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THE NEGATIVE IMPACT OF HIKING ON THE MOUNTAIN ENVIRONMENT – THE POSITION OF POLISH SCIENTISTS IN COMPARISON TO GLOBAL LITERATURE

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Abstract

Purpose. In this article, the position of Polish scientists is presented with regard to the impact of hiking on the environment, particularly mountain areas, by reference to the broader context of selected works of global literature.

Method. The paper is mainly in the form of a review of literature connected with Earth sciences, chiefly geomorphology. Particular emphasis is placed on the effects of hiking, which have been divided by impact type (e.g. compaction and soil erosion, initiation of morphogenetic processes, impaired water circulation, destruction of plant biomass and changes in the plant and animal world).

Findings. The Polish scientific contribution to the subject area presented should be considered significant, however, it does differ in certain characteristics from the achievements of the wider world. Considerable attention has been devoted to means of counteracting particular negative effects of tourism, both the technical (remodelling of trails and their surroundings) and organisational aspects (management of tourist traffic).

Research and conclusions limitations. The position of Polish science is mostly presented, however, this is done in comparison to the broader global literature on the topic.

Practical implications. The suggested means of counteracting the negative effects of hiking may be useful while planning tourist infrastructure, especially in protected areas.

Originality. In the paper, a complex review is presented regarding the opinions of Polish scientists, not only on the topic of the negative impact of hiking, but also methods of its prevention.

Type of paper. Literature review.

Keywords: tourist trails, hiking, environmental management.

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Introduction

For many years, Polish and global scientists have failed to recognise the impact of tourism on the natural environment and cultural landscape. The first serious studies in this regard were thus conducted in the 1970s, with an intensification coming in the second half of the 1980s, when tourism had already been highly developed [Myga-Piątek, Jankowski 2009]. O. Rogalewski [1977] was one of the first Polish authors to address the general causes of devastation to the natural environment as a result of tourist traffic. In his view, they include:

- an excessive number of tourists in relation to environmental capacity;
- inappropriate forms of sightseeing, often associated with improper adaptation of tourist sites to the needs of tourism (e.g. tourist dispersion throughout an area, trampling vegetation and causing ground erosion due to a lack of suitable paths and established viewing areas);
- inappropriate use of tourist sites (e.g. recreational tourism in protected areas);
- lack of appropriate tourist behaviour (noise, littering, picking flowers, disturbing animals);
- improper location as well as type of tourist structures and facilities (mainly related to poor adaptation to terrain, tourist traffic intensity and its directions, as well as architectural forms typical of an area).

The conflict between tourism (including hiking) and the mountain environment (but also between different forms of tourism) was analysed by J. Czerwiński, B. Mikułowski and J. Wyrzykowski [1991], taking the example of the Polish Carpathians and Sudety Mountains into account. They emphasized that “the development of tourist infrastructure is in itself a threat to the environment” [p. 58], which may be due to improper location (including excessive concentration) or lack of adequate treatment facilities for wastewater from tourist lodges. As a result of their analysis, they indicated rational directions for the development of tourism, with particular emphasis on natural protected areas, acceptable combinations of different forms of tourist use and the optimal tourism capacity in mountain areas. Z. Denisiuk [2009] analysed the potential for development of various forms of tourism and satisfaction of tourism needs in landscape parks. According to the author, “tourist traffic should be subject to more stringent restrictions at smaller sites, at sites with a high proportion of reserve protection, during periods of reproductive activity of animals and in adverse weather conditions (e.g. during prolonged rain and at times of spate water). In addition, relatively greater restrictions are present in mountain and upland areas” [Denisiuk 2009, p. 37]. More general models of the relationship between tourism (including various types of tourism and recreational activities) and the natural environment were presented by A. Krzymowska-Kostrowicka

[1997], Y. Leung and J. Marion [2000], M. Mika [2004], P. Pawlaczyk [2002] and G. Wall and A. Mathieson [2006]¹. A brief overview of these issues was presented by M. Barker [1982], M. Jodłowski [2001], C. Krajczyńska [2010], M. Mika [2001, 2003, 2008], Z. Mirek [1995, 2010], U. Myga-Piątek and G. Jankowski [2009], S. Sprincova [1972] and M. Staffa [1992]. Several papers on the impact of tourism on the natural environment of mountain areas were written by W. Kurek [1999, 2004a, 2004b, 2005]. It must be borne in mind that mountain areas are particularly sensitive to the effects of tourist activity. This is becoming increasingly important today, when the space available for qualified tourism continues to decline.

The work covers studies on the environmental impact of one of several forms of tourist activity pursued along tourist trails – hiking, undertaken in mountain areas. Its aim is to make a comparison of Polish and non-Polish literature, however, emphasis is placed on the Polish perspective. As a consequence, the Polish literature is represented to a greater extent. It was selected to demonstrate various processes from different perspectives (geology, geomorphology, botany, zoology, spatial planning), showing research from the most important Polish scientific centres (mostly Cracow, Warsaw, Wrocław, Poznań, Gdańsk, Rzeszów). Of course, a large fraction of the studies focuses on the mountain ranges considered as the most popular from the tourist perspective (Tatra Mountains, Pilsko Massif, Karkonosze Mountains), but the author attempts to show reports also from other regions. On the other hand, among the non-Polish literature, works by the most appreciated authors are cited most often (among others, N. Bayfield, D. Cole, D. Dale, Y. Leung, M. Liddle, T. Weaver), however, areas other than Great Britain and USA are also presented thanks to works by other authors. The comparison of Polish and non-Polish literature on the covered issues seems important as it allows evaluation of specific topics, methods, scales of analysis and results. Is the position of Polish scientists similar or not to studies presented in global literature? Do the changes have a similar course, obviously depending on natural conditions?

The effects of hiking are almost always associated with a relatively large number of people pursuing these activities on a narrow strip of land. The consequences, however, are smaller than in the case of single points, as the linear, two-dimensional form is associated with some kind of dispersion of tourists [Wall, Mathieson 2006]. Hiking is also regarded as relatively less harmful compared to e.g. downhill skiing. It is very difficult to specify which type of activity causes more damage to the environment, as the nature and intensity of changes depend on a number of factors (including intensity of tourist traffic, the overlapping effects of various forms of tourism, vegetation, ground resistance and slope gradient). Nonetheless, it is gen-

¹ Contains reference to numerous earlier published papers by European (mainly British) and American authors. An earlier edition of this book (A. Mathieson and G. Wall, *Tourism Economic, Physical and Social Impacts*) appeared in 1982.

erally assumed that skiing is more destructive than hiking along a narrow stretch of land [Kurek 2004a]. This conclusion was drawn by N. Bayfield [1973, 1979] in his studies conducted in Scotland (mainly the Cairngorm massif), E. Gorczyca and K. Krzemień [2006, 2009] and K. Krzemień [1997] in studies conducted in the Monts Dore, France, M. Mika [2004] in studies in Beskid Śląski and P. Skawiński [1993] in research on Kasprowy Wierch peak and in Goryczkowa Valley in the Tatra Mountains. Furthermore, C. Pickering, W. Hill, D. Newsome and Y. Leung [2010] compared the effects of hiking, mountain biking and horse riding on vegetation and soils both in Australia and the United States of America. Unfortunately, according to a survey conducted by A. Buchwał and M. Rogowski [2007], tourists are only vaguely aware of the negative impact of tourist traffic on the environment and do not always understand the reasons for measures taken to counteract this (compare [Adamski, Kolasińska, Witkowski 2016], [Guo, Smith, Leung, Seekamp, Moore 2015] and [Kolasińska 2010]). Polish literature on the subject touches mainly on the environmental consequences of hiking.

The negative impact of hiking on the environment

The morphogenetic role of hiking consists mainly of the mechanical tourist impact on the biologically active surface of tourist paths and trails and their immediate surroundings. The first studies describing trampling-related disturbances of plant vegetation near hiking paths date back to the interwar period [Liddle 1997; Mika 2004]. However, the research was not developed until the second half of the 20th century. The impact of hiking can be divided into several forms, depending on the mechanism of changes, their actual source(s) and the subject undergoing these processes. The classification of the effects of hiking presented below was prepared by the author according to the literature in order to show the complexity of the phenomena, their sequence and correlations. The first seven items are, in a sense, potentially divisible into stages of environmental destruction. Other processes mentioned in the following items, to a greater extent, take place simultaneously. The list includes only those entries in the literature which provide a broader approach to a given process. However, some of the publications address the entire set of phenomena and hence, these are not assigned to specific items, but only mentioned later in the work according to relevant subject area.

- Mechanical degradation and reduction of vegetation cover biomass (including mycelium) on and around paths (broadening of paths, creation of desire lines) and at trail interchanges and nearby tourist resorts² un-

² Trails running through meadows are usually wider than those leading through forests, as the traffic is at least partially channelled by trees and bushes. This is confirmed by both

til the appearance of the soil surface as a result of trampling [Barančok, Barančokova 2007; Bolland 1982; Cole 1978, 1991, 1995a, 1995b; Cole, Bayfield 1993; Cole, Trull 1992; Czochoński 2000; Dale, Weaver 1974; Fidelus 2007a; Gołaszewski, Rojan, Tsermegas 2010; Guzikowa 1982³; Kellomäki 1977; Kroh 2002; Michalik 1972, 1996a; Mirek, Piękoś-Mirkowa 1979; Pawlaczyk 2002; Piękoś-Mirkowa 1982; Piękoś-Mirkowa, Mirek 1982; Poleno 1988; Rączkowska, Kozłowska 2010; Roovers, Verheyen, Hermy, Gulinck 2004; Ukkola 1995; Weaver, Dale 1978], and sometimes, as a result of the traffic to shelters; tearing off whole fragments (packets) of turf saturated with meltwater and rainwater [Cole 1991]; changes to and destruction of the root system, causing fungal infections and impaired growth as well as death of trees and shrubs; picking plants with attractive appearance, including protected species [Bogacz 1974; Mirek, Piękoś-Mirkowa 1979; Swatowska 1996], damage to tree bark and breaking plant shoots, branches and even whole plants, shortening their life span [Bandola-Ciołczyk, Kurzyński 1996; Bogacz 1974].

- Topsoil compaction and related modification of its air and water properties [Fidelus 2007b; Kopeć, Głab 2002; Liddle, Greig-Smith 1975; Łajczak 1996; Poleno 1988; Prędko 2002; Szydarowski 2000; Weaver, Dale 1978]: destruction of humus horizon or distortion of soil profile surface levels, changes in mechanical structure⁴, reduction of rainwater infiltration and the water holding capacity of soil [Ukkola 1995], chemical changes in the soil (loss of carbon and nitrogen), reduced soil biological activity, reduced aeration, changes in acidity values, increased thermal conductivity, over-drying of upper layers and wind-erosion; sites devoid of vegetation are characterised by higher temperatures and faster heating, which can further accelerate the weathering of parent rock.
- Devastation of paving rubble, loosening and fragmentation of base material, which then becomes more prone to wind-erosion and flushing; disruption of weathering mantle stability; direct displacement of loose rock material by tourists (rocky tongues on slopes below the path).
- Disruption of water circulation [Łajczak 1996]: reduction in infiltration and supply to underground water reservoirs, reduced retention, forma-

U.S. [Dale, Weaver 1974] and British research [Bayfield 1971]. The development of vegetation in the affected areas can occur only 5–10 years after the trampling ceases (provided that soil degradation did not occur, a factor capable of preventing regeneration of vegetation), while the total restoration of the damaged ecosystem may take as long as 15–20 years [Zaręba 2010].

³ On the basis of transect studies on trails leading through the meadows in the Pieniny National Park, M. Guzikowa [1982] notes that damage to plant communities due to excessive trampling occurs in just a few years, while the regeneration process is much longer (probably about 15–20 years).

⁴ Peat areas are especially vulnerable to degradation – a single passage of several persons along the same path causes permanent changes in the structure of the peat [Pawlaczyk 2002].

tion of erosion runoffs, conservation of compacted and icy snow covers on pathways resulting in delayed and shorter vegetation period [Buchwał, Fidelus 2008; Fidelus 2007b]; water uptake by tourist lodges and shelters; accelerated disappearance of mountain lakes due to increased emission of particulate matter and initiation of mass movements by tourists; reshaping stream beds through construction of stone dams [Balon 2001b].

- Initiation of morphogenetic processes on exposed soil [Barančok, Barančokova 2007; Barczak, Jankow, Kubinek, Struś, Wołowicz 2002; Buchwał, Fidelus 2008; Fidelus 2007a, 2007b⁵; Gorczyca 2000; Gorczyca, Krzemień 2009; Kurzyński, Michalik 1982; Łajczak 1996]: slope-wash, mud-and-debris flows, dispersed downwash and linear wash [Kasprzak 2005, 2006], aeolian processes (deflation), cryogenic processes (nivation), the impact of needle ice [Mazurski 1972], splash and gravitational and pluvial-gravitational processes.
- Erosion of exposed and compacted soil cover devoid of vegetation on and around the path as far as the rock rubble surface of mountain slopes or even the bedrock [Cole 1978; Dale, Weaver 1974; Weaver, Dale, 1978], which is especially evident below the upper limit of the forest and on the ground thresholds; movement of rock material down the slope and its accumulation [Łajczak 1996].
- Development of microrelief forms on paths (fluting, grooves, erosion troughs and channels, upslope erosion indents, erosion thresholds, shelves between tree roots, eversion hollows, gelideflation steps, nival niches, deflation niches, crionival niches, deflation pavement, turf monadnocks, terraces and troughs caused by trampling, embankments along the paths, alluvial fans, talus fans, accumulation tongues and landslide dumps), leading to further degradation and trampling of alternative paths by tourists [Barančok, Barančokova 2007; Barczak et al. 2002; Buchwał, Fidelus 2008; Fidelus 2007b, 2010; Gorczyca 2000; Krusiec 1996; Krzemień 1997; Łajczak 1996⁶; Mazurski 1972⁷; Szydarowski 2000; Wałykowski 2006].

⁵ In both works, the intensity of morphogenetic processes on tourist trails in the Tatra Mountains is analysed depending on the morphogenetic periods and geoeological belts.

⁶ Based on the research results from the Pilsko Massif, A. Łajczak [1996] distinguished five steps of forming erosion rills, even leading up to exposure of solid rock at the bottom of the V-shaped valley.

⁷ Based on field research in the Karkonosze (Giant) Mountains, K. Mazurski [1972] presented an interesting classification of microforms which can be found on tourist trails. The triggered changes (mainly erosion processes) lead to the development of initial microforms (trampled paths, ruts and scarps), which, in time, are transformed in early microforms (flutes, mini terraces, cobblestones, heaps of soil and pyramidal heaps) and then into developed microforms (troughs, rubble steps, material fillings, complex terraces, debris cones, bars and mini eversion hollows). New manifestations of erosion developed within the created microforms are called complex microforms.

- Changes in plant species composition and disruption to altitudinal zonation: restriction of the growth of certain species due to soil degradation (including compaction); an increase in the proportion of species resistant to trampling at the expense of more vulnerable species, resulting in formation of specific carpet communities consisting of non-native species (largely moss) on and around paths [Cole 1978; Dale, Weaver 1974; Guzikowa 1982; Pawlaczyk 2002; Kellomäki 1977; Rączkowska, Kozłowska 2010; Roovers et al. 2004; Weaver, Dale 1978]; spreading of ubiquitous (cosmopolitan), synanthropic and ruderal species along trails and routes, transported from valleys and lower parts of the mountains to higher areas on the shoes and clothing of tourists, with the resulting displacement of species native to the habitat [Benninger-Truax, Vankat, Schaefer 1992; Cole 1978; Guzikowa 1982; Michalik 1972; Mirek, Piękoś-Mirkowa 1979; Pawlaczyk 2002]; synanthropisation, including via eutrophication of the environment, littering (including left-over food) and waste dumps near lodges and shelters⁸, as well as the establishment of rock gardens, flower beds, etc. near lodges [Guzikowa 1982; Mazurski 1998; Mirek, Piękoś-Mirkowa 1979; Piękoś-Mirkowa, Mirek 1982⁹; Swatowska 1996].
- Destruction of vegetation by landslide material or that carried by rain-water from areas where soil was exposed due to trampling, with the resulting release of loose material and initiation of gravitational processes [Fidelus 2010; Szydarowski 2000].
- Changes in the animal world: mechanical injury to animals, bird nests, burrows and ant hills; inadvertent or deliberate killing of invertebrates, reptiles and amphibians which are considered dangerous or arouse aversion due to their appearance [Starzyk 1974]; disturbance of animals by noise, traffic and interference with migration routes, causing psychological and behavioural changes in animals, reduction in their living space, problems with access to food, impaired immunity to diseases, reduced fertility and changes in population size [Kurzyński, Michalik 1982; Pawlaczyk 2002]; synanthropisation of fauna – changes in the lifestyle and dietary behaviours of animals causing dependence on humans; attraction of animals to certain areas due to feeding and the presence of landfills, leading to changes in the composition of their diet

⁸ Waste is produced by tourists and tour operators. It originates from tourist service facilities and infrastructure maintenance.

⁹ Based on studies conducted in the Tatra Mountains, the authors concluded that tourism-related vegetation modifications near lodges and shelters are “relatively short lived”, as “the non-native species there are at the limits of their ecological capabilities” [Piękoś-Mirkowa, Mirek 1982, p. 173]. Only a few species become established there, mainly in open or semi-open habitats. In general, however, after the cessation of human activities, synanthropic plants quickly disappear.

- [Adamski 1996; Ukkola 1995; Wall, Mathieson 2006]; acclimatisation under strong human pressure; encroachment of non-native species of invertebrates (mainly insects) together with synanthropic vegetation.
- Degradation of rock surfaces (rocks) owing to tourist-induced erosion (abrasion); deliberate removal of rock fragments; creation of stone piles.
 - Soil pollution due to improper disposal of garbage and leakage of operating fluids from lodge and shelter equipment and hostel service vehicles.
 - Water pollution caused by wastewater from lodges or shelters as well as low-standard and insufficient sanitary facilities [Choiński, Galas, Jodłowski, Pociask-Karteczka, 2007; Mazurski 1998], by leakage of operating fluids from equipment and improper storage of waste; water pollution caused by tourists themselves, which is particularly evident near Morskie Oko (Sea Eye Lake) in the Tatra Mountains, where tourists throw various objects into the water, e.g. coins ('for good luck'), garbage and food scraps ('feeding fish'), drop litter or relieve themselves among rocks and mountain pines by the lake and wade or soak their feet in the water, thus, affecting the structure of bottom deposits [Choiński et al. 2007; Kapera 2007]; all of this leads to eutrophication of mountain reservoirs, ecological imbalance and changes in the trophic chain.
 - Air pollution due to the emission of carbon dioxide and other harmful substances generated by coal, coke and oil heaters used in lodges and shelters [Mazurski 1998] as well as due to emissions from hostel service vehicles; the high energy consumption of traditional heating devices used in some lodges.
 - Deterioration of aesthetic landscape values (urban development) due to irrational use of land, fragmentation, creation of unsightly structures not integrated into the landscape (often makeshift seasonal facilities), destruction of vegetation (including deforestation for construction of new structures), trail erosion and littering [Kapera 2007].
 - Increased risk of fire due to campfires and dropping cigarette butts [Grzelak, Harabin 2010; Pawlaczyk 2002]; blackening of branches by smoke rising from campfires located near trees and shrubs [Bogacz 1974].

Most Polish studies on the effects of hiking (but also cycling or ski touring) on the natural environment are performed on a local scale and cover some of the phenomena listed above. M. Ewertowski and A. Tomczyk [2007] presented a tabular overview of selected Polish studies on the subject and proposed the use of GIS tools for assessing the state of the geographical environment along tourist trails for the integration and analysis of terrain and cartographical data; a similar proposition was made by Z. Jała and D. Cieślakiewicz [2004], Z. Magyari-Sáska and S. Dombay [2008], A. Tomczyk and M. Ewertowski [2013], but also by K. Taczanowska, L. Gonzalez et al. [2014], who used an interesting mixed method consisting of GPS tracking and graph theory. According to M. Ewertowski and A. Tomczyk [2007],

Tab. 1. Areas in Poland studied by Polish researchers in terms of the negative impact of hiking

Areas / Obszary	Studies / Badania
Tatra Mountains	Balon 2001a, 2001b; Buchwał, Fidelus 2008; Buchwał, Rogowski 2010; Chabowski 2014; Choiński et al. 2007; Ciapała, Zielonka, Kmiecik-Wróbel 2010; Cieszewska, Deptuła 2013; Czochoński 2000 ^{a)} ; Ewertowski, Tomczyk 2007; Fidelus 2007a, 2007b, 2008, 2010; Gołaszewski et al. 2010; Gorczyca 2000; Gorczyca, Krzemień 2006, 2009; Kopeć, Głab 2002; Kroh 2002; Krusiec 1996; Krzemień, Gorczyca 2005; Mirek, Piękoś-Mirkowa 1979; Piękoś-Mirkowa 1982; Piękoś-Mirkowa, Mirek 1982; Rączkowska, Kozłowska 2010; Skawiński 1993; Starzyk 1974; Szydarowski 2000; Witkowski, Mrocza, Adamski, Bielański, Kolasińska 2010
Pieniny Mountains	Adamski, Kolasińska, Witkowski 2013, 2016; Adamski et al. 2014; Gorczyca, Krzemień 2006; Guzikowa 1982 ^{b)} ; Kolasińska 2015; Witkowski et al. 2010 ^{b)}
Gorce Mountains	Tomczyk, Ewertowski 2013; Waldykowski 2006
Pilsko Massif ^{c)}	Adamski 1996; Bandała-Ciołczyk, Kurzyński 1996; Kurzyński, Łajczak, Michalik, Mielnicka, Witkowski 1996; Łajczak 1996, 2003, 2004; Michalik 1996a, 1996b; Mielnicka 1996; Witkowski 1995, 1996
Babia Góra Massif	Bogacz 1974; Buchwał, Fidelus 2008; Buchwał, Rogowski 2010
Beskid Śląski Mountains	Mika 2001, 2004
Bieszczady Mountains	Kurzyński, Michalik 1982; Myga-Piątek, Jankowski 2009; Prędko 2002
Karkonosze (Giant) Mountains	Jala, Cieślakiewicz 2004; Kasprzak 2005, 2006; Mazurski 1972, 1998, 2010; Myga-Piątek, Jankowski 2009; Parzóch, Katrycz 2002; Swatowska 1996
Ojców National Park	Barczak et al. 2002; Witkowski et al. 2010

a) Author presented an original relief degradation typology in tourist areas.

b) Authors explored the effects of trampling on the tourist trails in this area and the possible measures for its counteraction.

c) The majority of works concerning Pilsko Massif are part of a monograph entitled *The impact of skiing and hiking on the natural environment of the Pilsko Massif* [Łajczak, Michalik, Witkowski, (eds.) 1996]. Some of its conclusions, however, raise certain doubts, as the authors (particularly A. Łajczak [1996]) claim that hiking has greater impact on the degradation of soils and relief than downhill skiing, which is contrary to the results of most research conducted to date (see the Introduction section of this paper). It seems that an insufficient account was considered when regarding the differences in time since the commencement of these types of tourist activities in the Pilsko Massif. In addition, hiking is blamed for the intensification of erosion within the downhill ski runs while overlooking the fact that erosive changes were originally initiated by deforestation and turf destruction during the construction of ski runs, by skiing and snow groomers. It may be of consideration as to what the severity of the erosion on the tourist paths which currently intersect the downhill runs would be if the latter did not exist.

Source: Author's own elaboration.

“studied on and around tourist trails, was the impact of tourist traffic on one of the components of the geo-ecosystem: relief, soil, vegetation, fauna, tourist infrastructure or a complex of these” [p. 272]. Polish researchers often focus on high mountain areas – the Tatra Mountains, the Pilsko Massif, Mount Babia Góra and the Karkonosze (Giant) Mountains (Table 1). They have also addressed the effects of hiking beyond Poland, e.g. in the Monts Dore Massif, located in the highest part of the Massif Central in France [Gorczyca, Krzemień 2006, 2009; Krzemień 1997], and the Slovakian Tatras [Fidelus 2010]¹⁰. The effects of trampling have also been investigated by foreign researchers (Table 2). While analysing the effects of trampling, D. Cole [1978, 1991, 1995a, 1995b], D. Cole and N. Bayfield [1993] and D. Cole and S. Trull [1992] focused on developing a standard experimental method for assessing the intensity of this adverse phenomenon and the resistance of vegetation to trampling, taking even factors as specific as shoe type or hiker weight into account and studying the course of changes for each plant species alone. R. Knapp and M. Ducey [2010] presented an original method which requires investigating only selected parts of the trail net-

Tab. 2. Areas studied by selected foreign researchers in terms of the negative impact of hiking

Studies / Badania	Areas / Obszary
Barančok, Barančokova 2007; Barančokova, Barančok 2007	High Tatras in Slovakia
Benninger-Truax et al. 1992	Rocky Mountain National Park, Colorado, USA
Cole 1978, 1991, 1995a, 1995b	Various mountain areas in USA, mainly the Rocky Mountains
Cole, Trull 1992	Northern Cascade Mountains, USA
Dale, Weaver 1974; Weaver, Dale 1978	Northern Rocky Mountains, USA
Kellomäki 1977; Ukkola 1995	Finland
Liddle, Greig-Smith 1975	Northern Wales
Magyari-Sáska, Dombay 2008	Romania
Pickering et al. 2010	Australia and USA
Roovers et al. 2004	Central Belgium
Shackley 1999	Peru
Taczanowska, Brandenburg et al. 2014	Tatra National Park, Poland
Taczanowska, Gonzalez et al. 2014	Danube Floodplains National Park, Austria

Source: Author's own elaboration.

¹⁰ The author compared the nature and intensity of anthropogenic effects on tourist paths and trails in the northern and the southern slopes of the Tatra Mountains.

work in order to obtain the overall results. A GIS-based method was proposed by Z. Magyari-Sáska and S. Dombay [2008], while three complementary procedures for assessing the condition of hiking trails were developed by Australian researchers W. Hill and C. Pickering [2009].

In general, it is clear that well-organised hiking tours along tourist trails have relatively small impact on the environment, especially with respect to vegetation and soil cover [Dale, Weaver 1974; Denisiuk 2009; Kurek 2004a, 2005; Weaver, Dale 1978; Zabierowski 1982]. Adverse effects occur only in the case of an excessive intensity of traffic and improper preparation of paths, as well as with the use of desire paths¹¹ and in the most crowded areas, e.g. at trail intersections, viewing points, rest areas and around campsites, particularly those wild and seasonal, without proper infrastructure (sanitation facilities, waste-bins etc.). It should be noted, however, that trampling-related changes are usually preceded by less visible processes, such as changes in flora composition associated with the accidental introduction of foreign plant species or behavioural and structural changes in the fauna [Pawlaczyk 2002], which occur even with a low intensity of tourist traffic. Moreover, such changes occur not only on the path and in its immediate vicinity, but also across a wider area around the trail [Barančokova, Barančok 2007]. According to B. Mielnicka [1991, 1992, 1996], M. Guzikowa [1982], B. Konca [1984], R. Olaczek [1982], A. Sobczak [1983] and M. Staffa [1992], most damage is caused by mass tours involving people exhibiting poor tourist behaviour and limited knowledge of the environment as well as the principles of sightseeing and hiking. Such tourists typically produce a great deal of noise, scare away animals, drop litter, pick plants and move around in groups off the trails, breaking tree branches and shrubs. Some of the tourists use desire paths, trampling out new routes. Unfortunately, mass tourism dominates in most national parks. In contrast, sporadic hiking does not cause significant changes in the environment [Balon, German, Maciejowski, Ziaja, 2001]. Another important risk factor is the activity of tourist facilities (e.g. lodges and shelters), which are often located in areas of particular natural value.

In the case of broadly understood erosive effects related to hiking, it is clear that hiking simply triggers or intensifies natural morphogenetic processes [Buchwał, Fidelus 2008; Fidelus 2007b; Kasprzak 2006; Krusiec 1996], the course and intensity of which depends on several factors, including: 1) ground resistance and soil type, 2) exposure and slope gradient of land surface (also the presence of wide areas enabling trail expansion), 3) geoecological belt (defining a set of climate and vegetation characteristics in

¹¹ The issue of hiking off trails (so-called illegal dispersion) in national parks and nature reserves in Poland was investigated by Z. Witkowski et al. [2010] and particularly in the case of Pieniny National Park, by P. Adamski et al. [2013] and A. Kolańska [2015], and for the Polish Tatra National Park, by S. Chabowski [2014].

relation to the relief), 4) water relations, 5) type of plant community near the trail, 6) trail characteristics (width, type and condition of the surface, additional surface protection, trail course – adaptation to the terrain orography as well as the needs and physical capabilities of the average tourist), 7) intensity and seasonality of tourist traffic (and other means of using the trail and its surroundings, if any), and 8) availability and attractiveness of off-trail sites [Bogacz 1974; Czochoński 2000; Ewertowski, Tomczyk 2007; Fidelus 2007a, 2008; Gołaszewski et al. 2010; Mirek, Piękoś-Mirkowa 1979; Szydarowski 2000; Wall, Mathieson 2006].

Paths running perpendicular to contour lines with a slope gradient of more than 20–25° are particularly vulnerable to degradation [Fidelus 2007a; Kasprzak 2006; Krusiec 1996; Łajczak 1996; Mazurski 1971, 1972]. However, according to A. Marsz [1972, as cited in Pawlaczyk 2002], rapid deterioration of soil and vegetation cover occurs on slopes above 7° and even due to low-intensity trampling (hence, such slopes should be closed to pedestrian traffic). This claim is a very rigorous one and, if implemented, would essentially prevent tourism in mountain areas. Although sections perpendicular to contour lines, often based on old firebreaks or skid trails, reduce the time required to climb elevations and are thus popular among tourists, they pose a serious threat to the environment. Concentration of tourist traffic in a narrow stretch of land confined by dwarf mountain pine contributes to a deepening of footpaths [Gołaszewski et al. 2010]. On the other hand, M. Ewertowski and A. Tomczyk [2007] recognise the positive effects of tall vegetation along trails, as this prevents travellers from straying off the trail, reducing damage, which is usually of a linear rather than surface nature. According to the authors, other factors which prevent straying include running the trail through traverses (limited by a steep slope on both sides), running the trail over a narrow valley floor in the immediate vicinity of a stream (on one side, the trail is limited by a steep valley slope, on the other, by the stream) and artificial protection (fences).

Means of preventing selected negative effects of hiking

Many papers related to erosion on tourist trails provide solutions for its prevention and limitation. Forms of development for highly eroded trails – without prospects for natural regeneration of soil and plants – include special constructions aimed at preventing erosion, as well as at deposition of soil material and regeneration of plant cover. Among these are wooden or stone steps (barriers) preventing the flow of material in erosion drainpipes, meshes and mats retaining rock material [Barczak et al. 2002; Gorczyca 2000; Krzemień 1997; Łajczak, Krzan, Michalik, Skawiński, Witkowski 1996; Ukola 1995] and permanent barriers made of spruce poles arranged parallel

to levels or as a truss with the empty space filled by turf or other biological materials of local origin, or covered with a thin layer of soil [Skawiński 1993]. The meshes are made of natural fibres or plastic, then sown with various species of grass. Other proposed approaches also include the insertion of wooden poles, the spreading of gravel or rock rubble on trails and covering exposed soil areas and tree roots with appropriate materials (such as reeds). Slopes with damaged plant cover are sheltered with straw, improving conditions for growth, and then, sown with grass [Krzemień 1997]. Many erosive forms are simply covered (buried).

First, however, an area subject to regeneration of soil and plant cover must be secured against the mechanical impact of tourists. For this purpose, artificial obstacles are used to outline the course of the trail clearly and direct tourist traffic towards it. These include tapes, posts, curbs, barriers (high and low), rails and fences, and even water ditches. It is important that all forms of trail fencing, their lengths and their design, be adjusted to the requirements of animal movement [Bolland 1982]. Other means include beams, boards, wooden poles, trusses, scattered rocks or other obstacles preventing widening of the trail, departure from it and trampling out shortcuts. If such protections are properly fixed, soil can accumulate between them and, as a consequence, plants may encroach, while they can also be covered at once with turf. Since the damage and erosion of trails results in intense trampling of the sides of paths and alternative paths, the proper technical preparation of the path is also important so that walking is more convenient on it rather than next to it. The goal is the repair of the surface of the path and, if traffic is high, even the introduction of an artificial surface, but above all, the appropriate dispersal of rain and meltwater from the path using wooden or rock steps, gutters and culverts. Otherwise, even an artificial surface will be washed away by water and mud-and-debris flows [Buchwał, Fidelus 2008; Buchwał, Rogowski 2010; Cole 1991; Fidelus 2007a, 2008; Gorczyca 2000; Guzikowa 1982; Krusiec 1996; Rączkowska, Kozłowska 2010; Staffa 1985, 1992].

As noted by K. Parzóch and M. Katrycz [2002], one means of protection against washing away is covering trails with cobblestone, tarmac or rock blocks, as in the Karkonosze (Giant) Mountains. They do not comment, however, as to whether those solutions are fully effective and appropriate, since it must be stressed that all construction work on trails also has impact on the environment. R. Olaczek [1982] mentions a “chequered pattern of stone slabs made of appropriately selected material” [p. 47]. Also used are the metallised surface, a covering of local rubble (breakstone) and construction of steps made of wood and rubble or rocks in order to level greater slopes. In the case of the surroundings of the Gąsienicowa and Kondratowa mountain pastures in the Tatra Mountains, J. Fidelus [2007a] described the following artificial surfaces: built up with rocks or stone blocks, the metallised surface (sometimes

bounded with rocks) and the cobblestone surface; only 11% of the length of the trails in this area had a natural surface. On the other hand, A. Swatowska [1996] believes that mountain trails should be natural paths, improved only by the levelling the surface and provision of appropriate drainage, and that an artificial surface is acceptable only on sections with particularly heavy traffic. The rock material used for the construction of the trails should always be of local origin. Retaining walls are used on steep slopes to reduce the dynamism of erosive processes (the soil cover washing away and crawling down) and can, in certain situations, direct tourist traffic, while footbridges are built and planks laid on boggy sections [Barczak et al. 2002; Buchwał, Rogowski 2010; Cole 1991; Fidelus 2008; Gorczyca 2000; Kasprzak 2005, 2006; Mazurski 2010; Mielnicka 1992; Partyka 2010b; Skawiński 1993]. On the other hand, according to J. Gajewski [2007], bordering Tatra Mountain paths with rocks and walls while covering them with pebbles and earth is not effective, with tourists still (and perhaps all the more) walking on the sides of these paths, trampling them, the trails deteriorating as a result. Nor are wooden barriers always effective, instead marring the landscape.

In conclusion of the the above study, it must be said that in order to restore the soil cap and the plant cover in a given area, it is first necessary to limit or eliminate the impact of the factor triggering the erosion, then to restrict erosion and, finally, to take steps leading to the restoration of soil and plants, such as sowing seeds, covering soil with plant material, covering the surface with peat substrate, implanting turf and planting trees and bushes [Łajczak et al. 1996]. A list of devices preventing illegal dispersion and the resulting erosion was prepared by S. Ciapała et al. [2010], based on the example of the Tatra Mountains. Among the means of channelling tourist traffic, they listed tourist trails, 'no passage' signs, traffic marking tapes, information boards presenting rules relating to behaviour at protected sites, wooden beams placed on trail sides across their course (so-called stumblers), wooden handrails, balustrades and fencing, wooden trail width limiters (curbs), fencing of beauty spots, and portable toilet cabins (in order to eliminate the main reason for departure from the most popular trails). The means of preventing tourist erosion include rock stairs, wooden steps filled with rocks, earth steps strengthened with beams, wooden stairs, rock slope reinforcements, road edge reinforcements, stream and brook edge reinforcements, and wooden, stone or metal water drains [Ciapała et al. 2010]. It is important to match not only the type of protection to traffic intensity, but also its design and scale. As stressed by J. Czochoński and D. Borowiak [2000], it is not possible to indicate any universal types of technical treatment with respect to tourist trails, as these must be "adjusted to local environmental conditions and the manner of impact of the tourist traffic on the environment" [p. 358–359]. Various managing strategies for tourist trails were investigated by Y. Leung and J. Marion [2000] as well as by J. Marion and Y. Leung [2004].

As noted by M. Kasprzak [2006], “none of the protections help prevent destruction of roads permanently. Even the most solid artificial surfaces eventually become washed out (due to scouring) and collapse, and their further destruction leads to the stripping of the outer layer of the slope cover” [p. 184]. Furthermore, technical treatments and appropriate shaping of infrastructure may improve the condition of the environment and increase tourist volume only with respect to certain aspects. Although appropriate preparation of the path surface prevents the trampling and destruction of soil and undergrowth, it does not make the scaring of animals any less likely, and perhaps even increases potential for introduction of foreign plant species [Pawlaczyk 2002]. J. Partyka [2010a, 2010b] turns attention to the impact of tourist trail or beauty spot protection on the landscape, which is often associated with the introduction of concrete and metal barriers and bridges – for example the trail on the summit of Szczeliniec Wielki in Stołowe (Table) Mountains National Park, the platform at Dark Cave (Jaskinia Ciemna) in Ojców National Park or the stairs over the boulder fields in Świętokrzyski National Park.

Beyond building up trails, the prevention of their erosion or rehabilitation may be accomplished by regulating (limiting) tourist traffic, especially during the spring season when the soil is saturated with water (a limitation of tourist traffic in the period when the soil is saturated with water has been proposed by D. Cole [1991] and J. Fidelus [2007a], among others). It is, however, usually difficult to achieve this. Such regulation has been partially effective around the Kasprowy Wierch mountain peak (the routes of some paths have been corrected) [Skawiński 1993] and on Pilsko [Łajczak et al. 1996]. Adverse changes in the area of the Kasprowy Wierch mountain peak continue, caused by the permanently high tourist traffic. Changes on the tourist paths of Kasprowy Wierch which occurred within a single year are described by Z. Rączkowska and A. Kozłowska [2010]. An interesting proposition with respect to the regulation of hiking traffic, based on a study of traffic intensity and destruction of paths, has been offered for Pieniny National Park by A. Bolland [1982]. His suggestions were, however, rejected. More recently, detailed rules for the reorganisation of tourist traffic in the vicinity of Morskie Oko lake in the Tatra Mountains – assuming the closure of a section of a trail and plotting a new path, thereby pushing tourist traffic away from the water – have been suggested by A. Choński et al. [2007], while general issues related to the management of tourist traffic throughout the Tatra National Park were discussed by P. Skawiński [2010]. When changing the route which a trail follows, it is crucial to mark the new variant appropriately and erase the signs on the old one effectively. The new route should also offer a higher standard of hiking than the current variant and the adjacent areas thanks to a good surface, appropriate drops and, where possible, additional attractions.

The route of many trails has been changed based solely on intuitive assumptions rather than in-depth study of ecological correlations [Cole 1978]. D. Cole [1978, 1991] provides criteria which should be followed when making the decision as to whether a bypass is to be prepared for a given section or whether it is simply enough to prepare the section appropriately. The decisive factors are: whether an area with more erosion-resistant soil is available, the area (length) of problematic sections, the total resistance of the environment, the resistance of individual plant communities, the ability of the destroyed areas to regenerate and the potential for appropriate directing tourist traffic (effectively closing the old trail). With the appropriate information available as early as the trail planning stage, it is possible to select the route which will have the smallest impact on the environment [Cole 1978]. Experience shows that the revival of plants on damaged sections, even after complete elimination of tourist traffic, is very slow (and sometimes never occurs), because – as mentioned above – the tourist traffic is only a factor initiating degradation, with the key role later played by natural factors. As such, A. Bolland [1982] stresses that despite traffic regulation, the path surface (of both the old and new sections) continues to require various technical treatments, such as hardening trails using rocks or wood and fencing paths at more devastated sites.

Naturally, besides the construction of trails it is necessary to design the supporting infrastructure in an appropriate manner, i.e. to construct only the necessary devices in suitable locations and using proper technology, and to ensure that they merge well into the landscape and culture. A. Łajczak et al. [1996] and U. Myga-Piątek and G. Jankowski [2009] believe that certain solutions can be of significant assistance in disciplining tourists. These include boards and ideographs providing rules to follow at a given protected site, a schematic map of tourist trails and boards reminding tourists to walk on the marked trails, not leaving them, informing of rehabilitation works. Among older papers, the importance of a campaign to improve tourist behaviour was also stressed by A. Bolland [1982] and M. Guzikowa [1982]. A good practice is the creation of a tourist development plan for each national park (including so-called studies shaping the tourist and didactic function) or, on a larger scale, for all protected areas [Baranowska-Janota 2007; Stasiak 1997].

Summary

Although recognised only in the late 20th century, the impact of hiking on the environment, particularly mountain areas, has received increasing scientific attention mainly due to the often high intensity of adverse environmental consequences. Polish scientific achievements, studying the impact of using

hiking tourist trails on the mountain environment, must be considered significant, although – compared to the international achievements – they are usually local and more qualitative than quantitative in orientation. Most authors, especially of the most recent papers in geomorphology, focus on a single valley or a few trails, inventorying the changes caused by hiking and then describing them (usually by division into several categories). Much less frequent are detailed analyses and assessments of the forms and volume of materials removed. Polish researchers, however, have been observing transformation and damage of a nature similar to that observed by researchers from other countries of similar climate. Considerable attention has been devoted to means of counteracting certain negative effects of tourism, both the technical (remodelling of trails and their surroundings) and the organisational aspects (management of tourist traffic). Particularly valuable are the proposals to limit and prevent erosion on tourist trails, including the proposals to reorganise the trail network by taking local environmental conditions into account. Unfortunately, such suggestions, supported by scientific proof, have not always been implemented. Recommendations for preventing tourist erosion on trails vary significantly, from barriers and other obstacles channeling tourist traffic, to special devices intercepting mineral and organic materials, draining water from trails, and onto artificial surfaces. In general, however, it must be borne in mind that first of all, the intensity of the factor causing the erosion must be removed or limited, and only then can steps be taken to restore or rehabilitate the soil and plant cover.

A great number of papers deal with the impact of hiking on the environment. Other forms of active tourism (for example cycling or cross-country skiing) are studied much less often. This is due mainly to the popularity of the respective forms of recreation in Poland. Cycling tourism has been developing only since the 1990s (with the first cycling trails being constructed around that time) and cross-country skiing, after many years of regression, has only recently begun to attract more tourists (and compared to hiking or downhill skiing, is still considered a niche activity). These relationships have an unambiguous effect on the scale of the transformations caused by these three types of tourism. As far as the selection of the research area is concerned, the highest Polish mountain formations – the Tatra Mountains, the massifs of Babia Góra and Pilsko, the Bieszczady Mountains and the Karkonosze (Giant) Mountains – are the most popular choices. Of particular interest is the first of the areas listed, in fact, the only area of Poland of a typical high-mountain form, occupying only 0.3 percent of its area, and simultaneously, a national park visited by the largest number of tourists (around 2.5 m people each year, i.e. approx. 30% of the total number of tourists visiting Polish national parks). This involves many negative effects on the precious local environment, a situation which has been noticed by Polish scientists and studied thoroughly. In other re-

gions, analyses are only fragmentary. Beyond Poland, the interest of Polish researchers lies primarily in the mountains of Slovakia, the Alps and the Massif Central, but the majority of texts on these mountain ranges focus on the effects of downhill skiing.

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