2000). Nutrient competition influences phytoplankton dynamics (Tilman 1978), with morphological features reflecting lake trophic state (Naselli-Flores 2014). Community changes have been related to changes in phosphorus availability in individual lakes (Berman et al. 1972, **Padisák and Istvánovics 1997**).

Zoobenthos – Studies of lake zoobenthos (Thienemann 1922) are an uninterrupted topic in the SIL collection (Jónasson 1978), including documentation of declines in abundance with fish predation and eutrophication (Straskraba 1965, Jónasson 1984) and changes in community structure with acidity (Raddum and Sæther 1981). The invasive zebra mussel (*Dreissena polymorpha*) can restructure food webs by shifting productivity from the pelagic to the benthos, with increases in phytobenthos, macrophytes, and non-zebra mussel zoobenthos (Spear et al. 2022).

Zooplankton – The jubilee review by Brudin (1974) documents developments in limnetic zoogeography during the early decades. A noteworthy discovery was that in the absence of fish predation, large zooplankton dominate and influence plankton associations (**Hrbácek et al. 1961**). Grazer–grazed relationships influence planktonic interactions, resulting in periods of clear water and algal blooms (Lampert 1978). Species richness of crustacean zooplankton increases with lake size (Dodson 1991) and densities increase with eutrophication (Rask et al. 2002), whereas the ratio of zooplankton to phytoplankton declines because of a low proportion of edible algae in lakes dominated by Cyanobacteria (Heathcote et al. 2016). In reservoirs, community structure can vary between lotic and lacustrine locations (Pinel-Alloul and Méthot 1984). Diel vertical migration of zooplankton, determined by light, can be reduced both in amplitude and magnitude by urban light pollution, potentially contributing to increased algal biomass (**Moore et al. 2000**).

Eutrophication and lake management – Phosphorus, once considered a trace element (Frey 1990), was linked to eutrophication in Swiss lakes (Thomas 1968). Subsequently, whole-lake experiments demonstrated the response of algal biomass to phosphorus, furthering the understanding of eutrophication (**Schindler 1988**). Changes in Lake Washington in response to an increase and subsequent decrease of the nutrient income supported the external phosphorus loading concept (Edmondson 1961, 1972). The response of the Yahara chain of lakes (Madison, WI, USA) to fluctuations in phosphorus loading over several decades provides further support (Lathrop and Carpenter 2013). Internal phosphorus loading was found to be important in lakes with anoxic hypolimnia (Nürnberg and Peters 1984) and can maintain *Microcystis* blooms during summer (Sakamoto and Okino 2000). Additional research shows some lakes require both phosphorus and nitrogen reduction to control eutrophication (Muhid and Burford 2012, Smith et al. 2016, Lewis et al. 2020, Maberly et al. 2020). There are examples of successful lake restoration efforts (de Bernardi et al. 1996), and removal of common carp from lakes benefits water quality (Huser et al. 2022). Biomanipulation, however, has been more successful in explaining food web interactions than accomplishing lasting improvements in lake water quality (Gliwicz 2005). A global dataset showed location (longitude/latitude) and nitrogen were stronger predictors of microcystin occurrence than phosphorus (Buley et al. 2021), and growing evidence shows the negative impacts of algal toxins on aquatic organisms and humans (Christoffersen and Burns 2000, Willen et al. 2011). Recent focus has turned to prevention measures (Spears et al. 2022) with near-term ecological forecasting proposed (**Carey et al. 2022**).

Running waters – The biological and water quality characteristics of running waters are major topics in the SIL collection (Patrick 1950, Macan 1961, 1974, Illies and Botosaneanu 1963, Lake et al. 1994, Ward 1998), including invertebrate production (Benke 1993). Edaphic features of valleys largely determine stream characteristics (**Hynes 1975**) and account for the variability of the broad global range in water quality (Meybeck 1996). Invertebrate communities also reflect the geology and organic matter of the valley (Gílason et al. 2000). The role of the terrestrial–aquatic linkage is further characterized by the landscape perspective of the flood pulse concept (**Junk 2005**), with emphasis on the integral role of floodplain forests (Décamps 1996) and the riparian zone (Cummins 2002). Longitudinally, riverine energetics and biogeochemical cycling are altered by natural and anthropogenic discontinuities (Stanford et al. 1988, Wang et al. 2018). Cyanotoxin occurrence is increasingly a feature of large rivers (Graham et al. 2020). A literature review suggests both nitrogen and phosphorus control should be considered to reverse eutrophication in streams (Dodds and Smith 2016).

Tropical limnology – Stratification patterns of tropical lakes were documented early by Ruttner (1931) where energetic processes are potentially more than double those at higher latitudes because of higher temperatures and other factors (Lewis 2010). Studies of tropical inland waters, however, lag behind those of temperate systems (Gessner 1964, Tundisi 1984, Kilham and Kilham 1990, Melack 1996). Threats to the conservation of tropical systems, including widespread introductions of exotic species, require multi-scale approaches to achieve reversal (Dudgeon 1994, Lowe-McConnell 1994), including the benefits of reductionist and holist strategies in aquatic ecology (Rigler 1975). Rivers in monsoonal Asia are considered some of the most endangered ecosystems in the world (Dudgeon 2002).

Response and role of lakes in climate change – Moss et al. (2011) underscored the synergy and feedback effects between eutrophication and climate warming. Subsequent updates (**Dokulil 2014**, **Meerhoff et al. 2022**) focused on landscape-level changes that include altered hydrology, greater nutrient loading, and fire frequency resulting in cyanobacterial dominance and measurable changes in biotic communities. With hydrological extremes, water level fluctuations will increase eutrophication symptoms, including frequent cyanobacterial blooms (**Zohary and Ostrovsky 2011**). There are measured responses of phytoplankton and lake temperature in Europe and Asia in response to extreme climate events (Weyhenmeyer et al. 2002, Kumagai 2008, Jung et al. 2016, Kwang-Seuk and Joo 2016, Woolway et al. 2020). Lake ice is a powerful climatic indicator of increasing air temperature, reflecting both large- and small-scale weather phenomena (Livingstone 2000, Magnuson et al. 2000, Likens 2019). Aquatic systems are sources of greenhouse gases that contribute to climate change, with some eutrophic lakes acting as sinks (Adams 1996, Kortelainen et al. 2000, Balmer and Downing 2011). Strong longitudinal and seasonal patterns in carbon dioxide emissions from reservoirs have been related to photosynthesis and decomposition (**Li et al. 2018**). Global change has prompted a network to understand, predict, and communicate lake ecosystem responses (Hanson et al. 2016), stimulating the convergence of limnology and oceanography as global change brings human impact to all water resources (Downing 2014).

Additional contributions – Notable papers not included elsewhere in this review include the ionic composition of lake waters (Rodhe 1948), buoyancy regulation of planktonic algae (Fogg and Walsby 1971), studies in paleolimnology (Dmitriev 1969, Frey 1974, Horie 1981), acid precipitation (Wright and Snekvik 1978), oxygen content of fresh waters (Mortimer 1981), microbiology (Overbeck and Ohle 1964, Jannasch 1969, Overbeck 1974), and caloric equivalents for calculating ecological energetics (Cummins and Wuycheck 1971), along with many others.

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