

Inle: A large Myanmar lake in transition

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Abstract

Inle Lake is situated in the southern part of Shan State in Myanmar. It is the country's second-largest lake, home to more than 120 000 people and a large bird sanctuary and a major source of hydroelectric power for southern Myanmar. Several distinct environmental problems have arisen in the lake basin. A long-term decrease in lake area has taken place over the last 30 years, probably because of siltation and climate. The drought of the last 2 years in particular has caused a drop in hydroelectric power output, which is affecting southern Myanmar. Many marginal parts of the lake are occupied by elephant grass mats (*Saccharum spontaneum* L.), known locally as *kaing*. These mats mature to form solid, floating islands, which are used for a unique form of agriculture but are also an increasing source of pesticide and fertilizer runoff into the lake. Textile cottage industries also abound, and both natural and manufactured dyes are discharged into the lake. Households, including many houses built on stilts in the lake, are a source of garbage and sewage. Livestock breeding also is a source of sewage. Shifting (*taungyar*) cultivation and village expansion has greatly increased erosion. Dredging is now necessary in many places and water clarity has decreased. The Inle carp (*Cyprinus carpio intha*), known locally as *nga-phane*, plays an important role in the food supply, as well as being a cultural symbol of the local Intha people. *Nga-phane* population abundance is currently low, probably because of changes in water chemistry and decreased clarity in the lake water. Partially because of the perceived potential for tourism, many sectors are now involved in lake rehabilitation and management.

Key words

aquatic plants, Burma, erosion, fish, lake conservation, lake dwellers, pesticides, restoration, sewage, water quality.

INTRODUCTION

Inle Lake is situated in the southern part of Shan State in Burma (now officially known as the Union of Myanmar). The lake is located approximately 30 km south-west of the State's capital Taunggyi (Fig. 1), and extends from approximately 20° 15' to 20° 45' N latitude and 96° 49' to 96° 48' E longitude. Inle Lake is a highly important water body in several respects. First, more than 120 000 people inhabit the lake vicinity. Some villages are built on stilts in the lake itself. They are inhabited primarily by the Intha people, who are culturally and linguistically distinct from their neighbours (Bruneau & Bernot 1974). The lake is an integral part of the livelihood of the local people, who fish in its waters and cultivate a variety of crops on its floating islands. Second, the lake is a source of water for one of the country's most

important hydroelectric complexes, which supplies much of southern Myanmar's electricity. Third, the lake is the habitat for a large variety of migrating waterfowl and other birds and the area has been designated as a national sanctuary for birds. Finally, because of its picturesque setting and diverse fauna, as well as the unique lifestyles and traditions of its human inhabitants, the lake is renowned and is one of the primary tourist destinations in Myanmar.

The pressure of human population growth, however, combined with certain agricultural and industrial practices, has degraded water quality and led to additional environmental problems in the surrounding watershed. Partly because of the lake's current and potential role in tourism, many agencies are involved in seeking to prevent further deterioration. Here we review some basic characteristics of the lake, as well as the stresses it is facing. Our goal is to gather together existing information to provide a reference point for future researchers, describe certain unique features of the lake to aquatic ecologists and acquaint researchers and colleagues with the problems faced by this important water body and give it the attention it deserves within the conservation

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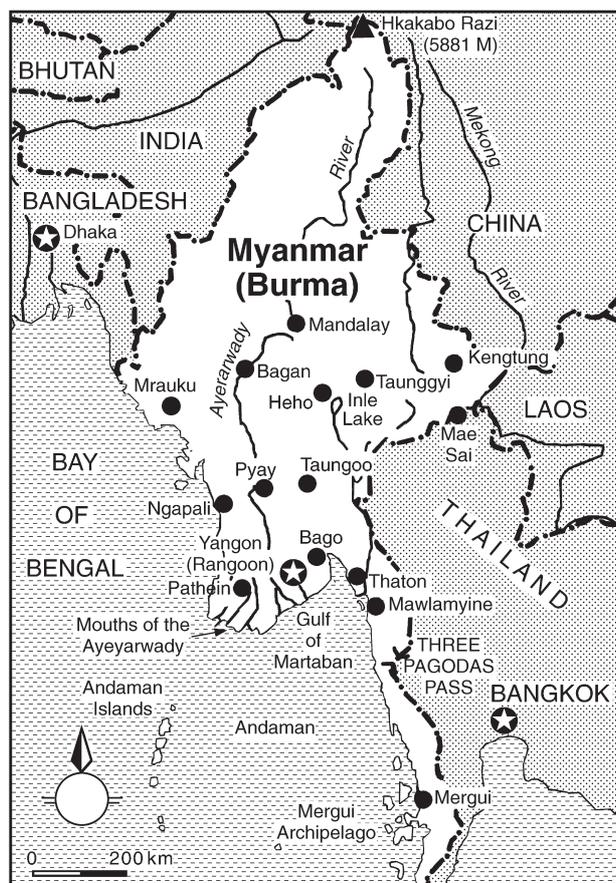


Fig. 1. Map of Myanmar, showing the location of the Inle Lake region.

community. Almost nothing has been published on Inle Lake limnology in the professional literature, our account therefore rests on unpublished reports and theses (especially Thi Dar Win 1996), personal experience, and personal communications from colleagues.

PHYSICAL FEATURES

Inle Lake is situated on the Shan plateau and the lake basin is part of the Shwenyaung rift valley. To the north is a flat plain known as the Inle or Nyaungshwe Plain. The area immediately south of the lake is also relatively flat. To the east and west are mountain ranges with peaks reaching 2000 m a.s.l., although the average elevation is approximately 1200 m a.s.l. The Sindaung range is found to the east, and the Letmaunggwe, Thandaung, and Udaung ranges to the west. The mountains and hills are dissected by many valleys with streams, which are at times torrential. Lower down, deposits from silt-laden streams have built up coastal lowlands, especially in the north-east and south-east portions of the lake. The total area of the drainage basin is 3700 km².

As elsewhere in Shan State, the underlying bedrock is mostly limestone. Limestone characteristics such as sink

holes, caves, intermittent streams, and hot springs are significant natural features of the western and eastern part of the watershed. In fact, a hot springs spa operates near Kaungdine, a village on the north-western shore.

On the higher flanks of the mountains, a thin covering of mountainous red soil covers the plateau limestone (Thi Dar Win 1996). The topsoil is mostly humus, but is easily eroded by *taungyar* (slash-and-burn) cultivation, cutting of wood, and burning of undergrowth. A thicker profile of red-brown forest soil underlies evergreen and deciduous forests on the lower flanks of the mountains. These soils are clay, with humus and other materials, and can deteriorate under *taungyar* cultivation. Mixtures of clay, silt, humus and water, known as swampy soil, are found in the north-east and south-west plains. They are probably the remnants of an old lake bed and now support mostly *kaing* grasses (further discussed later), cane forest and bamboo groves. Meadow clay soil is found to the east of the lake; it has low absorbing power and poor structure for cultivation. Finally, the lake itself is underlain by a light grey alluvium eroded from the watershed and deposited by tributaries.

The eastern part of the basin accounts for only 10% of the catchment area, the western part 53%, and the northern part the remaining 37% (Thi Dar Win 1996). Thirty streams flow into the lake: 17 from the east, 12 from the west, and only one from the north, the Nanlit Chaung, which flows by the main town of Nyaungshwe about 2 km from the lake itself. The only outlet, Nam Pilu or Balu Chaung, is in the south and flows into a stream, Poon Chaung, ultimately leading to the Thanwin River (Salween River) and then into the Andaman Sea by the city of Mawlamyine (Moulmein).

Inle is Myanmar's second largest lake (Indawgyi in Kachin State is the largest). The average elevation of the lake surface is 890 m a.s.l. The elongated shape is approximately aligned on a north-south axis, and the north and south ends taper to a relatively narrow breadth. Khin Thant (1967) reported a lake approximately 23 km long and 11 km wide, but less than 30 years later Thi Dar Win (1996) reported water surface dimensions of only 11 km long and 5 km wide. Apparently, a dramatic shrinkage has taken place over the past few decades. Thi Dar Win (1996) states that the lake has a maximum potential area of 260 km², but that in recent years it has never occupied more than 155 km², even during the rainy season. The various maps we have examined show inconsistencies in lake shape and dimensions. Even Landsat thematic mapper images are not definitive (Gesellschaft für Angewandte Fernerkundung mbH 1999), because the truly limnetic region gradually blends with a littoral zone into extensive swamp and other wetland regions. Because of the flatness of the basin and the low hydraulic residence time of the lake, there is probably much variability in the lake

perimeter on seasonal and interannual scales, in addition to the decadal scale already mentioned. Annual inflow water volume is typically $1.1 \times 10^8 \text{ m}^3 \text{ year}^{-1}$. The storage capacity of the lake is $3.5 \times 10^7 \text{ m}^3$. Even at maximum storage capacity, the hydraulic residence time of the lake must be only 0.32 years, which implies the potential for large variability in residence time and lake volume even at the seasonal scale. Indeed, lake depth fluctuates with the seasons, usually averaging approximately 4 m in the hot season and 7 m during the rainy season. The map provided here (Fig. 2) does correspond to the general features of recent Landsat images, but it should not be considered a definitive description, if indeed one can be given.

The Inle Lake basin has a warm, humid, temperate climate (Thi Dar Win 1996). Minimum temperatures occur in December, when the typical daily range is 13–24°C. Maximum temperatures occur in April, when the typical daily range is 21–32°C. Occasionally, the area experiences severe winter cold spells and crop-killing frosts can occur. However, the lake is large enough to ameliorate temperature conditions in the basin, and frosts rarely affect crops grown on or near the lake. Precipitation exceeds 5 cm month⁻¹ from April through to November and peaks in August with typical rainfall of 20 cm. In summer, the prevailing winds are south-westerly warm tropical winds from the Bay of Bengal, and are more than 7 km h⁻¹ on average in May–June. In winter, they are north-easterly cold continental winds from central Asia, less than 5 km h⁻¹ on average in December–January. Because of the local topography, these winds tend to be experienced as southerly and northerly, respectively, in the Inle basin. Humidity ranges from less than 40% in March to almost 90% in August.

BIOLOGICAL FEATURES

Native aquatic plants include pondweed (*Potamogeton*), coontail (*Ceratophyllum*), bladderwort (*Utricularia*), stone-wort (*Nitella*), mustgrass (*Chara*), and elephant grass (*Saccharum spontaneum* L.). The latter, known locally as *kaing*, is important in the structure of floating islands for agriculture, as well as for weaving mats. Pondweed is used as a food source by both people and fish. Water hyacinth (*Eichhornia crassipes* (Mart.) Solms), known locally as *baedar*, was introduced to the lake as an ornamental plant, probably during the early 1900s. Although it is useful for improving the structure and fertility of floating islands, the extremely abundant plant population also obstructs waterways around the lake. Swampy soils to the north-east and south-west of the lake contain cane forest (*kyu*) and bamboo groves, in addition to *kaing*.

Five fish families inhabit Inle water, mainly carp, catfish, and murrels, and also an endemic cyprinid (Kottelat 1986).

Khin Thant (1967) found 23 fish species during her surveys of the lake. We found 14 species during recent surveys (Table 1). Other taxa are farmed in local fish ponds. In Aindaunggyi village fish ponds, for example, *shwe-wah-nga-gyin* (*Cyprinus carpio*) and *myet-sar-nga-gyin* (*Ctenopharyngodon itellus*) are being grown. The Inle carp (*Cyprinus carpio intha*), known as *nga-phane*, plays an important role in the food supply, as well as being a cultural symbol of the local Intha people (Bruneau & Bernot 1974). Intha fisherman harvest the carp with conical nets stretched

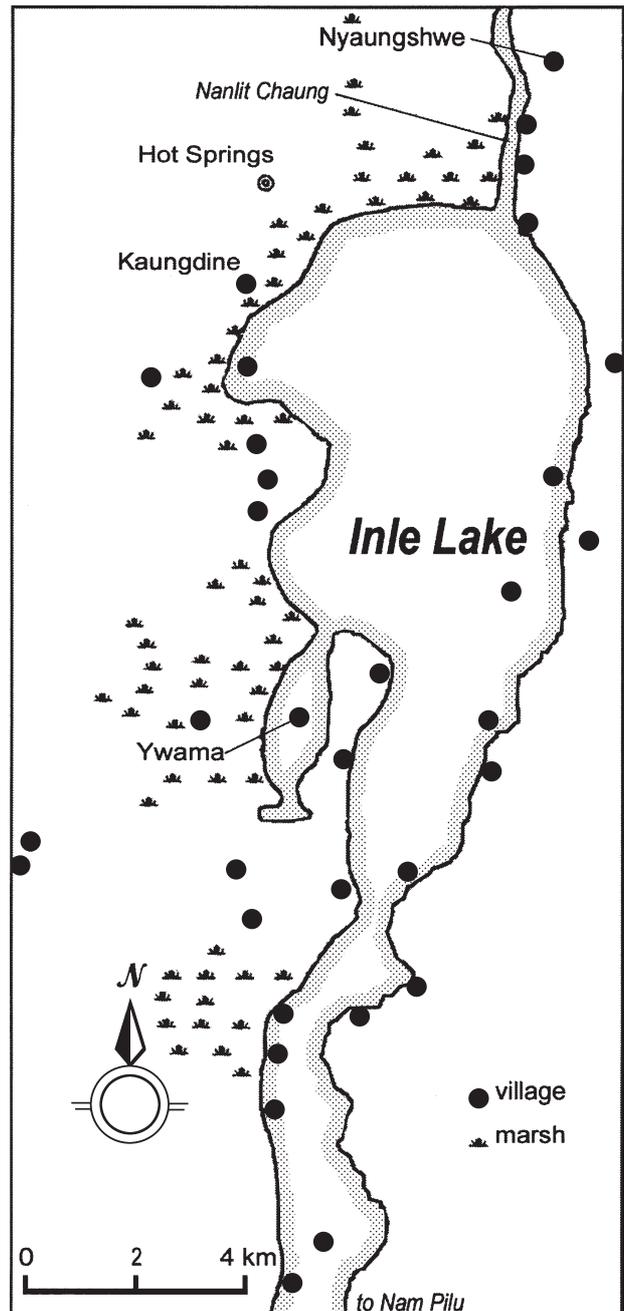


Fig. 2. Map of Inle Lake, showing the locations of main villages in and around the lake.

Table 1. Fishes in Inle Lake (surveyed in 1997)

Scientific Name	Vernacular Name
Family Clariidae	
<i>Clarias batrachus</i>	nga-khu
Family Ophiocephalidae	
<i>Ophiocephalus striatus</i>	nga-yan
<i>Ophiocephalus harcourt</i>	nga-ohn-met
Family Cyprinidae	
<i>Cyprinus carpio intha</i>	nga-phane
<i>Cirrhina latia</i>	nga-lu
<i>Barbus sarana caudimarginatus</i>	nga-khone-ma
<i>Barbus scanicus</i>	nga-yit
<i>Barbus stedmanensis</i>	nga-taung-new
<i>Discognathus lamta</i>	nga-taing-tet
<i>Lepidocephalus berdmorei</i>	nga-tha-le'-doe
<i>Nemachilus brevis</i>	nga-pyay-ma
Family Symbranchidae	
<i>Amphipnous cuchia</i>	nga-shint-mwe'
<i>Monopterus albus</i>	nga-shint-ne
Family Notopteridae	
<i>Notopterus notopterus</i>	nga-phae

over wood and bamboo frames (Fig. 3). Several other kinds of nets are also in use, and a variety of harpoons are employed to spear fishes. The Intha propel their flat-bottomed boats in a unique way. Standing at the stern on one leg, they operate the oar by wrapping their other leg around it. This leaves the arms free to manage the fishing nets. It also gives the rower a higher vantage point from which to navigate around floating macrophytes as well as to spot fish. *Nga-phane* population abundance is currently low probably because of changes in water chemistry and decreased clarity. These fish can breed the whole year in clear water, which is becoming scarcer in the lake. Aquarists prize certain Inle fish (Foersch 1986) but at present, this is unlikely to place any pressures on rare species.

The influence of the underlying limestone on water chemical composition may account in part for faunal differences between Inle and the vast Ayeyarwady (Irrawaddy) River system, the most important in the country. Specifically, phytoplankton primary productivity may have been low historically, judging from productivity at higher trophic levels. For example, Khin (1948) noted that no fast growing species of carp occurred, and most of the carp species were of small size. In addition, the catfish *nga-khu* (*Clarius batrachus*) was comparatively smaller than in the Ayeyarwady. Khin also identified the murrel *nga-yant* (*Ophiocephalus striatus*) as the only species in the area growing 'to a good size of 10 lb or more in weight.'

**Fig. 3.** Inle Lake dwellers rowing and fishing in the traditional manner.

Inle is rich in birds; at least 57 species of forest birds and 43 species of waterfowl can be found on the water and in nearby wetlands and forests (Zin Oo, unpubl. data, 1995). All are protected by law since Inle Lake became an official bird sanctuary in 1985. The total area of the sanctuary is approximately 643 km², extending from Nanthee village to Moe-Byae' dam. Several species of egret, seagull, cormorant, wild duck, and magpie are abundant in north-west Inle. Migratory birds usually come to Inle wetland areas in October as the monsoon rains diminish and depart in May as the rains intensify. Wild duck, which are particularly abundant, migrate seasonally from the Yunnan Plateau and other adjacent areas of China. In addition to fish and waterfowl, aquatic animals found in Inle include several species of frog and tortoise, as well as otters, which live near tributary streams and the lake shore.

Population figures are available for Nyaungshwe Township, which approximately coincides with the drainage basin. Populations during the 1973, 1983 and 1993 censuses were 77 032, 95 349, and 121 279, respectively. The exponential growth rate is approximately 2.3% per year. The population is concentrated toward the west and south-west of the lake, where most of the floating-island cultivation takes place. In addition to the Intha and the Bamar, the national majority ethnic group, the main ethnic groups in the Inle region are Shan, Pao, Danu and Taungyo.

Much of the northern and western portion of the Inle region is occupied by *kaing* vegetation, although it occurs elsewhere as well. This swampy grassland accumulates organic matter and eventually matures to form solid floating islands. These islands may be submerged either partially or completely. Farmers cut off portions of the *kaing* islands and transport them to appropriate places where they are staked to the lake bed with bamboo poles (Fig. 4). The islands (*ye-chan*) are typically approximately 2 m wide and 40 m long,



Fig. 4. Floating islands used for agriculture that are staked into the lake bed with bamboo poles.

but may be as large as 8 m wide and 100 m long. Silt and clay alluvium from the lake bottom and weeds, such as water hyacinth, are used to augment the structure and fertility of these islands. A variety of flower, vegetable and fruit crops are cultivated year-round. The resulting peninsulas and islands form a network of canals that are the main transportation routes for the Intha. In Ywama, a village located in a western bay of the lake, canals form the streets and most daily activities are conducted from boats. The floating market at Ywama draws vendors and buyers from around the lake basin and further afield.

ENVIRONMENTAL PROBLEMS AND REHABILITATION ACTIVITIES

Malaria is common in the hilly areas around the lake, where poor drainage favours the breeding of mosquitoes (Thi Dar Win 1996). Some mosquito populations appear to have developed pesticide resistance. Although there is no specific published health information available, it is safe to assume that other water-related diseases are present in the area, just as they are present throughout Myanmar in areas that are in proximity to lakes and rivers. These water-related diseases include gastroenteritis of unspecified aetiology, as well as bacterial and amoebic dysentery, typhoid and many others. Proper sanitation systems are lacking and much household garbage and sewage waste ends up in the lake. Livestock breeding also contributes organic waste with potential pathogens. Although water for domestic use may be taken from different parts of the lake, the opportunity for contamination is high.

The Inle area is well known for its textile products. Major textile cottage industries in eight villages use both natural and chemical dyes, which affect water quality locally. Recently, there has been a shift from the use of local cottons to imported wools to use in the weaving of shawls. As the

imported materials are already dyed, the shift has probably led to a decrease in dye wastes, at least for this particular product. Rice mills, oil mills and other food-processing activities are also common, and local impacts from wastes are likely, although undocumented. Inle Lake is an important waterway for transportation and more than 1500 motor launches are found in the region. Most are driven by diesel fuel. Motor workshops are found throughout the area and, because of the relative shallowness of the lake, petroleum hydrocarbons are undoubtedly a significant contaminant of its waters.

The main economic activity of the Inle Lake region, however, is floating garden agriculture. In 1996, 3200 ha of floating island was cultivated. The tomato is the primary cash crop and its cultivation occupies approximately half of the floating garden area (Thi Dar Win 1996). Other important floating garden crops include garlic, citrus, pulses, betel vines, gourds and flowers. The farmers use fertilizer and pesticides on their crops, especially on tomato. Typically, 80–160 kg ha⁻¹ of triple superphosphate is used on tomato fields alone in one growing season. Red spider mites and cutworms are the major tomato pests, and the main pesticides used to control them are monochlorophos and cypermethrin, respectively. Rodents swim to and from the islands and damage crops. The unskilful use of inappropriate pesticides, especially refractory organochlorine compounds, is considered a major problem for both water quality and public health in the basin. Apparently, there is much room for improvement by using integrated pest management techniques, including using different crop strains and arranging better timing of planting, spraying and harvest. Because of the perceived effects of careless pesticide use on human health, some local authorities have banned any increase in floating island cultivation.

Deforestation is a major problem in the surrounding mountains, especially in the western watershed of Inle Lake. Shifting cultivation practices on the adjacent hills contribute to erosion of soil. Expansion of villages in the watershed has also increased the suspended sediment load to the lake. Although one can still see the bottom in the centre of the lake, according to local inhabitants, the clarity has decreased over the years. Siltation by sandy loams in tributaries and certain portions of the lake has blocked or changed the traditional flow pattern of the water. The sediment load from these tributaries is approximately in proportion to their catchment areas, with the total sediment load amounting to $2.6 \times 10^6 \text{ m}^3 \text{ year}^{-1}$, and approximately 25% of this load may be deposited in the lake. Dredging and other maintenance activities are necessary to maintain navigation channels along tributaries and in the lake itself. Typically, channels of 12 m width and 1.2 m depth are being maintained. In

Table 2. Conservation activities in the Inle Lake basin

Activity	Organization
Construction of silt-catching earth dams on both flanks of the lake	Irrigation Department; Save the Children Fund/US (Myanmar Program); local community
Dredging silt and alluvial sand from the lake	Irrigation Department
Controlling spread of wild floating islands, wild grasses, water hyacinths and other weeds	Irrigation Department; local community
Public education on proper handling of pesticides and fertilizers	Agriculture and Occupational Health departments
Habitat conservation	Wildlife and Forestry departments
Public education on reforestation	UNDP
Public environmental awareness training workshops	Irrigation, Agriculture, and Forestry departments; Save the Children Fund/US (Myanmar Program); local community
Public awareness signs and billboards	Agriculture and Forestry departments; Save the Children Fund/US (Myanmar Program)

addition to eroded silt, domestic and industrial solid waste as well as aquatic plant debris is slowly accumulating in the lake basin.

Other reasons behind the long-term decline in lake area are not clear, although climate may be playing a role. Sinkholes may also be a factor; other lakes and ponds in southern Shan State have disappeared because of sinkholes (Khin Thant 1967). Certainly, the drought of the last 2 years has had a devastating effect on Inle, which has a very short residence time. The lake feeds the Lawpita hydroelectric power station downstream on the Nam Pilu, which provides a major part of the energy supply to southern Myanmar and the capital. The drought has been partially responsible for rotating electric power blackouts, which have affected large parts of the country.

Because of Inle Lake's role as a major tourist attraction, a conservation and restoration program for the watershed was launched in 1997. The executive committee comprises members from the government of Shan State, Nyaungshwe Township local authorities, and representatives from government agencies (irrigation, agriculture, and forestry departments). The project is an ongoing process. Lake management now involves many government sectors but public awareness and participation also play a vital role (Table 2). Although there are local successes, it is too early to predict any major outcome of these rehabilitation measures.

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