



Global environmental consequences of tourism

Stefan Gössling*

Institute of Cultural Geography, Albert-Ludwigs-Universität, Werderring 4, 79085 Freiburg, Germany

Abstract

In 2000, almost 700 million international tourist arrivals were counted worldwide. Even though a global activity of this scale can be assumed to have a substantial impact on the environment, its consequences have never been assessed and quantified. In this contribution, five major aspects of the leisure-related alteration of the environment are investigated: (1) the change of land cover and land use, (2) the use of energy and its associated impacts, (3) the exchange of biota over geographical barriers and the extinction of wild species, (4) the exchange and dispersion of diseases, and (5), a psychological consequence of travel, the changes in the perception and the understanding of the environment initiated by travel.

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1. Introduction

Ecosystems provide services essential to humanity, which in short can be described as supporting life, supplying materials and energy, absorbing waste products, and providing culturally valuable assets (cf. Daily, 1997, 2000). Maintaining ecosystem integrity must thus be a primary human goal, which is nevertheless difficult to achieve because little is known about the temporal and spatial scales over which ecosystems should be safeguarded, the limits to replace their functions, or the levels of stress they can endure as complex, interacting, and interdependent systems (Costanza, 2000). In the light of these uncertainties, it is important to understand the contribution of human activities to ecosystem change, and how these activities might reduce the ecosystems' capacity to maintain a continuous flow of services.

Tourist activities impact directly and indirectly on ecosystems. Coral reefs, for instance, can be damaged through trampling, buying, or collecting reefs species (a direct impact occurring locally), or through increased water temperatures as observed during El Niño Southern Oscillation (ENSO) phenomena. ENSO phenomena have increased in frequency and intensity in recent decades (IPCC, 2001), which is likely to be a result of global climate change related to human activities

including travel (an indirect impact occurring on large regional scales). While the local ecological effects of tourism have been relatively well researched (summary e.g. in Hunter and Green, 1995), there is little information on how these effects add up globally. Furthermore, the non-physical consequences of travel have remained little investigated, although they might be as important for global environmental change. There is evidence that travel changes our understanding of the environment in a way detrimental to the goals of sustainability (Gössling, 2002). The aim of this article is thus to (i) identify the areas where tourism contributes to global environmental change, (ii) summarize the available data and scientific knowledge in these areas, (iii) establish first-order estimates of the scale of the occurring changes, and (iv) assess the significance of these changes for sustainability.

2. Method

In order to approach the problem, the aspects of global environmental change considered to be most critical for ecosystems were reviewed. For example, Sala et al. (2000) identified land use change, climate change, biotic exchange, atmospheric carbon dioxide (CO₂) increase, and nitrogen deposition as the most important factors that will lead to the loss of ecosystems and biodiversity in the future. Five major fields of global

*Tel.: +49-761-203-3567.

E-mail address: stefan.gossling@humecol.lu.se (S. Gössling).

environmental change to which tourism contributes were finally identified (compare Section 3). In a second step, the scientific literature was reviewed and evaluated. However, it soon became obvious that existing sources in journals and books were only of limited use for the purpose of this paper because quantitative information was rarely provided and not always comparable. In order to overcome this problem, national statistics (e.g. tourism and travel surveys) were used as indicators and data were extrapolated on the base of reasonable per tourist averages. As the article seeks to identify the impacts related to leisure-tourists (as opposed to business tourists; definitions according to World Tourism Organization), calculations were made for the former wherever possible. However, leisure- and business tourists could not always be distinguished and some of the calculations do thus include both groups, which has been indicated in the text. Most of the calculations provided in the following are first-order estimates based on a poor statistical database. The degree of uncertainty of the calculations has thus also been indicated in the text.

3. Global environmental consequences of tourism

The global environmental consequences of tourism can be divided into physical and psychological ones. Their impact can be both direct and indirect. Ultimately, all changes initiated by tourism occur locally or individually, but add up to global phenomena.

From a global perspective, tourism contributes to:

1. Changes in land cover and land use.
2. Energy use.
3. Biotic exchange and extinction of wild species.
4. Exchange and dispersion of diseases.
5. Changes in the perception and understanding of the environment.

Furthermore, water use should be seen as an important issue, because many regions face water scarcity. Tourism often seems to accelerate existing problems because tourists shift their water demand to other regions, often water scarce areas like coastal zones. Furthermore, they seem to use substantially more water on a per capita basis than at home, thus increasing global water demand. A short discussion of the topic is provided in Section 3.6.

3.1. *Land use and land cover change*

Human land use and land cover change have transformed 30–50% of the Earth's ice-free surface (Vitousek et al., 1997). Land use change is defined as the alteration of the way humans use land, while land cover

change is the alteration of the physical or biotic nature of a site (Vitousek, 1994). Land use change and land cover change are subsumed in the following under land alteration, because they can occur simultaneously and may often have similar ecological consequences. Land alteration is seen as the single most important component of global environmental change affecting ecological systems (Vitousek, 1994; Vitousek et al., 1997). Even land not transformed directly by human action is often affected by the fragmentation of the surrounding areas. Tourist infrastructure development is often an important agent in this process, particularly in coastal zones. It should also be noted that land alteration is an important cause for the release of greenhouse gases like CO₂, methane (CH₄), and nitrous oxide (NO_x) (IPCC, 2001), thus interacting with other aspects of global environmental change.

The use and conversion of lands is central to tourism. Worldwide, large areas are used to build tourist infrastructure like, for example, in the Alps, the Mediterranean, or coastal zones throughout the tropics. Land is primarily converted for the construction of accommodation establishments, even though the direct land-use for tourism and recreation also includes airports, roads, railways, paths, trails, pedestrian walks, shopping areas, parking sites, picnicking areas, campsites, summerhouses, vacation homes, golf courses, ports, marinas, ski areas and lifts, as well as additional lands needed for the production of food to supply hotels and restaurants, burying grounds for solid wastes, lands to treat waste waters, and areas required for the production of the infrastructure needs of this industry (computers, TVs, beds, etc.). The area affected by tourism is thus significantly greater than the directly built area. However, an estimation of the total land used, converted or affected by tourism or recreation is difficult. Forests and coastal zones, for example, are important ecosystems attracting hundreds of millions of visitors each year, but the area affected by their activities is virtually impossible to calculate: forest outdoor activities include picking mushrooms, berries, flowers, and herbs, picnicking, river and lake fishing, motor boating, jet and water skiing, white and flat water canoeing/kayaking, technical rock and ice climbing, orienteering, all terrain vehicle and dirt bike driving, mountain biking, hiking, horse riding, bird watching, photography and painting, survival training, alpine skiing and snowboarding, cross-country skiing, snowshoeing, snow-mobiling, (ice) fishing, dog sledding, sailing, and hunting (Vail and Hultkrantz, 2000). These activities may often be multi-purpose, for example, a recreational walk combined with mushroom picking. It is thus only possible to make an estimate of the most important land use categories. These include the land needed for accommodation establishments, traffic infrastructure (airports, railways, roads, ports, and marinas),

and golf courses. No data was found for the leisure-related use of areas for skiing and other sports. All calculations presented in the following include direct and indirect land alterations. In the case of accommodation establishments, for example, this comprises the built area, access roads, parking sites, and surrounding greens and gardens.

3.1.1. Accommodation establishments

Hotels, hostels, motels, pensions, bed and breakfast, self-catering accommodation, bungalows, vacation homes, holiday villages, campsites, and farms are just some examples of accommodation establishments, of which the World Tourism Organization counts more than 80 different categories. These are responsible for most of the direct land alteration linked to tourism. Apart from rooms, accommodation buildings often provide restaurants, kitchens, car parks, retail outlets, swimming pools, gardens, lobbies, etc. The area required for tourism can be calculated using land use per bed as an indicator. Land use per bed is a measure of the area required for a hotel at ground level, including gardens, parking sites, swimming pools, etc. divided by the total number of beds.

Basically, the area required per bed varies substantially depending on the type of accommodation establishment. For example, Grenon and Batisse (1989, cited in GFANC, 1997) report areas of 25–100 m² required per bed in hotels and other accommodation businesses at ground level: average land use per bed varies between 50 m² for rented, self-catering accommodation, 50 m² for camping and caravan sites (per place), 30 m² for hotels and youth hostels, and 100 m² for holiday villages. For the latter category, these figures may be conservative. For example, a survey of holiday villages in Germany, The Netherlands, and Belgium (Lüthje and Lindstädt, 1994, own calculations) revealed land use values of 157 m² per bed. Furthermore, the average size of the villages in the survey by Lüthje and Lindstädt (1994) was 41 ha, but there is a strong trend towards larger villages, which have since the mid-1990s generally been larger than 100 ha (Strasdas, 1992). Land use per bed was found to increase with size in such holiday villages ($n = 28$; $r = 0.77$) and overall land use per bed in holiday villages might thus increase substantially in the future.

Krippendorff (1986) provides data for Switzerland, reporting that there were 250,000 rented villas (*chalets*) and vacation homes in 1985, totaling 1 million beds. For each *chalet*, vacation home, etc. he assumes area requirements of 650 m², or 160 m² per bed (including infrastructure, such as connecting roads, parking sites, etc.). In comparison, the 7200 hotels in Switzerland required an area of about 1100 m² per hotel, or 30 m² per bed. In the whole of the country, hotels (800 ha, 5%) and other accommodation (16,000 ha, 95%) may thus

have required an area of 16,800 ha. Overall, accommodation establishments required 0.4% of the total land area in Switzerland in 1985.

Land use for tourism may be particularly extensive in the tropics, where lands are often comparably cheap, leading to the construction of relatively large hotels. For example, a survey of the land used for 5 resort hotels in the Kiwengwa area, Unguja Island (Tanzania) indicated that on average 284 m² of land were used per bed (Dahlin and Stridh, 1996; Gössling, 2001a). Overall, the total area designated as future tourist area in Unguja Island (435 ha) represents about 0.3% of the island's total terrestrial area.

Land use also seems to increase with the standard of the hotel, even though the available data does not allow for statistical testing of this hypothesis. However, as an example, the Lemuria Resort, a five-star hotel in the Seychelles, is spread over an area of 110 ha (this includes a golf course). Statistically, this amounts to more than 4580 m² per bed (or approximately 2290 m² excluding the golf course). Wong (1998) reports that the Bintan Beach International Resort in Malaysia, built as an “amalgam of integrated resorts” (Wong, 1998, p. 94), requires an area of 23,000 ha. Up-market hotels and resorts may thus occupy large areas both in absolute and relative terms. In contrast, hotels in cities may require comparably small areas as a result of the high value of prime sites. They are often functional blocks with relatively limited areas available for gardens, forecourts, and swimming pools (cf. Jim, 2000).

In order to calculate the area required by tourist accommodation on a global scale, a number of assumptions had to be made. First, all existing types of accommodation establishments were divided in six categories: hotels, campsites, pensions, self-catering, holiday villages, and vacation homes. Second, for each of these categories, an average bed space was assumed. This average takes into consideration the varying degree of space needed by different accommodation establishments at ground level. An analysis of a data set provided by WTO (2001, pers. comm.) revealed that there were approximately 32,590,000 beds existing in the 121 countries included in the database. The most recent data available for each country was from 1995–1999.

Hotels were found to account for 47% of all beds available worldwide in accommodation establishments (including 1–5 stars, unclassified, motels, beach hotels, etc.), while campsites followed with 27%, pensions with 12% (including bed and breakfast, guesthouses, rest houses, hostels, inns, etc.), self-catering accommodation with 11% (including bungalows, rented villas, cabins, mountain huts, etc.), holiday villages with 2%, and vacation homes with 2% (Fig. 1).

So far, this calculation excludes roughly 85 countries. In another, more general database, the WTO (2001, pers. comm.) provides (incomplete) data for another 35

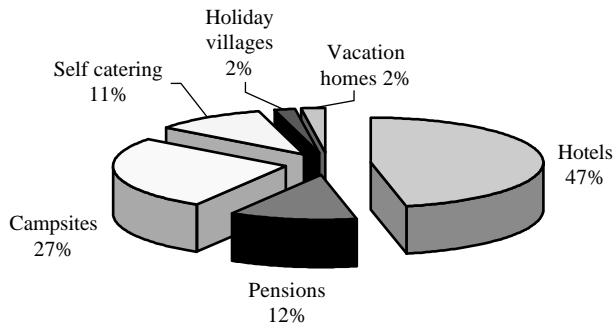


Fig. 1. Distribution of beds in different accommodation categories (1995–1999). Source: WTO (2001, pers. comm.).

Table 1
Accommodation and land use, world (1995–1999)

Type	World (%)	Area per bed (m ²) ^a	Beds (million)	Area, world (ha)
Hotels	47	30	15.98	47,940
Campsites	27	50	9.05	45,250
Pensions	12	25	4.06	10,150
Self-catering	11	50	3.62	18,100
Holiday villages	2	130	0.75	9750
Vacation homes	2	200	0.68	13,600
Total	100	—	34.14	144,790

^aThe area use per bed in different accommodation establishments was based on the following assumptions: hotels may on global average require 30 m², which includes city hotels as well as extensive resort hotels; places on campsites may require similar areas worldwide (50 m²) as will pension-like establishments (25 m²); self-catering accommodation is assumed to be more space intensive (50 m²); holiday villages seem to require 100–157 m² per bed, which may increase in the future (an average of 130 m² is assumed here); and vacation homes seem to be the most land intensive form of leisure establishments (200 m²).

countries. Adding the available data for these (approximately 1,550,000 beds), leads to the conclusion that there may have been about 34.14 million beds in accommodation establishments worldwide in the end of the 1990s. As pointed out, this estimate is conservative, as a considerable number of countries are not represented in this figure.

Table 1 shows the extent of lands used for accommodation establishments worldwide, based on the assumptions made above. In total, approximately 1450 km² of land may be used for accommodation. Note that data does not allow a distinction of leisure and business tourism.

3.1.2. Traffic infrastructure: airports, roads, railways, ports and marinas

It seems to be even more difficult to provide an estimate of the area used globally for other traffic infrastructure, such as airports, highways, railways,

parking sites, ports, marinas, etc. Thus, a more general approach is taken here. Built areas may cover 2% (3 million km²) of the terrestrial surface of the Earth, even though this estimate may vary depending on the assumptions made and the definitions used (Chambers et al., 2000). This proportion may be particularly higher in developed countries. For example, 11.8% of the total area of Germany (in 1995, UBA, 1998) consists of built land, and in Switzerland, the land covered by traffic infrastructure alone is greater than 2% (in 1997, Statistik Schweiz, 2001). Assuming, for the purpose of this article, that 50% (1.5 million km²) of the built land worldwide consists of airports, railways, highways, roads, parking sites, pedestrian walks, ferry terminals, marinas, and other traffic-related infrastructure, and assuming furthermore that, on global average, about one third of all traffic is leisure-related (compare Section 3.2.1), about 500,000 km² of the Earth's surface could be attributed to leisure-related travel. However, this calculation is useful only for the purpose of this study because the use of roads, etc. is multipurpose and a distinction is ultimately arbitrary.

3.1.3. Leisure activities: golf, ski, fun parks

The area occupied by golf courses is relatively well documented. In Europe alone there are about 5000 golf courses covering 200,000 ha of land and worldwide their number totals 30,000 (Planning Authority (Malta), 1997, quoted in Markwick, 2000). It is estimated that an 18-hole golf course requires approximately 50–60 ha of land. Assuming an average size of 45 ha per golf course worldwide (to account for 9-hole golf courses), the 30,000 golf courses in the world may cover an area of 13,500 km².

Little information is available on ski areas worldwide. Krippendorf (1986) reports, for example, that Switzerland has a dense network of tourist transportation systems, including about 500 cable railways and funiculars, as well as 1200 ski lifts, but there is no information about the area requirements of these. In particular, there is no information on the areas required for skiing. The same applies for fun parks, such as the various Disneylands, etc.

3.1.4. Indirect land alterations

Tourism can also alter lands indirectly, because infrastructure development may contribute to substantial coastal erosion and loss of lands. For example, Wong (1998) reports erosion rates of 2–7.5 m/year for beaches in Bali. In the British Virgin Islands, the building of roads led to severe erosion and sedimentation problems (Macdonald et al., 1997). These developments seem often to be related to tourism. In developing countries, tourism may also attract a large number of migrants in search of job opportunities. For example, Gormsen (1997) reports that the number of people in

Table 2
Tourism-related land alterations (1999)

Land alteration	Area (km ²)	Level of certainty
Accommodation	1450	Fair
Traffic infrastructure	500,000	Very poor
Golf courses	13,500	Good
Other land uses	?	—
Indirect land alterations	?	—
Total	> 514,950	

Cancun increased from 426 in 1970 to 177,300 in 1990, largely as a result of the tourism development in the area. Gössling (2001a) has described how tourism-led migration has substantially altered the coastal environment through housing constructions, unsustainable fishing patterns, and sewage disposal in Unguja Island (Tanzania). However, it seems impossible to calculate the extent of such indirect land alterations linked to tourism (Table 2).

Overall, leisure-related land use might amount to 515,000 km². It should be noted, though, that the degree of uncertainty in each of the categories (accommodation, traffic infrastructure, and golf courses) ranges from “good” to “very poor”. 515,000 km² represents 0.34% of the terrestrial surface of the Earth or 0.5% of its biologically productive area. This excludes land used to produce food, bury solid wastes, desalinate seawater, or to treat sewage. It also excludes land influenced in other ways, e.g. through noise, sewage, nitrogen deposition, acidification, etc. It should also be noted that less than 1% of the leisure-related land alteration is due to accommodation establishments, while traffic infrastructure requires 97% of the area. However, leisure-related land alteration may often be concentrated in relatively small areas with ecologically sensitive or, with respect to its biological productivity, ecologically valuable regions. The World Wide Fund for Nature (WWF, 2001) reports, for example, that about 54% of the Mediterranean coastline is now urbanized, mainly with construction related to tourism (hotels, airports, roads, etc.). Tourism is thus the most important factor causing a negative impact on the sensitive coastal and marine environments. Similar is reported by Van der Meulen and Salman (1996), who found that almost 75% of Mediterranean coastal dunes have been damaged or destroyed since the mid-1960s, mainly as a result of tourism. In the case of small islands, tourism-related land alteration may even be as high as 100% (for example in small atolls in the Maldives).

3.2. Energy use

Energy use has a wide range of environmental consequences. This is largely due to the fact that 85%

of the world's energy use is based on the consumption of fossil fuels (Biesiot and Noorman, 1999). When fossil fuels are burnt, they result in emissions of carbon dioxide (CO₂), nitrogen oxides (NO_x), water vapor (H₂O), hydrocarbons (HC), carbon monoxide (CO), soot (C), sulfur compounds (mainly SO₂), and non-methane volatile organic compounds (NMVOC). These emissions alter the composition of the atmosphere and they influence biogeochemical cycles. Emissions from fossil fuels have also complex effects on the biosphere because they influence species directly or can be transformed in physicochemical processes. Furthermore, emissions may have multiple, interacting impacts: rising CO₂ concentrations, for instance, force global warming, but they also influence plant physiology (respiration). These effects may aggregate, because a warmer climate will generally have negative consequences for ecosystems (Sala et al., 2000), adding on the effects of changing CO₂ concentrations, increased nitrogen deposition, or acidification of soils. In this context it should also be noted that energy use is likely to become relevant in other areas of global environmental change. Global warming is known, for example, to enhance the possibilities for the exchange and dispersion of diseases (cf. Moennig, 1992).

On a global scale, the most important effect of emissions from transport is their contribution to global warming. The warming effect of greenhouse gases is measured in terms of radiative forcing, which in turn can be translated into an increase in global mean temperature. From 1750 to 2000, all anthropogenic emissions of greenhouse gases have caused an additional radiative forcing of 2.43 Wm⁻², out of this 1.46 Wm⁻² from CO₂ (the most important anthropogenic greenhouse gas), 0.48 Wm⁻² from CH₄, 0.34 Wm⁻² from the halocarbons, and 0.15 Wm⁻² from N₂O (IPCC, 2001). The observed depletion of the stratospheric ozone layer from 1979 to 2000 is estimated to have caused a negative radiative forcing of -0.15 Wm⁻². On the other hand, ozone in the troposphere is estimated to have increased, leading to a positive radiative forcing of 0.35 Wm⁻². Global land and ocean surface temperature records show a corresponding temperature increase of about 0.6 ± 0.2°C (IPCC, 2001).

The use of energy for tourism can be divided in transport-related purposes (travel to, from and at the destination) and destination-related purposes excluding transports (accommodation, food, tourist activities, etc.). Environmental problems originating from energy use may be looked at from different perspectives using different parameters. For the purpose of this article, energy consumption and CO₂ emissions are used as proxies for the long-term impacts of tourism on the environment. Energy consumption is measured in mega joule (MJ) per passenger kilometer (pkm) or per bed night, and CO₂ emissions are calculated as

CO₂-equivalents (kg CO₂-e per pkm) to account for the direct and indirect additional warming effect of N₂O and H₂O. ‘Energy consumption’ as used in the following is equivalent to ‘energy intensity’, which is defined as the energy use per pkm measured in vehicle fuel efficiency (energy used per vehicle-km) divided by operational efficiency (passengers per vehicle). Energy use per bed night is a measure of the daily energy use per tourist in particular accommodation categories. Other effects of burning fossil fuels, such as nitrogen deposition, acidification, etc. are not considered here.

3.2.1. *Transport*

In 1990, the transportation sector was responsible for about 25% of the world’s primary energy use and for 22% of CO₂ emissions from fossil fuel use (IPCC, 1996). Purposes of travel include leisure, work, service/shopping, and other (Carlsson-Kanyama and Lindén, 1999). There is some evidence that leisure-related travel accounts for about 50% of all travel in the industrialized countries. This proportion has, for example, been found in travel surveys in Norway (for travel distance, Høyer, 2001), Sweden (for travel time, travel distance, and travel frequency; Carlsson-Kanyama and Lindén, 1999), Germany (for travel distance, excluding travel abroad; Heinze, 2000) and Austria (for travel distance; Knoflacher, 2000). However, in order to estimate the global share of leisure-related energy use, it is not sufficient to calculate fuel consumption only because up to 20% of the energy used during the entire life cycle of a car are needed for its production, maintenance, etc. (Lambrecht et al., 2001). Lenzen (1999) assumes even higher indirect energy requirements in the order of 25–65% for passenger transport.

The primary modes of motorized transportation relevant for leisure-related transport include aircraft (scheduled, charter, and scenic flights), ship (cruise ships, scheduled passenger ships, ferries, and other), car, bus/coach, caravan/campervan, train, and moped/motorcycle. Any exact global estimate of their contribution to energy use and CO₂ emissions would need to aggregate national statistics for all countries in the world (as far as these exist), which is beyond the scope of this paper. The results provided here can thus only serve as first-order estimates. In the following, it is distinguished between surface-bound travel and air travel, because aviation emissions need special consideration. They are released in 10–12 km height in the upper troposphere and lower stratosphere, where they have a larger impact on ozone, cloudiness, and radiative forcing than they do at the Earth’s surface (IPCC, 1999).

In the absence of global travel surveys, the following estimates are based on national ones. All surveys indicate that cars are the most important means of transport in tourism. In Germany, they were used for 49% of all holiday trips longer than 5 days, followed by

air travel (35%), bus (9%), and train (6%) (in 2000; F.U.R., 2001). In Sweden, cars were found to account for 73% of all leisure-related travel in 2000, followed by aircraft/train (20%, not further distinguished; SCB/SIKA, 2001). However, the distribution may be somewhat different looking at travel distances. In Norway, the average per capita mobility in 1992 was about 33 pkm per day. Leisure-related mobility makes up about half of this, or about 17 pkm per day. Of the 17 km, air-based tourist mobility constitutes about 6 km (Høyer, 2001). In Australia, average mobility was about 44 km per day per inhabitant (Lenzen, 1999), and in Sweden, daily travel has increased to about 45 pkm in 2000, about 45% of this for leisure-related mobility (car: 33 pkm, other: 12 pkm, not further distinguished; SCB/SIKA, 2001). In Germany, per capita mobility was 33 pkm in 1995 (car: 24 pkm, air travel: 4 pkm, train: 2 pkm, other: 3 pkm), about half of this for leisure-related purposes (BMV, 1996, excluding distances traveled abroad). An analysis by Schafer (2000) indicates daily per capita travel distances of 29 pkm in Great Britain (1995/1997, leisure-related: 41%), 41 pkm in The Netherlands (1995, leisure-related: 36%), 33 pkm in Switzerland (1994, leisure-related: 50%), and 62 pkm in the United States (1995, leisure-related: 31%). The values given include distances traveled abroad. Studies such as by Høyer (2001) show that international tourists may be responsible for a large share of the distances traveled in a particular country (e.g. >25% in the case of Norway).

Available data seem to indicate that daily mobility in industrialized countries may be in the order of 40 pkm per day, about half of this for leisure-related purposes. Out of the roughly 20 pkm traveled for leisure, car travel may account for 70–75%, air travel for 15–20%, and other means of transport for 5–10% (Table 3, cf. also Page, 1999, p. 131). This share might be somewhat different in reforming and developing countries, because even though the share of income spent for mobility and the time spent for daily travel may be similar (Schafer and Victor, 1999; Schafer, 2000), it can be assumed that the share of leisure-related purposes is lower, while the share of public transport is likely to be greater. Data provided by Schafer and Victor (1999) and Schafer (2000) indicate that daily travel may be 15 pkm per capita in reforming countries and about 6 pkm in developing countries. In developing countries, less than 10% of this may be for leisure-related purposes. There is no data available for reforming countries, but for the purpose of this study, it is assumed that 25% of all travel in these countries can be considered as leisure-related travel (3.75 pkm per capita per day). With respect to the different means of transport, it is assumed that 40% of the distances covered in reforming countries are by car, 5% by aircraft, and 55% by other means of transport, while in developing countries, distances

Table 3
Passenger kilometer by means of transport: leisure-related purposes (2001)

Means of transport	Industrial countries ^a (population: 900 million)			Reforming countries ^b (population: 400 million)			Developing countries ^c (population: 4,750 million)			Total pkm (billion)
	% ^d	pkm/cap/day	pkm (billion)	% ^d	pkm/cap/day	pkm (billion)	% ^d	pkm/cap/day	pkm (billion)	
Car	70–75	14.5	4763	40	1.5	219	20	0.1	173	5155
Air travel	15–20	3.5	1150	5	0.2	29	0	0.0	0	1179
Other	5–10	2.0	657	55	2.0	292	80	0.4	694	1643
Total	100	20	6570	100	3.75	540	100	0.5	867	7977

^a Industrialized countries: Australia, Canada, *Europe*, New Zealand, Japan, and USA.

^b Reforming countries: Bulgaria, Chile, Croatia, Czech Republic, Estonia, Hungary, Korea, Lithuania, Latvia, Macedonia, Malaysia, Poland, Romania, Russia, Slovak Republic, Ukraine.

^c Developing countries: all other.

^d Percentage of distances covered by this means of transport.

traveled by car are assumed to account for 20% (other means of transport: 80%).

According to this estimate, world travel was 23,970 billion pkm in 2001, which compares to 23,231 billion pkm calculated by Schafer and Victor (1999) for the mid 1990s. Leisure-related travel may, according to this estimate, only constitute one third of the total global (roughly 8 billion pkm), which is mainly a result of the low proportion of leisure-related travel in reforming and developing countries. The industrialized countries, which constitute only 15% of the world's population, account for 82% of the global leisure-related transport. The figures also suggest that global air travel for leisure-related purposes may have accounted for roughly 50% (1179 billion pkm) of the total passenger kilometers flown (2410 billion pkm in 1996, Schumann, 1997). However, this is a comparison of data for 1996 and 2001, and the actual figure may thus be somewhat lower than 50%, even though it also needs to be considered that some national statistics exclude distances traveled by air abroad (cf. Heinze, 2000 for Germany). The leisure-related proportion of air travel in the industrialized countries may thus be underestimated: for example, in the UK, international leisure trips represented 79% of all air trips (in 1996; Graham, 2000), and in Germany, leisure trips accounted for 69% of the total distances flown (in 1993, Knisch and Reichmuth, 1996).

In order to calculate the energy use associated with leisure-related transport, it is necessary to multiply the passenger kilometers traveled in industrialized, reforming and developing countries with a factor for energy use (Table 4). Available data suggests that energy use per pkm in the mid 1990s was 1.8 MJ for cars, 2.0 MJ for aircraft, 0.7 MJ for buses, and 1.0 MJ for trains (these latter two are summarized as "other", assuming an energy use of 0.9 MJ per pkm) (cf. Becken, 2001; Busch and Lubrichs, 2001; Carlsson-Kanyama and Lindén, 1999; Lambrecht et al., 2001; Lenzen, 1999; Lundli and

Vestby, 1999; Schafer and Victor, 1999). The following calculations are based on these averages, which in turn have been based on the consideration that (i) the majority of leisure-related travel takes place in the industrialized nations, and (ii) occupancy rates will be somewhat above average, because tourists often travel with partners or in small groups. It should be noted, though, that considerable ranges of energy use per pkm are given in the scientific literature, particularly with respect to air traffic. Carbon dioxide emissions depend on the energy intensity of a given mode, the fuel carbon content, and the degree of combustion. Schafer and Victor (1999) use a standard value of 20 g C/MJ for the fuel carbon content of light oil distillates. This factor is used to calculate CO₂ emissions (note that for air travel a conversion factor of 2.7 is applied to account for its effects at flight altitude).

However, so far the calculation has excluded other means of transport such as cruise-ships. A considerable share of tourists will start their journey by car, air travel, etc. and continue on board a cruise ship. Dickinson and Vladimir (1997) estimated that by 2000, as many as 8 million passengers per year could participate in cruising worldwide. As 30% of the people onboard may be staff (cf. Holloway, 1998), the actual number of people traveling as a result of cruising may even be higher. As reported by Lundli and Vestby (1999) for the coastal steamers of the Norwegian company "Hurtigruten", journeys by cruise ship are relatively energy intensive (7.2 MJ per pkm, including accommodation). For a rough calculation, it can be assumed that each of the 260 cruise ships operating worldwide by the mid-1990s (Holloway, 1998) used 20 t of fuel per day. Based on 300 working days per year, this would amount to 1.6 Mt of fuel use. Other boat traffic should also be considered: ferries, for example, constitute an important means of transport in leisure travel. Worldwide, there were 2150 roll-on roll-off short-sea ferries in operation. From the

Table 4
Global energy use and CO₂-equivalent emissions in leisure-related transport, 2001

Means of transport	Energy use			CO ₂ -e emissions		
	pkm (billion)	MJ/pkm	PJ	pkm (billion)	g CO ₂ -e/pkm	Mt CO ₂ -e
Car	5155	1.8	9279	5155	132	680
Air travel ^a	1179	2.0	2358	1179	396	467
Other	1643	0.9	1479	1643	66	108
Water-borne	?	?	107	?	?	8
Total	7977	—	13,223	7977	—	1263

^a For the purpose of the calculations, a conversion factor of 2.7 (2.5–3.0 is likely according to current scientific knowledge) was applied to account for the additional warming effect of air traffic (IPCC, 1999).

UK alone, it was estimated that around 50 million passengers would use ferries to travel to other countries by 2000, and for British Columbia (Canada), the estimate was 24 million for the same year (Holloway, 1998). Only part of these passengers will be leisure-tourists, but their energy use nevertheless seems to be substantial. Assuming, for a rough estimate, that each of these ferries entails an energy use of 400 l/h, with 10 working hours per day and 300 working days per year, this would result in 1.9 Mt of fuel use. If one third of this energy use is leisure-related, ferries alone account for another 0.6 Mt of fuel use. Travel by other boats on inland waterways, lakes, and along coastlines has to be added. In total, water-borne traffic may add 2.5 Mt of fuel (106.5 PJ) to global fuel use, resulting in 7.8 Mt of CO₂ emissions.

In total, global energy use associated with leisure-related transport may have amounted to 13,223 PJ and 1263 Mt of CO₂-e emissions in 2001.

There is comparably little information on the energy intensity of tourist activities at their destination, and there is some uncertainty in how far these activities have been included in national statistics on travel distances. In order to avoid double counting, these are not included in the following, even though this may lead to an underestimation of the total travel distances related to leisure. Two detailed surveys by Simmons and Lewis (2001) and Becken et al. (2001) show that tourists travel substantial distances at their destinations. Simmons and Lewis (2001) investigated the activities of charter tourists in Majorca and Cyprus, indicating average travel distances of 36 pkm per day in Majorca (of which by train: 4%, bus/coach: 91%, boat: 5%), and 107 pkm per day in Cyprus (of which by bus/coach: 67%, jeep: 16%, boat: 17%). Travel to souvenir shops and shopping centers accounted for an additional 14 km per bed night in Cyprus (50% by bus/coach and 50% by car/taxi). Travel to/from the airport accounted for 140 pkm in Majorca (97% by bus/coach, 1% by taxi, 1% by hired car) and 134 pkm in Cyprus (100% by bus/coach). Busch and Lubrichs (2001) found that distances driven to/from the airport were in the order of 205 pkm

in Germany (weighted average). Becken (2001) investigated the travel behavior of a long-term traveler (80 days) and a mobile home driver (31 days) in New Zealand. She found that the long-term tourist traveled about 95 pkm per day on average (public transport: 40%, car: 26%, train: 13%, bicycle: 9%, hitch-hiking: 7%, ferry: 3%, trekking: 2%, shuttle bus: <1%), which resulted in an energy use of 99 MJ per day. The mobile home tourist drove on average 158 pkm per day (mobile home: 98%, ferry: 2%), which entailed an energy use of 358 MJ per day. Other examples can be found in Busch and Lubrichs (2001), who also calculated an annual energy demand of about 13,100 MJ for leisure-related travel (transportation only) for the average German citizen above 14 years of age.

Finally it should be noted that indirect energy consumption is not considered here. This may, considering life cycles and infrastructure maintenance, be in the order of 25–65% of the direct energy use for passenger transport (Lenzen, 1999). Other effects of traffic, such as the exposition of people to noise, air pollution, and risk of death or injury, acid rains caused by emissions of NO_x and SO₂, and upper ozone layer depletion caused by emissions of chlorofluorocarbons from the air conditioning of the planes (Janić, 1999) are not considered either.

3.2.2. Destination

Within the destination, energy use can be divided in two broad categories, 'accommodation' and 'activities'. Energy use in the different types of accommodation includes heating, air conditioning, cooking, cooling, illumination, cleaning, and, in tropical or arid regions, the desalination of seawater. The energy used for construction and maintenance of the accommodation establishments, access roads, etc., as well as the energy required to provide both goods needed to maintain tourist flows (computers, beds, televisions, etc.) and the infrastructure to chose and book the journey (travel agency/travel provider, catalogue, information material, guide books), the import of food and the additional demand of the staff may be added. Activities include the

visitation of specific locations for recreational purposes, and may be generally divided into attractions (museums, visitor centers, botanical gardens, zoos, etc.), entertainment (cinema, bar, shopping, etc.), and sport activities (diving, skiing, jet boating, golf, horse-riding, etc.) (Becken and Simmons, 2002).

3.2.2.1. Accommodation. Energy use in hotels varies considerably, both with respect to the sources of energy used as well as the amount of energy consumed (Table 5). For example, Deng and Burnett (2000) found that electricity accounted for 73% of the overall energy use in hotels. Similar was found in New Zealand, where the main energy source for accommodation establishments is electricity (75% of total energy use), while coal accounted for 12%, LPG for 9%, petroleum fuel for 3%, and natural gas and wood for 1% (Becken et al., 2001). A survey conducted by Simmons and Lewis (2001) revealed an energy mix of electricity (57%), gas (8%), oil (<1%), gas oil (<1%), and electricity from renewables (34%) for one hotel in Majorca, and an energy mix of electricity (70%), gas (<1%), and oil (29%) for one hotel in Cyprus. Finally, Zmeureanu et al. (1994) reported a mix of electricity (29%), gas (26%), and steam (45%) for hotels in Ottawa, Canada.

In Hong Kong, 32% of total energy were consumed for air conditioning, 12% for lighting, 5% for lifts and escalators, 23% for other systems/appliances, and 28% for cooking and water heating (the latter based on gas and diesel) (Deng and Burnett, 2000). Overall, the amount of energy consumed in different hotels as well as

the environmental impact of their production and use may vary considerably (Table 5).

A study (electricity only) of hotels in Hong Kong indicated a very low average electricity consumption of 10.9 MJ per bed night (Burnett, 1994, quoted in Jim, 2000). However, this may underestimate total energy consumption by one-quarter, and such low values will generally only be the case in city hotels. Hotels investigated in the Seychelles indicated an energy use of 36–108 MJ per bed night, excluding the use of fossil fuels for cooking etc. (UK CEED, 1994). Hotels with self-supporting power generation may even use more energy per bed night. A survey by Gössling (2000) in Zanzibar, Tanzania found that crude oil consumption was 4.2 kg (221 MJ) per bed night for established smaller hotels and up to 21.5 kg (916 MJ) per bed night for newly opened resort hotels with still low occupancy rates. A reasonable average for well-established hotels was 6.0 kg (256 MJ) per bed night. These values exclude primary energy sources such as gas for cooking. For the purpose of the following calculations, an average energy consumption of 130 MJ per bed night is assumed for hotels (Table 6). Hotels use generally more energy per visitor, as they have energy intense facilities, such as bars, restaurants, and pools, and more spacious rooms. Accommodations in the category ‘pensions’ may have a comparably low number of beds and occupancy rates are assumed to be somewhat lower than those of hotels. Even though Becken et al. (2001) found rather high energy-consumption values in bed and breakfast facilities in New Zealand (110 MJ per bed night), a lower

Table 5
Energy use in tourism: accommodation

Type	MJ/bed night ^a	Region/reference year	Source
Hotel	155	New Zealand, 1998–2000	Becken et al. (2001) ^b
	51	Majorca, 2001	Simmons and Lewis (2001) ^c
	87	Cyprus, 2001	Simmons and Lewis (2001) ^c
	11	Hong Kong, 1994	Burnett (1994) in Jim, (2000)
	36–108	Seychelles, 1993	UK CEED (1994) ^d
	221–916	Zanzibar, 1999	Gössling (2001a) ^e
	256	Zanzibar, average hotels, 1999	Gössling (2001a) ^e
	200	Germany, 1982	Brunotte (1993)
B&B	110	New Zealand, 1998–2000	Becken et al. (2001) ^b
Motel	32	New Zealand, 1998–2000	Becken et al. (2001) ^b
Camping/hut	25	New Zealand, 1998–2000	Becken et al. (2001) ^b
Holiday village	91	Germany, 1993	Lüthje and Lindstädt (1994) ^f
Hostel	39	New Zealand, 1998–2000	Becken et al. (2001) ^b

^a Bed night (also guest or visitor night) is a parameter calculated by dividing annual energy use by the number of nights spent by tourists in a particular accommodation establishment. Energy use per bed night varies considerably in hotels and can only be explained considering a complex mix of factors (Becken et al., 2001).

^b Energy directly consumed, excluding business vehicles, etc., as well as losses for transformation, transmission or distribution of primary energy.

^c Annual averages, calculated from Simmons and Lewis (2001), based on the following conversion factors: 1 kWh = 3.6 MJ; 1 kg gas oil = 40.3 MJ; 1 kg oil = 42.6 MJ.

^d Based on a conversion factor of 1 kWh = 3.6 MJ, electricity only.

^e Based on a conversion factor of 1 kg crude oil = 42.6 MJ.

^f Based on a conversion factor of 1 kWh = 3.6 MJ and 1 m³ gas = 31.7 MJ (day visitors not considered).

Table 6
Global energy use accommodation, 2001

Accommodation establishment	Energy use per bed night (MJ)	Beds (million)	bed nights (million) ^a	Energy use (PJ)	CO ₂ -emissions (Mt) ^b
Hotels	130	15.98	2700.6	351.1	55.7
Campsites	50	9.05	995.5	49.8	7.9
Pensions	25	4.06	686.1	17.2	2.7
Self-catering	120	3.62	611.8	73.4	11.6
Holiday villages	90	0.75	126.8	11.4	1.8
Vacation homes	100	0.68	49.6	5.0	0.8
Total	—	34.14	5170.4	507.9	80.5

^a A global occupancy rate of 46.4% was assumed here for the categories hotels, pensions, self-catering, and holiday villages (calculated from data provided by WTO (2001) for 159 countries for the years 1995–1999); for campsites, a lower occupancy rate of 30% was assumed, taking into consideration strong seasonal variations, and for vacation homes, an occupancy rate of 20% was used.

^b Based on an emission factor of 43.2 g C/MJ (Schafer and Victor, 1999 for the 1990 world electricity generation mix).

average of 50 MJ is assumed here for all accommodation establishments in this category. Campsites were assumed to have the lowest energy use of all categories with 25 MJ per bed night, while holiday villages were calculated with 90 MJ per bed night. It should be noted that these average values are based on only one source (except for hotels). No data is available for self-catering facilities and vacation homes. These were assumed to consume 120 MJ and 100 MJ per bed night.

According to this estimate, the approximately 5.2 billion nights spent in different accommodation establishments resulted in an energy use of about 508 PJ and CO₂-emissions of about 81 Mt. Note that this includes both leisure and business tourists.

3.2.2.2. Activities. Tourists are usually active at their destinations, and go on several excursions. Becken and Simmons (2002) identified activities of New Zealand tourists and calculated their energy-intensity (excluding transport to/from the activity, Table 7).

Table 7 shows that the energy-intensity of different tourist activities varies widely, and it seems to be difficult to allocate an average amount of energy used per vacation for such purposes. For the purpose of this study, it was assumed that an average tourist uses 250 MJ of energy for ‘activities’ during a longer vacation, which seems to be a conservative estimate for leisure tourists (cf. Becken and Simmons, 2002; Becken et al., 2002). However, as statistics do not allow a distinction of leisure and business tourists, this value was used to calculate an average. Extrapolated to 700 million international tourists in 2000, energy use for ‘activities’ may have been in the order of 175 PJ. However, this calculation excludes leisure-related activities at home. As Busch and Lubrichs (2001) have shown for Germany, the energy used for transport to make short leisure-related journeys (<5 days) and day trips may by far exceed the energy needed for longer (often international) vacations (>5 days). It can thus be assumed that the total energy use for activities is at least

Table 7
Energy use in tourism: activities (New Zealand, 2000)

Activity (excl. transport)	MJ per tourist
Heli-skiing	1300
Scenic flights	340
Diving	800
Scenic boat cruises	165
Sailing (motor)	140
Guided walks	110
Adventure activities	57
Rafting	36
Experience centers	29
Zoos	16
Museums	10
Visitor centers	7

Source: Becken and Simmons (2002).

twice as high (350 PJ) as that of international tourism alone. It should be noted, though, that there is a high degree of uncertainty considering this estimate.

3.2.3. Summary energy use

Table 8 summarizes the worldwide energy use for tourism-related transport, accommodation, and activities.

According to the calculations made here, global leisure-related travel may have consumed approximately 14,080 PJ of energy in 2001. This may slightly overestimate leisure-related energy use, because business travel has been included in the categories accommodation and activities. However, there is also a risk of underestimation because the calculation has been based on conservative estimates and indirect energy requirements have not been considered.

Overall, transport is by far the most important factor contributing to leisure-related energy use and emissions of greenhouse gases: results indicate that transport may be responsible for almost 94% of the overall contribution of tourism to global warming. Overall, leisure-related energy use may be of minor importance, though,

Table 8
Global tourism-related energy use and resulting CO₂-e emissions (2001)

Category	Energy use (PJ)	CO ₂ -e emissions (Mt)
Transport (incl. ship, etc.)	13,223	1263
Accommodation	508	81
Activities	350	55
Total	14,081	1399

if compared to global energy consumption: in 1996, global primary energy use was 392,600 PJ and global emissions of CO₂ amounted to 23,903 Mt (BMW, 1999). Extrapolated to 2001, global energy use may have been 433,400 PJ, and CO₂-emissions may have amounted to 26,394 Mt (growth rate 2%). Leisure-related energy use may thus correspond to about 3.2% (14,080 PJ) of the global total and CO₂-emissions (adjusted for NO_x and H₂O emitted by aircraft) may be in the order of 5.3% (1400 Mt CO₂-e) of the global total.

3.3. *Biotic exchange and extinction of wild species*

Human mobility has caused a massive exchange of species that in turn affects biological diversity and ecosystem functioning through the homogenization of biota and the disruption of natural systems (cf. Vitousek et al., 1997). The main ways for species to enter new environments seem to be international commerce, trade in live organisms, and transport by tourists. Tourism can also contribute to the extinction of species through disturbance, collection, trampling, and buying of animal and plant species.

Tourism contributes to the movement of species in several ways. Most important is probably the direct transfer, which can be voluntary, as in the case of plant and animal species acquired as souvenirs (both dead and alive), or unwillingly, like the transport of viruses, bacteria, protozoa, insects, and other small organisms by different means of transport, in cloths, luggage, and on or within the bodies of tourists and animals. However, tourism may also contribute in other ways to the exchange of biota. Hotels in coastal areas, for example, often import plant species alien to these environments in order to establish gardens rich in flowering plants. Cruise ships, boats, etc. are also known to transport large numbers of organisms over long distances. For example, the United States' Environmental Protection Agency (1996, quoted in Davies and Cahill, 2000) reported that almost one third of the 130 non-native species introduced to the Great Lakes since 1800 has been carried by ships. Wilson (1997) reports that 40 of the non-native species in the Great Lakes have appeared since 1960, and in San Francisco Bay, more than 50 non-native species have appeared

since 1970. In total, about 12,000 flowering plants have been imported to Europe, out of which 687 have become naturalized (Sukopp, 2001). Similar figures for the Netherlands suggest that out of the 7000 flowering plants imported, 220 have become naturalized. In Germany, 412 neophytes have become naturalized, while 47 indigenous taxa have become extinct, and another 118 are threatened with extinction. The proportion of neophytes in the central European flora may be as high as 6–16% (vascular plants), and even higher in islands (Azores: 60%, Canary Islands: 40%, New Zealand: 25%). Locally, new species may contribute to an increase in species numbers, but from a global perspective transfer leads to the homogenization of the plant kingdom (Sukopp, 2001). However, the scientific understanding of the role of leisure-related transport in these processes seems to be poor.

Data provided by customs may give some insights into the order of magnitude of voluntary species transports. At Frankfurt am Main airport (Germany), 857 travelers were controlled in 2000 and found to carry 4000 parts and products of protected species or living protected organisms. Among the seizures were a relatively large number of live animals, namely 25 living tortoise, 33 parrots, 740 frogs, and 471 aquatic snails (Hauptzollamt Frankfurt, 2001). These figures seem high, but statistically only one in 57,500 travelers at the airport was transporting protected species or products made of these. However, the “true” number of transported species may be higher, as only 5% of all incoming passengers are controlled based on random sampling and “risk-oriented” assessments (Kolodzeiski, customs Frankfurt am Main, 2001, pers. comm.). It should also be noted that the figures do not include non-protected species, as these are not registered by the customs.

In total, 28,360 products of threatened species were found by the German customs in 2000 (compared to more than 67,500 in 1999; Zollkriminalamt, 2001). Data provided by the French customs for 1996 indicates seizures of about 700 kg ivory and 400 live animals (compared to more than 1,400 live animals in 1995) as well as 11,000 parts and products of dead species (CITES, 2001). It is not clear, though, how many non-protected species were imported, and which share of the passengers could be considered as leisure-tourists. In order to understand the importance of these transports for biotic exchange, it would also be necessary to know how many of the living species are held in capture as compared to the proportion released or planted in the wild. Of those surviving in the wild it needs to be known how they impact on the indigenous flora and fauna.

However, tourists can also contribute to the extinction of species through the disturbance of habitat (directly and indirectly) and collection, trampling, or buying of animal and plant species or products. For

example, tourists may exert substantial direct pressure on animals in protected areas. In some countries, for instance, guides may feel obliged to respond to the wishes of tourists to closely interact with the animals. This may reduce the breeding success or threaten populations with human pathogens as reported for primate and monkey groups encountered by nature tourists (Ferber, 2000). Buying souvenirs, tourists also exert substantial pressure on certain species. Shark jaws and teeth, for example, have become sought after souvenirs in many tropical countries, which may lead to increasing hunting pressure and in the final stage of this process to the regional disappearance of certain shark species (Gössling, 2001a). Indirect pressure on plants and animals may result from increased levels of emissions of various trace-gases through leisure-related transport, as for example described for the National Park Bayerischer Wald in Germany (Brüggemann, 1997). Tourists are also known to frequently collect souvenirs (for example shells, parts of corals, etc.) or to buy parts or products of rare or threatened species. These can include conchs and shells, blue, black, red, and white corals, stuffed animals, etc. In some countries such as the Seychelles, where strict environmental conservation laws largely prohibit the collection of shells and corals, souvenirs may even be imported from other countries, creating large “souvenir hinterlands”. Through trampling, tent camps, etc. tourists contribute directly to the disturbance of ecosystems (cf. Obua, 1997). However, there is no global data existing and leisure-related impacts and their global importance are thus difficult to assess.

3.4. *Exchange and dispersion of diseases*

The movement of infectious organisms by tourists is an important aspect of international travel. Tourists are both at risk to acquire new infections and they aid as vectors in the global dispersal of microbes, a process that has become a matter of hours with the rise of air travel (Wilson, 1997; Rodriguez-Garcia, 2001). Infectious diseases account for 33% of the mortality throughout the world, and over the past three decades about 30 new disease-causing organisms have been identified (Rodriguez-Garcia, 2001).

Tourism can contribute in different ways to the exchange and dispersion of pathogens. Basically, diseases can be human and non-human, vectors can be human and non-human, and the transport of the organisms causing them can be active (voluntarily and/or conscious) and passive (unwillingly and/or unconscious). Humans can transport microbes in or on their bodies, in food, seeds, cloths, goods, and other products and they are often responsible for the transport of non-human vectors that may carry microbial flora.

Tourism is an important factor in the exchange and dispersion of diseases. For example, travel to tropical and subtropical countries has been made responsible for a substantial increase in incidences of tropical diseases in industrialized countries (Degremont and Lorenz, 1990; Loscher et al., 1999; Ostroff and Kozarsky, 1998). The relative importance of tourism in this process can be expected to become even more important with increasing tourist numbers and travel distances. Furthermore, a growing proportion of tourist activities is nature-based, adventure-oriented and bound to remote areas (Ahlm et al., 1994). All these trends ultimately mean an increasing exposure to a larger variety of (partly unknown) species and pathogens. Simultaneously, concern is growing about the re-emergence of diseases thought to be under control or declining, the appearance of new diseases, and increases in resistance among infectious organisms (WHO, 1998a, b). Tourism does also increase the opportunities for genetic exchange among microbes and enhances the selection and spread of resistant strains, as well as the evolution of viruses in new environments, which makes the treatment of a growing number of diseases more problematic (Goldsmith, 1998; Moennig, 1992; WHO, 1998a, b). Locally, tourist infrastructure may substantially alter the habitats of disease-carrying insects and animals. Irrigation of hotel gardens, for example, may create puddles that provide good breeding conditions for malaria-carrying mosquitoes. However, the indirect contribution of tourism to the exchange and dispersion of disease may be as important as its direct effects. Tourism has been shown to contribute to climate change, which in turn will lead to the spread of old, new, and re-emerging infectious diseases (Kumate, 1997; WHO, 2000b). Climate change is also believed to lead to continued ENSO phenomena (IPCC, 2001), which have strong effects on the climate in regions with the least financial resources: southern Africa, parts of South America and South-east Asia. In these areas, the number of people killed, injured or made homeless by natural disasters caused by ENSO is increasing, and there has been growing recognition of links between El Niño and disease. The El Niño cycle is associated with increased risks of some of the diseases transmitted by mosquitoes (malaria, dengue, and Rift Valley fever), because these vectors can increase substantially in numbers after heavy rainfalls in dry climates or as a result of droughts in humid climates (where, for example, rivers may turn into strings of pools). Warmer temperatures may also allow the disease to proceed in highland areas (WHO, 2000a). Tourism may also indirectly increase health problems because reports of epidemics may be suppressed or played down in developing countries to avoid the negative effects of bad health news on the tourist industry (Goldsmith, 1998). In the following, some of the diseases most frequently acquired by travelers are

discussed. Most of these are associated with travel to developing countries.

3.4.1. Travelers' diarrhea

Traveler's diarrhea is one of the most common illnesses associated with travel. Even though this disease does usually not have severe health consequences for the traveler, it may reduce the enjoyment of the vacation substantially (Cartwright, 1996). For travelers from Europe and North America to developing countries, travelers' diarrhea is the most common health problem reported by 30–80% of international tourists (Clift, 2000).

3.4.2. Malaria

Malaria is considered to be the world's most important tropical parasitic disease, with an annual prevalence of 300–500 million clinical cases worldwide. Each year, over 1 million fatal cases are reported, the majority of them among children in Africa (WHO, 1998c). Imported cases of malaria have become frequently registered in developed countries, too. Currently, over 20 million tourists visit malaria-infested areas (Clift, 2000). In 1996, 10,000 cases of imported malaria were reported in the European Community alone (WHO, 1998d): for example, there were 2500 reported cases in the UK, 2117 registered in France (with the total number of cases estimated at 5109, 20% more than 1995), about 770 in Italy, and 1021 in Germany (an increase of 9% over 1995) (Bradley et al., 1998; Sabatinelli and Majori, 1998; Legros et al., 1998; Apitzsch et al., 1998). The most common variety of imported malaria protozoa in Germany, the UK, France and Italy was *Plasmodium falciparum*. Case fatality of *P. falciparum* per 1000 infections was 8 in the UK, 3.3 in France, 35 (women) and 13 (men) in Italy, and 24 in Germany (Bradley et al., 1998; Sabatinelli and Majori, 1998; Legros et al., 1998; Apitzsch et al., 1998). Worldwide, malaria incidence among travelers from Europe and North America to tropical countries may be in the order of 0.25% (Clift, 2000). Cases of imported malaria have generally shown a general upward trend since the mid-1970s.

In many developing countries, cases of malaria are diagnosed and treated in the home or by private sector practitioners, often incompletely. This speeds up the spread of parasite resistance, which is considered as a serious problem by the World Health Organization (WHO, 1998c). Resistance has, for instance, caused a dramatic rise in the costs of drugs for treating uncomplicated cases of malaria from about US\$0.15 to over \$2.00 in parts of the Indochina peninsula and in the Amazon region of Brazil (Trigg and Kondrachine, 1998). Tourists seem to contribute to the development of resistance because protection is taken irregularly or not completed (Apitzsch et al., 1998).

3.4.3. Sexually transmitted diseases

Sexually transmitted diseases (STDs) constitute the largest category of human diseases in the world today. The WHO (1997) estimates that there are 333 million new cases of STDs each year, one third of these occurring in young people under 25 years of age. Apart from the acquired immunodeficiency syndrome (AIDS), the four most common STDs are gonococcal infections (62 million cases), chlamydial infections (89 million cases), syphilis (12 million cases), and trichomoniasis (170 million cases) (WHO, 1996). STDs have far-reaching health, social and economic consequences, and they facilitate the transmission of the human immunodeficiency virus (HIV), which causes AIDS (WHO, 1997). While there is basically no information on the incidences of STDs among international tourists, Clift (2000) estimates that the risk of infection with HIV may be as high as 0.01% for travelers from North America and Europe to developing countries (with a substantial risk in other countries, too). HIV is of particular concern, because it can only move from one place to another as a consequence of human movement, and the speed with which the virus has moved geographically since the late 1980s is seen as a reflection of the volume and extent of human mobility: tourism is held responsible as one of the major factors in the transnational expansion of the virus (Quinn, 1994; Thirumoorthy, 1990).

By 1998, 1.9 million cases of AIDS were reported to the World Health Organization, and the overall number of infections is estimated to be of the order of 30.6 million worldwide (WHO, 1998b). Many of the infections among tourists seem to be related to risk behavior. For example, research in the UK found that 10% of young men and 4% of young women traveling abroad alone were sexually active with a new partner, and 25% of these reported unsafe sex (Bloor et al., 1998). Elliott et al. (1998) quoted in Clift (2000) accompanied a group of young people on a dance holiday to Ibiza. Of 160 young people studied, 30 reported sex with new partners, and over half of them reported unsafe sex. In a survey on sexual holiday behavior of gay men in southern England, 48% reported sex with a new partner, 29% reported penetrative sex, and 4% reported penetration without consistent use of condoms (Clift, 1999). Kleiber and Wilke (1995) report for Germany that 5–10% of all new HIV-infections are caused by sex-tourists. Even though sexually risky behavior must not necessarily increase among tourists, tourists may nevertheless have new (local) partners and thus contribute to the dispersion of the virus: behavioral data on inconsistent use of condoms indicate that homosexual men, heterosexual men, and business travelers may be at increased risk of exposure to STDs, including HIV infection (Mulhall, 1996; Carter et al., 1997).

3.4.4. *Other diseases*

Other diseases that can be exchanged and spread through travel to tropical countries include hepatitis A, B, and C, Yellow fever, Lassa fever, Legionnaire's disease, cyclosporiasis, *Vibrio cholerae* O139, hantavirus, variant Creutzfeldt-Jacob disease, dengue fever, cholera, schistosomiasis, leptospirosis, and viral hemorrhagic fevers (Loscher et al., 1999; Ostroff and Kozarsky, 1998; WHO, 1999, 2000b-d). Again, there is little information about the global dispersion of these diseases by tourism, but incidences among travelers from North America and Europe to developing countries were 1.25% in the case of acute febrile respiratory tract infection, 0.3% for Hepatitis A, and 0.03% for Typhoid (India, north/north west Africa, Peru) (Clift, 2000).

3.4.5. *Diseases brought to host populations*

While there seems to be surprisingly little information on the impact of diseases brought by travelers to local populations, these are clearly vulnerable to death and disability due to accidents, violence and injuries caused directly and indirectly by tourism, and they have to bear the consequences of undesirable behaviors such as those related to sex tourists. Furthermore, tourists are also responsible for changes in ideas, values and norms, which may affect health. For example, tourists in developing countries may contribute to the increasing consumption of "junk food", alcohol, tobacco, etc. by local populations (Rodriguez-Garcia, 2001). All these changes may exacerbate already existing health problems, particularly in developing countries.

Overall, tourists seem to be at a reasonably low risk of acquiring diseases, if they act carefully and follow prescriptions for prophylaxis (Clift, 2000). However, even though quantitative estimates are difficult, tourists seem to be a major factor in the exchange and dispersion of disease, particularly considering indirect effects (ENSO, etc.). Clearly, the consequences of travel for health may be primarily felt by local populations in developing countries and often affect those with the least financial means to cope with disease.

3.5. *Changes in human–environmental relations*

From a psychological perspective, tourism and travel initiate changes in the perception and the understanding of the environment. The environment is understood here as a set of complex, interacting relations between the individual, society, and nature (cf. Steiner, 1993). In the context of global environmental change, alterations of the understanding of the environment, both with respect to environmental knowledge, environmental attitudes, and environmental behavior, could both facilitate or complicate the restructuring of societies towards sustainability. Tourism, particularly nature tourism, is

believed to foster environmental consciousness and to result in an increased knowledge about the environment (e.g. WWF, 1995). However, while such changes of the perception and understanding of the environment have generally been understood as supportive of sustainable development, it is argued here that they may not necessarily lead to changes in attitudes and more environmentally friendly behavior. In fact, there is some evidence that a paradoxical situation occurs: even though the knowledge about the environment may increase among travelers, personal behavior may be characterized by increased resource consumption (Gössling, 2002).

In "western" societies, the environment is a social construction, with the understanding of "nature" largely being built on its culturally constructed representations, such as national parks and zoos (cf. Norton, 1996). Travel might change the perception of the environment through the process of traveling itself (the world may "shrink" in the eyes of frequent travelers, a process of *cosmopolitization*), the experience of new "representations of nature" (protected areas, "natural" sites, and other symbols of the "natural", leading to *environmental consciousness*), and through the encounter of two socio-cultural systems, the native system, which is invaded by tourism, and the tourist system (*intercultural encounters*). In the latter case, tourism may also change the hosts' perception and understanding of the environment.

3.5.1. *Cosmopolitization*

Social identities emerge out of particular social structures that incorporate the elements space, time, and memory. These elements are continuously negotiated, a process in which travel plays an important role. While limited or virtual traveling (e.g. by watching TV) might enforce local embedment in juxtaposition to an imagined or perceived other (such as a neighboring country), massive mobility might instead transform social identities towards a cosmopolitan configuration of the self as localities and their characteristics lose importance with respect to space, time, and memory (Urry, 1995). In other words: travel, both for work and tourism, disrupts the very sense of what is a person's home. Without this sense, citizens do not perceive themselves as part of places any longer, and develop cosmopolitan identities. Tourism can thus be seen as an agent of modernization, which decontextualizes and dissolves the relationships individuals have with society and nature. In the context of global environmental change, this is problematic because cosmopolitan people may increasingly lose their understanding of the ecological limits of places, for which local knowledge is required, and, ultimately, the very responsibility to care for places. This is of importance, because decreasing local attachment seems to develop in parallel with

increasing resource consumption (cf. Borgström-Hansson and Wackernagel, 1999).

3.5.2. *Environmental consciousness*

One of the major factors leading to the global increase in tourism is the growth of an environmental consciousness (Urry, 1995). Environmental consciousness comes basically into existence through education, film, or written media and the comparison of the character of the physical and built environment of different places through traveling. Through travel, humans also have the opportunity to experience representations of nature, such as national parks, biosphere reserves, world heritage sites and other protected areas, as well as zoos, botanical gardens, “designed” landscapes, and city environments. These representations of nature can also be understood as symbols. O’Rourke (2000), for example, has described how wild animals are seen as symbols of naturalness and freedom in “western” societies. The “wild” is no longer perceived as a threat, but as a product of human management and protection (O’Rourke, 2000, p. 149). A wide range of species popular among tourists function as such symbols of the “wild” and “natural” which tourists wish to experience, for example elephants, gorillas, lions, crocodiles, but also elk, highland cattle, prehistoric horses, bison, etc. Tourism can thus generally be seen a result of altered human-environmental relations and as a process in itself fostering changes in human-environmental relations. This process may lead to increased environmental consciousness and the wish to experience further places—a self-reinforcing process leading to more travel.

3.5.3. *Intercultural encounters*

The meeting of tourists and hosts is known to initiate cultural change (e.g. Lea, 1988; Mathieson and Wall, 1982; Meleghy et al., 1985). However, the exchange of values, ideas, and conceptions through tourism and travel also leads to changing human-environmental relations. In developing countries, particularly “western” conceptions are adopted, because tourists from “western” societies account for the majority of the international tourist arrivals. With respect to local populations, the encounter between the different cultures can result in increasing market integration, shifts to new income sources, and changing social relationships (Gössling, 2001a, 2002). This, in consequence, may dissolve attachment to place, result in changing resource use patterns, and encourage the increased consumption of (industrial) goods and products. For the tourists, the encounter with the local socio-cultural system may, for example, result in a feeling of technological superiority (“being modern”), or an attempt to romanticize the “simple”, “nature-bound” lifestyles in rural areas of developing and developed countries (Gössling, 2002). This may also contribute to the process of decreasing

attachment to place, because the feeling of “being modern” or the romantic image of other lifestyles are both elements of the travel experience, and they are thus implicitly needed, unconsciously wanted, and explicitly sought after by the tourists. Ultimately, this may reinforce the Cartesian separation between “nature” and “culture” characterizing “modern” societies. As mentioned above, the loss of knowledge about the ecological limits of places, the alienation of lifestyles from the capacity of ecosystems to provide functions, goods, and materials, and the decreasing attachment to place are interacting processes. They are seen as the major factor in the global environmental crisis, and should thus be considered detrimental to sustainable development (Borgström-Hansson and Wackernagel, 1999; Hornborg, 2000).

With respect to travel, increasing environmental consciousness, travel experience, the availability of more financial means for recreation, and more cosmopolitan understandings of the world may lead to more travel and thus increased resource use (Gössling, 2002). These findings are supported by travel surveys, which show that travel increases with the level of education (SCB/SIKA, 2001; Busch and Luberichs, 2001) and income (SIKA, 2001; Busch and Luberichs, 2001). In Sweden, men with postgraduate education and men in the highest income group, traveled 70% and 54% more (travel distances) than men on average (SCB/SIKA, 2001; SIKA, 2001). These effects of international travel are difficult to quantify, but they are of great significance for global environmental change and sustainable development.

3.6. *Water*

Water is one of the most essential resources to humanity. Its availability and quality has received much international attention in recent years, because many countries are approaching serious water crises with depleted and heavily contaminated surface water and groundwater resources (Postel, 1992; UN, 1995). As a result of over-use, the frequency of seasonal water shortages and harmful events like algal blooms, which are linked to nutrient pollution, has grown significantly in the past two decades (UNDP/UNEP/World Bank/WRI, 2000). Conflicts arising from the global use of water are expected to exacerbate in the future, both as a result of a growing human population and the consequences of global environmental change for water quality and availability (Vitousek et al., 1997). Through tourism, water demand is shifted to water scarce areas, and humans staying in hotels seem to generally use more water than at home: water consumption per tourist seems to range between 100 and 2000 l per bed night (e.g. GFANC, 1997; Gössling, 2001b; Lühje and Lindstädt, 1994; UK CEED, 1994; WWF, 2001). The

WWF (2000) reports that the average tourist in Spain consumes 440 l per day, a value that increases to 880 l if swimming pools and golf courses exist. In Zanzibar, the average water consumption per tourist amounted to 685 l per bed night (Gössling, 2001b). This compares to an average use of, for example, 135 l per day in Germany (UBA, 1998). Tourism may thus substantially increase the overall use of water. However, existing data seem not sufficient to allow for detailed calculations on broad regional levels.

4. Conclusions

Five major fields of global environmental change were identified to which tourism contributes: change of land cover and land use, energy use, biotic exchange and extinction of wild species, exchange and dispersion of diseases, and changes in the perception and understanding of the environment through travel.

Land alteration is the most important driver of change in biodiversity, which interacts with other important components of global change such as global warming (Vitousek, 1994; Chapin III et al., 1997; Sala et al., 2000). According to the first order estimate provided in this study, tourism contributes with 0.5% to the alteration of biologically productive lands. The major proportion of land seems to be used for traffic-related infrastructure, but the uncertainty of this estimate is high. Land alteration may have detrimental consequences for biodiversity and reduce the capacity of ecosystems to provide services essential to humankind. However, the consequences of land alterations may differ qualitatively in different geographical settings. With respect to biodiversity, tourist infrastructure development may have the greatest impact on islands in the low latitudes, where species are often endemic and vulnerable to environmental change (cf. Cronk, 1997).

Leisure-related energy use is substantial. According to the results of this survey, tourism may be responsible for the consumption of 14,080 PJ of energy, resulting in emissions of 1400 Mt of CO₂-e (in 2001). Transport, accommodation, and activities are responsible for 94%, 4%, and 2% of the total, respectively. However, this estimate is conservative, because energy used for the construction and maintenance of infrastructure, etc. has not been considered. Overall, leisure-related human activities may contribute with 3.2% (14,080 PJ) and 5.3% (1400 Mt CO₂-e) to global energy use and CO₂-e emissions. This seems to be a minor share, but the analysis also revealed that the industrialized countries, which constitute only 15% of the world's population, account for 82% of the global leisure-related transport (distances). Furthermore, within the industrialized countries, a small group of long-distance travelers seems to account for most of the energy used. In Germany, for

example, the 14% of the longer vacation journeys to destinations outside Europe were responsible for almost 55% of the energy use. Similarly, air travel accounted for 80% of the energy used for longer vacation journeys, even though the aircraft was the means of transport only in one third of all cases (in 1997, Busch and Luberichs, 2001). Travel surveys indicate a strong correlation between income, education and distances traveled (SCB/SIKA 2001; SIKA, 2001, cf. also Busch and Luberichs, 2001). It thus seems that a minor proportion of the world's population (the better educated and wealthy, possibly less than 5% of the world's population) accounts for a major share of the leisure-related energy use (assumably more than 40%).

Per unit of energy used, air travel has the greatest impact on global warming. Even though it accounts for only 15% of the leisure-related distances traveled globally, it is responsible for about 18% of the energy use and 37% of the contribution of leisure-travel to global warming. This is particularly problematic, because the United Nations Framework Convention on Climate Change (UN-FCCC) does not cover emissions from bunker fuels, i.e., those sold in harbors (e.g. heavy fuel oil) and in airports (e.g. jet fuel). As a result, emissions from international aviation are not under international policy control (Olsthoorn, 2001).

The consequences of the release of greenhouse gases into the atmosphere are many, including global warming, sea-level rise, regional changes in precipitation, and ENSO phenomena. According to the International Panel on Climate Change (IPCC, 2001), global mean temperatures have risen by $0.6 \pm 0.2^\circ\text{C}$ in the period 1861–2000. Sea level rise has been between 0.1 and 0.2 m during the 20th century. Snow cover is very likely to have decreased by 10% in its extent since the late 1960s, and in the Northern Hemisphere, it is likely that there has been a 2–4% increase in the frequency of heavy precipitation events. Warm episodes of ENSO have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years. In the future, globally averaged surface temperatures are projected to increase by 1.4–5.8°C, and global mean sea level is projected to rise by 0.09–0.88 m over the period 1990–2100 (IPCC, 2001). Regionally, the consequences of environmental change may be devastating. The 1997/98 ENSO, for example, had severe impacts on the climate of the Indian Ocean. In March and April 1998, seawater temperatures rose by an average of 1.5°C above values measured during the same period in 1997. Following the event, coral mortality was greater than 50% over extensive areas in the Indian Ocean, Southeast Asia and the Caribbean (Lindén and Sporrang, 1999). Other examples of biological responses to climate change can, for example, be found in Pounds et al. (1999), Parmesan et al. (1999), and Hellberg et al. (2001).

The contribution of tourism to biotic exchange and the extinction of wild species are difficult to assess. Furthermore, not all species introductions have consequences, and only a few may actually impact on human health and that of other species. Tourism seems to primarily contribute to species extinction through direct processes, such as collecting and buying shark teeth, conchs, shells, corals, and other souvenirs. However, in the light of the current knowledge it seems to be difficult to assess the importance of tourism in this process.

Tourism is an important factor in the exchange and dispersion of disease. Tourists may acquire diseases themselves and contribute to the dispersion of pathogens. Statistically, the risk of infection may be as high as 30–80% for diarrhea, 0.3% for hepatitis A, 0.25% for malaria, and 0.01% for HIV for travelers from Europe and North America to developing countries. However, the indirect impacts on health associated with travel may be more important than the direct: travel contributes to global warming and ENSO phenomenon, which are believed to lead to a considerable increase in disease, particularly malaria. This may often expose those groups with the least financial means to new or more severe health problems. Tourists are also responsible for changes in ideas, values and norms, which may lead to the increased consumption of “junk food”, alcohol, tobacco, etc. by local populations, adding on existing health problems. Apart from a purely quantitative approach focusing on the tourists, it is thus necessary to acknowledge the complexity of the consequences of tourism for the health of the populations of the visited countries, too.

One of the ultimate goals of sustainable development is to foster responsible environmental behavior. Travel may foster environmental knowledge, but this will not necessarily lead to positive changes in attitudes, awareness and, ultimately, environmental behavior. Tourism may rather reinforce the human notion of being separated from nature, which may prove to be detrimental to sustainable development. Obviously, these consequences of tourism cannot be quantified.

Finally, it has been acknowledged that tourism increases water demand in water scarce regions, which may exacerbate existing problems, often to the disadvantage of local populations.

In summary, the study has shown that the environmental consequences of travel are substantial, particularly if looked at from a per capita perspective: there is strong evidence that a minority of the world population causes the majority of the negative effects associated with tourism and travel. Simultaneously, it seems as if humans in developing countries may suffer most from the negative consequences, often those with the least financial resources. In the future, leisure-related tourism will experience further rapid growth. It thus seems

necessary to deepen the debate on sustainability in tourism, and address the existing problems from a social, ecological and economic perspective. In this context, it also deserves mentioning that there is a rather strong consensus that a continuation of ENSO phenomena, changing patterns of precipitation (both in terms of distribution and intensity), and changes in snow cover and average temperatures will have severe consequences for the tourist industry (cf. Abegg et al., 1997; Behringer et al., 2000; Braun et al., 1999; Giles and Perry, 1998; Harrison et al., 1999; Koenig and Abegg, 1997; Maddison, 2001; Wall, 1998). Tourism can thus be said to be a major agent in global environmental change, and it will in itself be affected by this change. The restructuring of the tourist industry towards sustainability should thus lie in its own interest.

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