Environmental Impacts of Tourism on Lakes

7

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Abstract

Ecosystem services are the benefits provided to people by ecosystems and biodiversity. Fresh water is a 'provisioning' service referring to the human use of fresh water for several purposes. The hydrological cycle also sustains inland water ecosystems, including rivers, lakes and wetlands. These ecosystems provide regulating, supporting and cultural services that contribute directly and indirectly to human well-being through recreation, scenic values and fisheries. To maintain ecosystem health or ecosystem integrity, external or internal perturbations must be kept below the carrying capacity.

Anthropogenic disturbances of freshwater resources as a consequence of tourism are diverse. In many regions of the world, lakes and ponds in particular are important freshwater habitats providing significant attraction for the public. Impacts to lakes from tourist activities occur directly to the lake water and shoreline, or can affect the water body indirectly through various actions in the catchment. The response of a specific freshwater ecosystem depends on the type of interference as well as the type and size of the lake. Shallow lakes are affected and hence behave differently from deep lakes. Large lakes react in a different way than small lakes. Impacts are also modified and mediated by the characteristics of the catchment, such as morphology, size, land-use and population structure.

Impacts to tourist lakes are classified as direct and indirect effects and are analysed and exemplified.

Keywords

Ecosystem service · Eutrophication · Recreation · Water quality

7.1 Introduction

The human population benefits from a multitude of resources and processes that are supplied by natural ecosystems. These benefits are collectively known as ecosystem services. Fresh water as a water resource is a 'provisioning' service referring to the human use of fresh water and includes products like pure drinking water or clean water for recreation. In the near future, global change will alter the supply of ecosystem services that are so vital for us (Schröter et al. 2005).

Anthropogenic disturbances of freshwater resources as a consequence of tourism are very diverse. Lakes and ponds are particular important freshwater habitats providing significant attraction for the public. The intention of this review is to compile and summarize touristic impacts on lakes of any size.

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7.2 Environmental Impacts of Tourism

The quality of the environment, both natural and man-made, is essential to tourism. The relation between tourism and the environment is complex—many activities can have adverse environmental effects. Many of these impacts are linked with the construction of general infrastructure such as roads and airports, and of tourism facilities, including resorts, hotels, restaurants, shops, golf courses and marinas. The negative impacts of tourism development can gradually destroy the environmental resources on which it depends. On the other hand, tourism has the potential to create beneficial effects on the environment by contributing to environmental protection and conservation. It is a way to raise awareness of environmental values and it can serve as a tool to finance protection of natural areas and increase their economic importance. This branch called ecotourism is rapidly expanding.

Negative impacts from tourism occur when the level of visitor use is greater than the environment's ability to cope with this use within the acceptable limits of change. Uncontrolled conventional tourism poses potential threats to many natural areas around the world. It can put enormous pressure on an area and lead to impacts such as: soil erosion, increased pollution, discharges into the sea, natural habitat loss, increased pressure on endangered species and heightened vulnerability to forest fires. It often puts a strain on water resources, and it can force local populations to compete for the use of critical resources.

7.3 Water Resources and Tourism

A lake that is suitable for tourism must:

- Be easily accessible.
- Have the necessary infrastructure.
- Have warm water surface temperature preferably >20 °C.
- Have good water quality ('clean water').

The best category to comply with these criteria is an oligo-mesotrophic lake.

The tourism industry generally overuses water resources for hotels, swimming pools and personal use of water by tourists. This can result in water shortage and degradation of water supplies as well as generating a greater volume of waste water. Moreover, tourists have a tendency to consume more water when on holiday than they do at home. The amount used can be up to 440 L a day. This is almost twice as much what the inhabitant of an average city uses. Particularly in drier regions, water scarcity is then of particular concern.

Recreational activities of tourists on lakes are summarized together with their possible consequences and effects in Table 7.1. The relations between the entities in Table 7.1 are not meant, however, as being 1:1. One form of utilization may have several consequences resulting in a number of effects. Swimming, for instance, may cause eutrophication and contamination, which in turn can lead to increased nutrient load, reduced oxygen concentration and finally algal blooms.

Shallow lakes are usually more vulnerable to disturbances than deep lakes. Lakes that thermally stratify during summer act as nutrient sinks with no or little re-suspension. Internal nutrient load therefore is often negligible. In contrary, shallow lakes do not thermally stratify, nutrients are not permanently buried and re-suspension is common, which may lead to high internal loading. Short-term weather events and diurnal changes are more pronounced in shallower lakes compared with deep lakes. Morphometry, water level change and flushing are of much greater importance when lakes are moderately deep. The littoral zone and the aquatic vegetation are usually more significant for shallow ecosystems. These and other factors are summarized in Dokulil et al. (2012).

Off all the consequences mentioned in Table 7.1, eutrophication most severely affects water quality and hence lake tourism. Because of its importance, it is also one of the best studied impacts on lakes worldwide. The critical loading concept developed by Vollenweider (1976) and extended by Vollenweider and Kerekes (1982) works sufficiently well in most types of lakes (e.g. Dokulil and Teubner 2003, 2011). In shallow lakes, which are turbid or dominated by submerged macrophytes, however, chlorophyll concentrations often tend to be considerably smaller than predicted from total phosphorus (TP) because much of the phosphorus is unavailable (Dokulil et al. 2006). In such cases, restoration efforts can be made successful by applying bistable theory (Dokulil et al. 2006, 2011).

Disturbances by tourists impact not only the lake but also the shoreline, the watershed (catchment) including the ground water and even the airshed (atmosphere). The dimension of the impact in each category depends on a number of parameters describing the entity and diminishes the further one moves away from the water body. Effects on the lake depend on the size (large or small), depth (deep or shallow) and type (natural, constructed or urban).

Impacts affecting the shoreline are dependent on the nature of the shore (rocky, stony or sandy). In addition, the aquatic as well as the terrestrial vegetation, the structural diversity and the degree of modifications are important.

The areal size of the catchment in relation to lake area, the flat or mountainous morphology and the land-use primarily determine the loading to the lake. The degree of urbanization and the location relative to the lake in the watershed can influence lakes in many ways through population density and activity of residents and tourists.

Effects from the airshed can originate from the economic activity and population density of a wider region because of long-distance atmospheric transport under the influence of

Table 7.1 Summary of lake utilizations in touristic areas leading to various consequences and effects

Utilization	Consequences	Effects
Recreation	Eutrophication	Algal blooms
Swimming	Pollution	Reduced O_2 concentration
Angling	Littering	Waterborne diseases
Boating	Contamination	Fish kills
Water sports	Erosion	External/internal nutrient load
Scuba diving	Disturbances	Shore erosion
Shoreline activities	Noise pollution	Diffuse run-off
Watershed activities	Gas emissions	Vegetation destruction

The entities in the Table are not meant as 1:1 relations
See text for further explanation

Table 7.2 Overview on potential direct and indirect impacts by touristic activities on lakes

Direct impacts	Indirect impacts
Chemicals liberated from skin	Nutrient load from catchment
Nutrient release and input	Increase of internal load
Bacterial contamination	Chemical pollution through run-off
Sediment re-suspension	Waste and storm water input
Wave effects	Floodwater increase
Damage of water plants	Macrophyte removal
Alien species introduction	Water level changes
Changes in fish composition	Water abstraction (from lake and groundwater)
Waste dumping	Land-use change in the catchment (industrialization, vegetation change)
Shoreline constructions (housing, jetties and marinas buoys)	Increased urbanization
Littering	Soil sealing
Shoreline destruction	Gas emissions to the atmosphere
Shoreline vegetation change	Disturbance of wildlife
Disturbance of wildlife	Reduction in biodiversity
Fish farming	

weather conditions. All these impacts can further be differentiated into direct and indirect disturbances (Table 7.2).

7.4 Impacts on Lakes

Touristic impacts on lakes usually come from a number of recreational activities. The most important ones are swimming, boating and angling. These impacts will be discussed in the following sections.

7.4.1 Swimming

Swimming is usually positively linked with fitness and well-being. Risks associated with swimming in a lake come from turbidity, currents, pollution or pathogens contained in the water. These risks are commonly seen as ecosystem threats. Rarely, the people recognize that the swimmers themselves produce these risks when large numbers are involved, as in public beaches or pools.

Health problems largely originate from bacteria such as coliform bacteria, *Escherichia coli*, fecal streptococci, *Pseudomonas aeruginosa* as well as yeasts and fungi originating from swimmers, introduced by water birds or carried in through waste water discharged into the lake.

Ecological problems mainly come from the input of nutrients such as phosphorus and nitrogen either washed off from the skin or emitted via urine. On average, each swimmer or bather contributes 0.094 g P per day to the water body (Schulz 1981). According to Binder (1994), the critical phosphorus load should not exceed 0.07 g P m^{-2} a^{-1} for shallow lakes that are less than 5 m deep. Nutrient accumulation leads to increased turbidity due to enhanced algal growth, which can create pH problems and finally cumulate in algal blooms. These deteriorations can affect bathers. Turbidity reduces visibility thus increasing accident risks while hindering rescue operations. Certain algal types, particularly cya-

Table 7.3 Impacts, effects, potential risks and their significance resulting from angling and related activities. *Modified from Lewin et al. (2006)*

Example	Effects	Risks	Significance
Exploitation	Catch decline population fluctuations	Population collapse, decrease in genetic diversity	***
Size selectivity	Changes in length and age distribution	Truncation of natural age structure	***
Species selectivity	Selective removal of species	Alteration in species composition, changes in trophic cascade, loss of resilience	***
Stocking Transfer of (bait) fish	Negative impacts on local fish stocks owing to competition, predation, hybridization or diseases, non-indigenous species introduction	Native species decrease or are lost, fish communities change, ecosystem changes occur	***
Sex selectivity	Vulnerability of either males or females to angling	Effective population size decreases, effects on recruitment	**
Bye-catchcatch and release	Injuries and stress in species	Mortality immediate or delayed Sub-lethal fitness impacts	**
Nutrient input	Negative impacts on water quality	Eutrophication, water quality deterioration	**
Loss of angling gear	Damage to wildlife	Survival and fitness of birds Risks to humans	*
Disturbance of habitats and wildlife	Macrophyte damage, impacts on water birds	Loss of habitats, stress and reduced recruitment in birds	*
Boat traffic and noise	Wave action, emissions, stress	Negative impacts on littoral vegetation and on survival and fitness, decrease in water quality	*

nobacterial species can produce toxins, which are released into the water. Skin irritation or even allergic reactions in sensitive individuals are then possible. Algal blooms washed on shore create aesthetic problems not only by looking ugly but also because of the smell produced during decay.

7.4.2 Angling

Exploitation and impacts from angling have received much less attention compared with commercial fishing. Over the last decades, inland commercial fisheries strongly declined in economic importance in the industrialized countries while angling became increasingly more important particularly for tourism development. This is even true for the developing countries, where fishing is still important for subsistence (Cowx 2002a, b).

Although the management of recreational fishing has regionally received considerable attention, the dimension of angling and the potential impacts of fishing on fish populations and aquatic ecosystems are largely underestimated. A single angler may have a low or moderate impact on fish stock. It is, however, the cumulative impacts large numbers of anglers can induce which matter. Since angling is usually practiced during leisure time, it becomes increasingly important for tourism. Recently, Lewin et al. (2006) have extensively documented and discussed the potential impacts of non-commercial recreational fishing, angling and associated activities. Their main results are summarized in the following paragraph and in (Table 7.3).

The most severe impacts from angling are exploitation of fish stock, size and species selectivity. Exploitation rates can be highly variable ranging from less than 10% to over 80% depending on fish species. Among many other factors, rates also depend on the angling effort, which in turn is affected by local regulations particularly, the fishing period duration. Effects of exploitation can be compensated by fish stocking, which can be a major impact of the fishery on aquatic ecosystems. In addition, fish are often deliberately or accidentally introduced. The introduction of non-indigenous or alien fish species can have considerable long-term and widespread ecological and biological effects on native fish stocks.

Through their selectivity for fish species and size, anglers can be seen as keystone predators adding a further trophic level on aquatic ecosystems. Depending on the fish species targeted, angling can severely affect the trophic cascade. For a more detailed discussion, refer to the review by Lewin et al. (2006).

Activities related to angling can disturb littoral habitats through boating or near-shore trampling. Additional effects originate from wave action, noise and nutrient input (Table 7.3). The loss of fishing gear may seem unimportant but can, e.g. severely affect birds. A good example is provided by Pühringer (2011).

7.4.3 Boating

Any boat may interact with the aquatic ecosystem and disturb habitats but the major effects come from motorized watercraft such as commercial tourist boats, power boats or fishing boats. Personal watercrafts such as jet skis add additional effects (see http://ww.pwia.org/UserFiles/File/History-PWC.pdf). Effects of boating on aquatic systems are extensively discussed by Asplund (2000) and are briefly summarized here.

Boats have direct and indirect effects on a number of lake water, littoral and shoreline parameters. Water clarity

Table 7.4 Summary of potential mechanisms by boating on aquatic ecosystems and their effects. Modified from Asplund (2000)

	Emissions Exhaust	Propeller Hull contact	Turbulence	Waves Wake	Noise	Movement
Water Clarity		■	■	■		
Water Quality	■					
Shoreline erosion				■		
Macrophytes		■	■	■		
Fish	■	■	■			■
Wildlife		■		■	■	■
Human enjoyment	■			■	■	■

Shaded areas indicate potential effects

is affected by an increase in turbidity, nutrients or algal biomass. According to Yousef et al. (1980), waves generated by motorboat propellers increased phosphorus on average by 28–55 %. Maximum increase in turbidity was observed shortly after boating activity but remained high for almost 25 h. Sediment re-suspension, higher turbidity and larger TP concentrations tended to be greater in shallower lakes than deeper lakes (Asplund 1996).

Fuel leakage and emissions affect water quality by adding metals, hydrocarbons and other pollutants to the water. According to Wagner (1991), who provides a good review on the subject, toxic effects on aquatic organisms are in general minimal because amounts are usually small and hydrocarbons are highly volatile. However, polyaromatic hydrocarbons and fuel additives may have effects on drinking water supply. Moreover, accumulation in sediments in certain places, e.g. near marinas might be a problem for water organisms.

Wakes and waves produced by boats can be up to 40–50 cm depending on the size and speed. These waves can severely increase shoreline erosion (e.g. Johnson 1994) and may also indirectly affect submerged and emergent aquatic macrophytes through their movement but also through increased turbidity. Plant communities are more susceptible to direct effects from boat hulls or propellers (e.g. Asplund and Cook 1997).

Boats have very little direct effect on fish, fish breeding or fish behaviour. Of much greater importance are the indirect effects through the disturbance of fish habitats (Lagler et al. 1950). Similarly, wildlife is indirectly disturbed by the destruction of habitats and deterioration of water quality. Direct effects of boating on wildlife are noise and direct contact with propellers (Asplund 2000). Moreover, effects on human enjoyment, which disturbs peace and quiet, air quality, safety and crowding should not be under-estimated.

A further aspect of boating is the number of boats permitted on a lake because the effects on lakes mentioned earlier are cumulative and related to the quantity of boats. There is, however, very little scientific evidence on this aspect (Anthony and Downing 2003; Beachler and Hill 2003; Burger 2003). On Neusiedler See, a large shallow lake in Austria, for example, cumulative boat days for the period May to September 2004 to 2006 have increased from 488 to 584 with peaks occurring mainly on weekends and an ever-increasing tendency (Fig. 7.1).

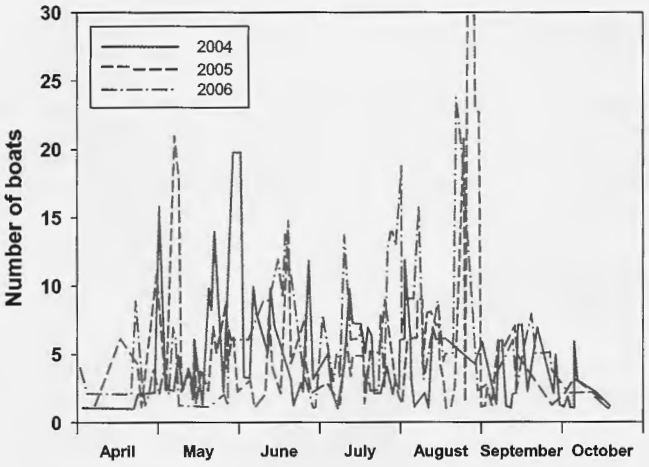

Fig. 7.1 Number of boats on Neusiedler See in the period April to October of each year from 2004 to 2006 (Herzig, personal communication)

7.4.4 Impacts on the Shoreline

Shore zones are characterized by the type of substrate, vegetation, slope and structural diversity. The zonation of the vegetation and the definitions are elegantly summarized in Fig. 7.2 reproduced here from Ostendorp et al. (2004). Shorelines are under pressure by a wide variety of human activities in the immediate lakeshore and remotely in the catchment. Recreation and tourism have direct impacts through facilities and increased numbers of holiday makers resulting in habitat destruction, trampling, littering and disturbance of breeding birds or sensitive mammals.

The degree of modification and the accessibility of the shoreline is an important aspect. In developed regions of

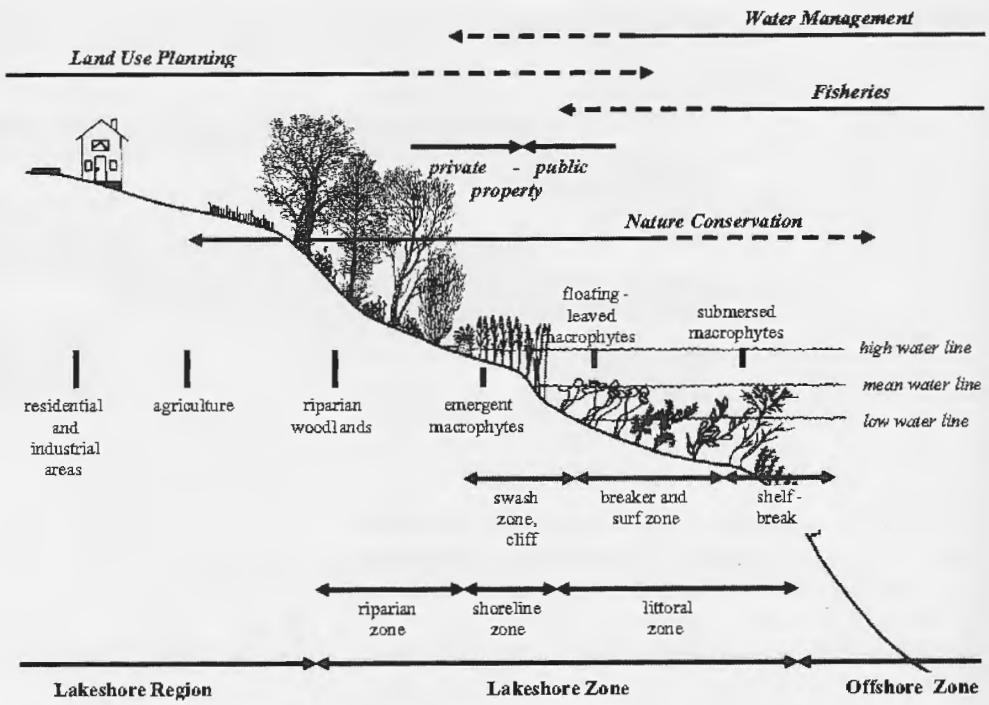

Fig. 7.2 Definitions and zonations of the lakeshore and littoral zone. Reproduced from Ostendorp et al. (2004)

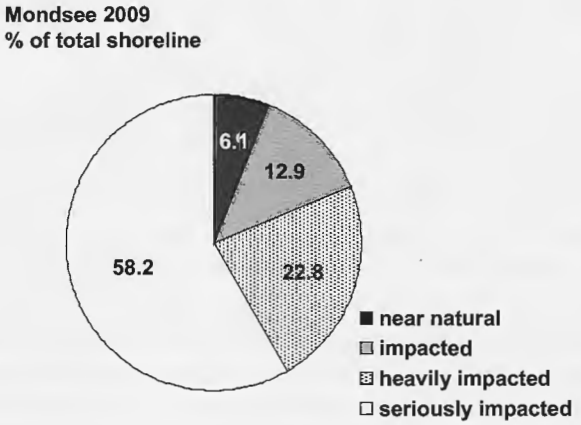

Fig. 7.3 Percentage of lakeshore modification in Mondsee 2008. Modified from Ritterbusch-Nauwerck (2011)

the world, only small fractions of the total shoreline are in a more or less natural state. A recent analysis of shoreline modification on Mondsee, a deep, touristic pre-alpine lake in the Salzkammergut region of Austria reveals that only 6.1 % of the lakeshore is in a near-natural state and more than 50 % is seriously impacted or inaccessible (Fig.7.3).

7.4.5 Impacts from the Catchment

Any tourist-related activities in the catchment, such as new apartments, holiday villages, sport centres, clearings for ski slopes and land-use changes, will ultimately have some sort of indirect influence on the receiving lake. At the landscape scale, physical processes such as orography and the size of the catchments contribute to their character and hydrology, influencing ecosystem functions such as water capture, water storage or floodwater detention (Everard et al. 2009). All these functions and their associated ecosystem services respond to climate change (Tucker and Slingerland 1997).

Eutrophication, primarily from diffuse sources, is a particular problem originating in the drainage basin. Relevant parameters are land-use and their intensity precipitation, population density, nutrient emission and nutrient retention. Associated with these factors is the degree of soil erosion from the catchment. For the receiving lake or lakes in the drainage basin, their landscape position, connectivity to other water bodies or wetlands as well as the lake network complexity is important (Martin and Soranno 2006). Moreover, as climate changes, extreme events in the drainage basin become increasingly important for nutrient transport and loading (e.g. Zessner et al. 2005; Strauss and Staudinger 2007). Recently, more holistic approaches have been used to evaluate pressures including tourism on trans-boundary lake districts (Klug 2010).

7.4.6 Impacts from the Airshed

Similar to the disturbances from the drainage basin, impacts arise from long-distance transport of air pollutants in the airshed. These pollutants can originate to some extent from tourist-related activities and may significantly influence lakes. Most notable is the acidification problem created

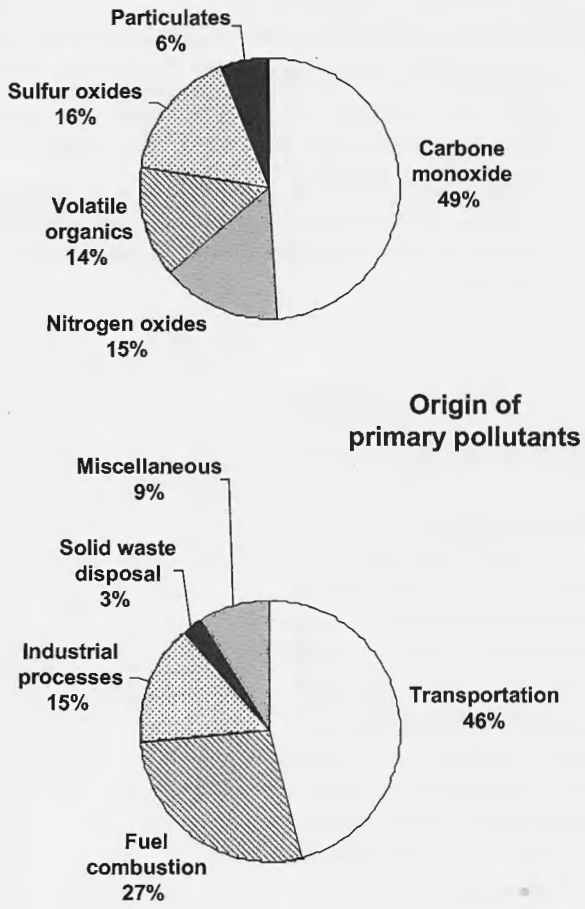

Fig. 7.4 Relative proportion of gaseous primary pollutants and their origin

mainly by gaseous emissions from fuel burning and exhausts from cars. Depending on many factors, in particular the geology of the catchment, acidification by primary pollutants (Fig. 7.4) or secondary pollutants produced in the atmosphere primarily decreases the pH values in streams, rivers and lakes. As a consequence, a multitude of complex direct and indirect effects occur in freshwater biological systems (D'Itri 1982).

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