UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

Polish Journal of Natural Sciences

(4/2024) 39

PUBLISHER UWM
OLSZTYN 2024

The Polish Journal of Natural Sciences is indexed and abstracted
in Biological Abstracts and Biosis Previews

The print edition is the primary version of the Journal

The Journal is also available in electronic form on the websites
http://www.uwm.edu.pl/polish-journal/ (home page)
https://czasopisma.uwm.edu.pl/index.php/pjns/about (electronic platform; submissions)

PL ISSN 1643-9953

Publisher UWM Olsztyn
ul. Jana Heweliusza14
10-718 Olsztyn-Kortowo, Poland
tel.: +48 89 523-36-61
fax: +48 89 523-34-38
e-mail: wydawca@uwm.edu.pl

Edition 56 copies; publisher's sheets 7.4; number of printed sheets 6.0
Print Zakład Poligraficzny UWM w Olsztynie
order number 27

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Environmental Engineering

Humans and Environment

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(4): 203–215, Y. 2024

DOI: 10.31648/pjns.9512

EFFECT OF LIVEWEIGHT ON HAEMOLYMPH BIOCHEMICAL AND HORMONAL PROFILE OF GIANT AFRICAN LAND SNAIL (*ARCHACHATINA MARGINATA*) UNDER TROPICAL ENVIRONMENT

***Oluwatosin Olawanle Ajiboye*[1], *John Adesanya Abiona*[2], *Oyegunle Emmanuel Oke*[3], *Okanlawon Muhammed Onagbesan*[4]**

[1] ORCID: 0000-0001-6610-2382
[2] ORCID: 0000-0002-1159-8349
[3] ORCID: 0000-0002-9425-4217
[4] ORCID: 0000-0002-9019-8828
[1–4] Department of Animal Physiology, College of Animal Science & Livestock Production Federal University of Agriculture, Abeokuta, Nigeria

Key words: liveweight, biochemical parameters, *Archachatina marginata*, Giant African Land, snail, hormonal profile of haemolymph.

Abstract

Demand for giant African Land snail (*Archachatina marginata*) is on the increase in recent years, but not much is known about the health indicators of this animal under indoor or intensive rearing. The aim of the study was to determine the effect of liveweight on biochemical and physiological parameters of *Archachatina marginata* and to establish reference ranges for these parameters. Snails used were assigned to 3 groups of 20 snails each based on their liveweight. Haemolymph collected was analyzed for biochemical, hormonal and selected minerals. Result showed that the effect of liveweight was not significant ($P > 0.05$) for Total protein (TP), Triglyceride (Trig), Alanine transaminase (ALT) and Glucose (Glu). However, Liveweight had significant effect ($p < 0.05$) on Albumin (Alb), Aspartate transaminase (AST), Cholesterol (Chl) and Creatinine (Crt).

For hormonal profile, only T_4 was significantly influenced ($p < 0.05$) by liveweight, while effect of liveweight was not significant on Triiodothyronine (T_3), Follicle-stimulating hormone (FSH), Estradiol (E_2) and Progesterone (P_4). For haemolymph minerals, liveweight only had significant effect on Cu and Fe among others. Physiological profiles quantitatively recorded for each of liveweight groups by the the present standard protocols provide a reference basis to quantify physiological changes under different environmental conditions.

Address: John Adesanya Abiona, Federal University of Agriculture, Abeokuta, Nigeria, e-mail: abionaja@funaab.edu.ng

Introduction

Blood analysis has become imperative for a number of reasons. One of such is for the health analysis of an animal. Blood samples are routinely used in disease surveillance and diagnosis in companion animal, livestock and human populations, at times providing the first indication of health abnormalities (WILLARD et al. 1994, FELDMAN et al. 2000, STOCKHAM and SCOTT 2002). The haemolymph of several marine bivalve species is useful in the identification of pathogens and the evaluation of mussel condition (PAILLARD et al. 1996, ALLAM et al. 2000). The analysis of blood constituents has been used to evaluate physiological stress in numerous marine and terrestrial animals including fishes (MEKA and MCCORMICK 2005), crustaceans (UHLMANN et al. 2009), snails (RENWRANTZ and SPILVOGEL 2011), and freshwater crayfish (MALEV et al. 2010). Similar assessment strategies based on the non-lethal collection of haemolymph of freshwater bivalves have been used in study to conserve and protect endangered and declining populations (GUSTAFON et al. 2005a).

By using giant African land snails (GALS), several studies were carried out on their reproductive performance (ADIO 2010, ABIONA et al. 2012, ABIONA et al. 2016, ABIONA et al. 2018, ABIONA et al. 2021), nervous system structure (Adebayo 2011), and circulatory system structure (Salami 2010). Comparative studies have been done on the haemolymph of *A. marginata* and *A. achatina* (SODIPE 2011, ABIONA et al. 2013, ABIONA et al. 2014) and on the duration of aestivation on biochemical and biophysical parameters of *A. marginata* (ABDUSAMMAD 2010). All of these published works were conducted by lethal sample collection methods.

By means of lethal blood sampling, haemolymph was collected to study the effect of parasites, including trematodes and nematodes relevant to human health, on their snail hosts (BROCKELMAN 1975, 1978, BROCKELMAN and SITHITHAVORN 1980) or to investigate compounds of biomedical importance e.g. c-reactive protein (CRP) (AGRAWAL et al. 1990). Veterinary surgeons and others investigating disease in captive snails may also need to take blood samples as part of diagnosis (COOPER and KNOWLER 1991). However, lethal sampling of a small number of animals is unlikely to reveal statistically convincing health information (WOBESER 1994, DORAN et al. 2001).

The assessment strategies based on the nonlethal repeated collection of haemolymph from GALS need to be developed for physiological examination of these animals. GALS has been identified as a health risk in some parts of the western world. However, they remain a favored food resource in other parts such as the African and Asian continents. Recently, the increasing demand for GALS of *Archachatina marginata* as a food supply have intensified effort to enlarge local snail farming scales. However, the lack of sufficient knowledge on critical physiology necessary to boost their reproduction has been interfering with cultivating GALS successfully. Facts relating to health indicators are not well understood and are not readily available to farmers. Provision of relevant information in this area is seriously needed both at local and international levels to further improve farmer's earning and livelihood.

Understanding of GALS's haemolymph chemistry is a fundamental measure for the ultimate establishment of snail farming protocol. The aim of this study was to determine the effect of liveweight on the haemolymph biochemical and physiological parameters in three liveweight categories of *A. marginata* using non-lethal method of hemolymh collection (AJIBOYE 2021) and to develop a set of reference standards for the three weight categories considered.

Materials and Methods

Experimental design and management of animals

Sixty snails used for this study were sourced locally in Abeokuta, Ogun State, Nigeria. The snails were assigned to 3 groups of 20 snails each based on their liveweights (Treatment 1: 100–200 g, Treatment 2: 201–300 g, Treatment 3: 301–400 g) which may not be age related. The snails were acclimatized to laboratory environment before the commencement of haemolymph collection.

Haemolymph collection. Four milliliter (4 ml) of haemolymph was collected from the foot sinus using a 23 Gage needle and syringe. Haemolymph collected was thereafter analyzed to obotain biochemical profiles of hormons and selected minerals.

Haemolymph collection was carried out after cleaning the snails with sterile water. Detailed demonstration of haemolymph collection is shown in Figure 1 (AJIBOYE et al. 2022).

Biochemical analysis of Haemolymph. Total protein and albumin concentrations of each individual were determined using the biuret method described by HENRY et al. (1974). The glucose content was determined by the colorimetric method of BAUMNIGER (1974). The Triglycerides (Trig) and Cholesterol (Chl) assay were done following the method of GRANT (1987). Alanine transaminase (ALT), Aspartate transaminase (AST), and Creatinine were also determined by the methods described by BERGMEYER et al. (1985, 1986).

Fig. 1. Demonstration of haemolymph collection via the foot sinus with needle and syringe
Source: AJIBOYE et al. (2022)

Hormonal profile determination. Haemolymph concentrations of total trioiodothyronine (T_3) and tetraiodothyronine (T_4) as well as estradiol (E_2), progesterone (P_4) and follicle stimulating hormone (FSH) were determined quantitatively using commercial Bio-inteco ELISA kits after which results were read with ELX800 Elisa reader.

Selected haemolymph mineral determination. Selected haemolymph minerals like Zinc (Zn), Copper (Cu) and Iron (Fe) were determined spectrophotometrically by appropriate LABKIT.

Results

Effect of liveweight on haemolymph biochemical parameters of *A. marginata* is shown in Table 1. Liveweight had significant effect ($P < 0.05$) on the amounts of albumin, globulin, creatinine, cholesterol and aspartate aminotransferase. On the contrary, liveweight had no significant effect ($P > 0.05$) on those of total protein, glucose, alanine aminotransferase and triglyceride. Albumin concentration was found to be higher in both 100–200 g and 201–300 g liveweight group categories than in the 301–400 g group. The concentration of globulin was significantly higher in the 300–400 g group than in the 100–200 g and 201–300 g groups. The pattern seen in creatinine was similar to those observed in albumin, but with the exception that the group of snails under 100–200 g were not significantly different from the 301–400 g. For cholesterol, the 301–400 g group had higher significant value than the 100–200 g and 201–300 g groups. AST values were significantly higher in snails of the 100–200 g and 201–300 g groups than those of the 301–400 g group.

Table 1

Effect of liveweight group on haemolymph biochemical parameters of *Archachatina marginata*

LWG [g]	Haemolymph Biochemical Parameters (±SE)								
	TP [g/dl]	Alb [g/dl]	Glb [g/dl]	Glc [g/dl]	Crt [mg/dl]	Chl [mg/dl]	AST [U/L]	ALT [U/L]	Trig [mg/dl]
100–200	3.61 ±0.19	1.86 ±0.1^{a}	1.75 ±0.12^{b}	14.36 ±0.93	1.57 ±0.20^{ab}	22.11 ±1.16^{ab}	64.20 ±3.6^{a}	20.67 ±1.83	18.02 ±2.82
201–300	3.73 ±0.19	2.13 ±0.1^{a}	1.62 ±0.12^{b}	14.69 ±0.93	1.90 ±0.20^{a}	19.65 ±1.16^{b}	63.87 ±3.6^{a}	19.80 ±1.83	23.75 ±2.82
301–400	3.46 ±0.19	1.17 ±0.1^{b}	2.28 ±0.12^{a}	16.57 ±0.93	1.17 ±0.20^{b}	25.25 ±1.16^{a}	46.27 ±3.6^{b}	22.47 ±1.83	17.59 ±2.82

Explanations: ^{ab} means with different superscripts within the same column differ significantly ($p < 0.05$); TP – total protein; Alb – albumin; Glb – globulin; Glc – glucose; Crt – creatinine; Chl – cholesterol; ALT – alanine aminotransferase; AST – aspartate aminotransferase; Trig – triglyceride; LWG – liveweight group

Effect of liveweight on haemolymph hormonal profile of *A. marginata* is shown in Table 2. It was clear from this table that livewight had no significant effect ($P > 0.05$) on follicle stimulating hormone (FSH), trioiodothyronine (T_3), estradiol (E_2) and progesterone (T_4). However, the value for T_4 was higher in 301–400 g than 100–200 g and 201–300 g ($P < 0.05$).

Table 2

Effect of liveweight group on haemolymph hormonal profile of *Archachatina marginata*

LWG [g]	Haemolymph hormonal profile (±SE)				
	FSH [mlU/ml]	T_4 [μg/dl]	T_3 [μg/dl]	E_2 [pg/ml]	P_4 [ng/ml]
100–200	29.53 ±0.50	1.32 ±0.17^{b}	1.51 ±0.12	6.64 ±0.20	2.05 ±0.14
201–300	30.31 ±0.50	1.30 ±0.17^{b}	1.29 ±0.12	7.08 ±0.20	1.79 ±0.14
301–400	30.76 ±0.50	2.90 ±0.17^{a}	1.13 ±0.12	7.17 ±0.20	1.72 ±0.14

Explanations: ^{ab} means with different superscripts within the same column differ significantly ($P < 0.05$); FSH – follicle stimulating hormone; T_4 – tetraiodothyronine; T_3 – trioiodothyronine; E_2 – estradiol; P_4 – progesterone; LWG – liveweight group

Table 3 shows the effect of liveweight on the quantities of selected minerals in the haemolymph of *Archachatna marginata*. Liveweight had significant effect ($P < 0.05$) on copper (Cu) and iron (Fe). However, for zinc (Zn), effect of liveweight was not significant ($P > 0.05$).

Table 3

Effect of liveweight group on selected minerals in *Archachatina marginata*

LWG [g]	Minerals (±SE)		
	zinc (Zn) [μg/dl]	copper (Cu) [μg/dl]	iron (Fe) [μg/dl]
100–200	397.40 ±33.90	505.90 ±17.90^{a}	372.90 ±30.80^{a}
201–300	414.70 ±33.90	471.30 ±17.90^{a}	295.70 ±30.80^{ab}
301–400	320.40 ±33.90	302.10 ±17.90^{b}	204.40 ±30.80^{b}
Reference	300–450	250–480	204–380

Explanations: ^{ab} means with different superscripts within the same column differ significantly ($P < 0.05$); LWG – liveweight group

Discussion

Liveweight had no significant effect on haemolymph total protein. The results on protein concentration in the three size groups of *Indoplanorbis exustus* and *Lymnaea acuminate F. rufescens* showed an increasing trend in relation to size/age. Other factors such as parasitism, bacterial challenge and starvation are considered very important factors controlling total haemolymph protein in molluscs (REJU 1990). The level of serum protein in *B. glabrata* was found to increase when challenged with live bacterium (CHENG et al. 1978). Haemolymph protein and free amino acid concentrations in *B. glabrata* were found to change due to infection (DUSANIC and LEWERT 1963, GILBERTSON et al. 1967, LEE and CHENG (1972). By day 70 post-exposure to the parasite *Schistosoma mansoni*, the total protein content had declined to one third of that in uninifected snails (GRESS and CHENG 1973, MANOHAR and RAO 1977). BECKER and HIRTBACH (1975) reported decrease in haemolymph protein after seven days of starvation in *B. glabarata*.

In snails, it has been identified that the lipids are involved in the animal's survival under physiological stress conditions, such as long feed restriction or when snails are parasitized, when the carbohydrates reserve are quickly depleted and the lipids are consumed more frequently (STOREY 2002, GIOKAS et al. 2005, BANDSTRA et al. 2006). LUSTRINO et al. (2010) reported that triglyceride metabolism in *A. fulica* is more influenced by photoperiod variations. REJU (1990) reported significant variation in total lipid concentration among snails of different size groups in *P. virens*. Lipid level was found to be significantly higher in small size groups than in the intermediate and larger groups. Considering the intermediate and larger groups as adults and hence reproductively very active, he attributed the low values to the utilization of lipid during gametogenesis. GOMOT (1998) also reported a decrease in the lipid content of *H. pomatia, H. aspersa* and *H. aspersa maxima* with age. Lipids are the metabolic storage products for producing gametes (WEBBER 1970) hence gametogenesis leads to a decline in lipid storage content which is reflected as low haemolymph lipid level in adults. The high haemolymph lipid content in small size group snails may be an indication of large scale movement of lipid to gonads prior to gametogenesis (REJU 1990). NICOLAI et al (2012) reported difference in triglyceride concentrations between physiological states but not between geographical origins in the land snail *Helix aspersa*. Contrary to Reju's findings, the results of this study indicated that liveweight had no significant effect on the concentration of triglycerides in *A. marginata* snails. Differences in synthesis and utilization of lipids between species may be responsible for the results obtained. The physiological state of the snails used may also be responsible for the difference in results obtained.

Alanine aminotransferase concentration was not significantly affected by liveweight. Aspartate aminotransferase was, however, significantly affected. This result corroborates the statement by SWAMI and REDDY (1978), that the size of the animal is one of the factors affecting transaminase activity. There was no significant difference between AST concentrations between liveweight group 1 and 2 (100–200 g and 201–300 g) snails with the concentration being higher in the liveweight group 3 (301–400 g) snails. REJU (1990) reported a decline in AST and ALT activity with increase in body size. According to him, the decrease was more prominent in ALT. The author attributed the decline in the activity of these enzymes to the general decrease of metabolic rate and growth rate noted in gastropods along with increase in size or progress in age (HANIFFA 1980; ALDRIDGE 1982). In small size group snails, increased metabolic and assimilation rates require transaminase in high concentrations while with decrease in metabolic turnover, in large snails, the levels of transferases also show a declining trend (REJU 1990). Other factors affecting the transaminase activity such as difference in species, season, food, size of the animal, and assay procedures (SWAMI and REDDY 1978) may be responsible for the differences in results obtained for ALT in these snails.

Liveweight had no significant effect on haemolymph glucose concentration. This result is contrary to that of SURESH (1990). Suresh reported considerable variations in total carbohydrate and glycogen levels in the three size groups of both *I. exustus* and *L. acuminate, F. rufescens*. In both species, a general trend for increase in the concentrations of both total carbohydrate and glycogen was observed in relation to the size/age of the animals. In both species, the largest size group showed highly significant increase in glycogen and carbohydrate levels than the other two size groups. According to him, it may be considered that age/shell size is a factor which to a certain extent determines the level of both glycogen and total carbohydrate in *I. exustus* and *L. acuminata.* Haemolymph glucose concentration in *A. marginata* does not seem to be weight dependent as can be deduced from the results of this study. Numerous factors have been reported to alter the haemolymph glucose concentrations in gastropods. They include (a) blood sampling procedures and other experimental manipulations (SUBRAMANYAM 1973), (b) quality of food assimilated (MEENAKSHI and SCHEER 1968, FRIEDL 1971, SCHEERBOOM 1978, STANISLAWSKI and BECKER 1979), and (c) quantity of food (SCHEEERBOOM 1978), (d) seasonal changes; the changes are usually in response to changes in environmental temperature and food availability and are often linked to seasonal reproductive cycles, (e) aestivation, which is characterized by a drop in oxygen consumption and haemolymph reserve carbohydrate (SWAMI and REDDY 1978, HORNE 1979), (f) circadian flunctuations, for instance in the slug *L. alte*, the total carbohydrate of several tissues was the highest during the inactive light phase and lowest during the active dark phase (KUMAR et al. 1981) and [g] parasitism; decreased tissue carbohydrate levels and/or decreased blood glucose concentrations as a result of infection in molluscs have been observed in a number of cases (LEE and CHENG 1971, ROBSON and WILLIAMS 1971, CHRISTIE et al. 1974, VAIDYA 1979, MOHAMED and ISHAK 1981).

The presence of thyroid hormones was reported for the first time in *A. fulica* a land gastropod by LUSTRINO et al (2017). Thyroid hormones and their receptors have been well studied in vertebrates but less is known about the mechanisms by which they regulate the physiology and behavior in molluscs (LUSTRINO et al. 2017). The presence of TSH receptors and the evidence of endogenous synthesis of TSH have been shown in the freshwater gastropod *Lymnaea stagnalis* (TENSEN et al. 1994), the sea hare *Aplysia californica* (HEYLAND et al. 2006), Pacific Oyster, *Crassostrea gigas* (Huang et al. 2015). According to LUSTRINO et al (2017) only T_4 was found in *A. fulica* by Radioimmunoassay (RIA) analysis and its level declined after both starvation and deproteinisation. According to them, T_4 concentrations varied greatly among the animals used for the experiment. Also, no significant correlation was found between the biomass of the molluscs and T_4 concentration. In this study, liveweight had no significant effect on T_3. It, however, had significant effect on T_4 in the larger snails (301–400 g). There was no significant difference in the liveweight effect on the smaller snails (100–200 g, 201–300 g).

Liveweight had no significant effect on FSH, P_4 and E_2. According to OKHALE et al (2018), the mean concentrations of the hormones were found to be significantly influenced by the reproductive phases and aestivation of the snails. Di Cosmo et al. (2001), reported that progesterone levels flunctuate according to the reproductive cycle in molluscs being very low during the non-vitellogenic period and increasing at the onset of vitellogenesis. Okhale et al (2018) reported that FSH was relatively unaffected by aestivation treatments across reproductive phases. The author, however, reported that there was a trend of higher concentration of FSH at the dormancy and a decline in the pre-spawning and spawning phases and an eventual upsurge at the post-spawning phase. Environmental conditions affect reproductive function in live snails (Celik et al. 2019). Optimal temperature, humidity and photoperiod encourage breeding activity of *C. aspersum* (Jeppesen and Nygard 1976, Daguzan 1982). From the current result, it may be inferred that these snails used in their study were probably not in the reproductive phase.

Liveweight had significant effect on Cu and Fe concentrations but had no significant effect on Zn concentration. This finding is in agreement with Lukong et al. (2012). Lukong et al. 2012, investigated the effect of prolonged aestivation on the composition of the major elements (K, Na, Ca, Mg, Fe and Zn) and found that the concentration of Zn did not change significantly throughout the experimental procedure while concentrations of Fe showed significant changes.

Accepted for print 26.11.2024

References

Abdusammad A.M. 2010. *Effect of duration of aestivation on haemolymph biochemical and biophysical parameters of two liveweight groups of Archachatina marginata Swainson.* 1821. Veterinaria, 4(4): 400–408.

Abiona J.A., Abioja O.M., Ayo-Ajasa O.Y., Oyesanwen M.T., Ihongbe R.A., Mshelbwala F.M., Oke O.E., Onagbesan O.M. 2021. *Effect of common salt (NaCl) on reproductive tract, biochemical parameters of Giant African Land Snail (A. marginata) during dry season*. Aquaculture Reports, 20.100695.

Abiona J.A., Akinduti P.A., Osinowo O.A., Onagbesan O.M. 2013. *Comparative evaluation of inhibitory activity of epiphragm from albino and normal skinned Giant African Land Snail (A.marginata) against selected bacteria isolates*. Ethiopian Journal of Environmental Studies and Management, 6(2): 177–181.

Abiona J.A., Akinduti P.A., Oyekunle M.A., Osinowo O.A., Onagbesan O.M. 2014. *Comparative evaluation of haemagglutination potential of haemocytes from two species of Giant African Land Snails* (*Archachatina marginata and Achatina achatina*). Fish shellfish Immunology, 38(1): 96–100

Abiona J.A., Ojo O., Ladokun A.O., Abioja M.O., Daramola J.O., James I.J., Osinowo O.A., Onagbesan O.M. 2016. *Effect of Mucuna pruriens on the reproductive tract of Giant African Land Snail* (*Archachatina marginata*). Nigerian Journal of Animal Science, 18(2): 315–321.

Abiona J.A., Olaoye G.T., Abioja M.O., Onagbesan O.M. 2018. *Effect of Zinc oxide on liveweight, reproductive organ dimensions, spermatozoa production of A. marginata during dry season*. Agricultura Tropica et Subtropica, 51(4): 147–154.

Abiona J.A., Sokoya Y.F., Osinowo O.A., Ladokun A.O., Abioja M.O., Onagbesan O.M. 2012. *Effect of egg weight on hatching weight and incubation period in Giant African Land Snail* (*Archachatina marginata*). Nigerian Journal of Animal Science, 14: 181–187.

Adebayo M.O. 2011. *Comparative study of the nervous system of Giant African Land Snails* (*Archachatina marginata and Achatina achatina*). M. Agric. Thesis, Department of Animal Physiology, Federal University of Agriculture, Abeokuta.

Adio B.R. 2010. *Effects of induced humidity on liveweight changes, sizes of reproductive organs and egg laying of Archachatina marginata* during the dry season. M. Agric. Thesis, Department of Animal Physiology, Federal University of Agriculture, Abeokuta.

Agrawal A., Mitra S., Ghosh N., Bhattacharya S.1990. *C-reactive protein [CRP) in haemolymph of a mollusc, Achatina fulica Bowdich*. Indian Journal of Experimental Biology, 28: 78–89.

Ajiboye O.O., Abiona J.A., Onagbesan O.M., Durotoye V.L. 2022. *Effect of site of collection and liveweight on hemolymph volume and survival of Archachatina marginata*. Journal of Molluscan Research, 28: 97–106.

Aldridge S.A. 1982. *Drug induced sexual dysfunction*. Clinical Pharmacology, 2: 141–147.

Allam B., Paillard C., Howard A., Le Pennec M. 2000. *Isolation of the pathogen Vibrio tapetis and defense parameters in brown ring diseases Manila clams Ruditapes philippinarum cultivated in England*. Diseases of Aquatic Organisms, 41: 105–113.

Bandstra S.R., Fried B., Sherma J. 2006. *High-performance thin-chromatographic analysis of neutral lipids and phospholipids in Biomphalaria glabrata patently infected with Echinostoma caproni*. Parasitology Research, 99(4): 414–418.

Baumniger R.N. 1974. *Analytical Chemistry. Cambridge Press, London*, pp. 83–85.

Bergmeyer H.U., Horder M., Rej R. 1986. *Approved recommendation (1985) on IFCC methods for the measurement of catalytic concentration of enzymes. Part 3. IFCC Method for aspartate aminotransferase*. J. Clin. Chem. Clin. Biochem., 24: 481–489.

Bergmeyer H.U., Horder M., Rej R .1985. *Approved recommendation on IFCC methods for the measurement of catalytic concentration of enzymes. Part 3, IFCC Method for alanine aminotransferase*. J. Clin. Chem. Clin. Biochem., 33: 321–238.

Brockelman C.R. 1975. *Inhibition of Rhabditis maupasi* (Rhabditidae:nematoda), *maturation and reproduction by factors from the snail host, Helix aspersa.* Journal of Invertebrate Pathology, 25: 229–37.

Brockelman C.R., Sithithavorn P. 1980. *Carbohydrate reserves and haemolymph sugars of the African giant snail Achatina fulica in relation to parasitic infection and starvation*. Zeitschrift fUI Parasitenkunde, 62: 285–91.

Brockelman C.R. 1978. *Effects of parasitism and stresson haemolymph protein of the African giant snail ,Achatina fulica.* Zeitschrift fiir Parasitenkunde, 57: 137–44

Celik M.Y., Duman M.B., Surhpek M., Uzun Goren G., Kayaoturk D., Karayucel S. 2019. *Growth and Mortality rates of Cornu aspersum*: *organic snail culture, Black sea region*. Journal of Agricultural Science, 25:189–196.

Cheng T.C., Guida V.G., Gerhart P.L. 1978. *Aminopeptidase and lysozyme activity levels and serum protein concentrations in Biomphalaria glabrata* (*Mollusca*) *challenged with bacteria*. Journal of Invertebrate Pathology, 32: 297–302.

Christie J.D., Foster W.B., Stauber L.A. 1974. *The effect of parasitism and starvation on carbohydrate reserves of Biomphalaria glabrata*. Journal of Invertebrate Pathology, 23: 297–302.

Cook A. 1989. *Slugs and snails*. Biologist, 36: 183–8.

Cooper J.E., Knowler C. 1991. *Snails and snail farming: an introduction for the veterinary surgeon*. Veterinary Record, 129: 541–549.

Daguzan J. 1982. *Contribution á l'élevage de l'escargot Petit-gris Helix aspersa* Müller. 2. Ann. Zootech., 31(2): 87–110.

Di Cosmo A., Di Cristo C., Paolucci M. 2001. *Sex steroid hormone fluctuations and morphological changes of the reproductive system of the female of Octopus vulgaris throughout the annual cycle*. Journal of Experimental Zoology, 289: 33–47

DORAN W.J., COPE W.G., RADA R.G., SANDHEINRICH M.B. 2001. *Acetylcholinesterase inhibition in the ridge mussel* (*Amblema plicata*) *by* chlorpyrifos: *implications for biomonitoring*. Ecotoxicology and Environmental Safety, 49: 91–98.

DUSANIC, G.D. AND LEWERT, R.M. 1963. *Alterations of proteins and free aminoacids of Australorbis glabratus haemolymph after exposure to Schistosoma mansoni miracidia*. Journal of Infectious Diseases, 112: 243–246.

FELDMAN B.F., JINKL J.G., JAIN J.C. 2000. *Schalm's veterinary hematology, 5th edn*. Lippincott Williams and Wilkins, Philadelphia, PA.

FRIEDL F.E. 1971. *Haemolymph glucose in the freshwater pulmonate snail Lymnaea stagnalis Basal values and an effect of ingested carbohydrate*. Comparative Biochemistry and Physiology, A 39A: 605–610.

GILBERTSON D.E., ETGES F.J., OGLE J.D. 1967. *Free aminoacids of Australorbis haemolymph: Comparison of four geographic strains and effect of infection by Schistosoma mansoni*. Journal of Parasitology, 53: 565–568.

GIOKAS S., PAFILIS P., VALAKOS E. 2005. *Ecological and physiological adaptations of the land snail Albinaria caerulea* (Pulmonata: Clausiliidae). Journal of Molluscan Studies, 71(1): 15–23.

GOMOT A. 1998. *Biochemical composition of Helix snails: influence of genetic and physiological factors*. Journal of Molluscan Studies, 64: 173–181.

GRANT G.H. 1987. *Amino acids and protein: Fundamentals of clinical chemistry*. WB Sander Company, Philadelphia, U.S.A, pp. 326–329.

GRESS F.M., CHENG T.C. 1973. *Alterations in total serum proteins and protein fractions in Biomphalaria glabrata parasitized by Schistosoma mansoni*. Journal of Invertebrate Pathology, 22: 382–390.

GUSTAFON L.I., STOSKOPF M.K., BOGAN A.E., SHOWERS W., KWAK T.J., HANLON S. LEVINE J.F. 2005a. *Evaluation of a non-lethal technique for haemolymph collection in Elliptio complanata, a freshwater bivalve* (Mollusca: Unionidae) Diseases of Aquatic Organisms, 65: 159–165.

HANIFFA M.A. 1980. *Studies on life span, growth increments and energy budget of freshwater snail Pila globosa* (*Swainson*) *in an artificial pond*. Proceedings: Animal Sciences, 89(3): 275–286.

HENRY R.J., CANON D.C., WINKALMAN J.W. 1974. *Clinical Chemistry; Principle and Technique 2nd ed*, Harper and Row Pubishers, New York, pp 54–56.

HORNE F.B. 1979. *Comparative aspects of an aestivation metabolism in the gastropod, Marisa cornuarietis*. Comparative Biochemistry and Physiology, A 64A: 309–312.

JEPPESEN L.L., NYGARD K. 1976. *The influence of photoperiod, temperature and internal factors on the hibernation of Helix pomatia* L. (Gastropoda, Pulmonata). Vidensk Meddr Dansk Natuhr Foren, 139: 7–20.

KUMAR T.P., RAMAMURTHI R., BABU K.S. 1981. *Circadiae fluctuations in total protein and carbohydrate content in the slug Laevicaulis alte* (*Ferrussac*,1821). Biological Bulletin (Woods Hole, Mass). 160: 114–122.

LEE F.O., CHENG T.C. 1972. *Schistosoma mansoni infection in Biomphalaria glabrata*: *alterations total protein and hemoglobin concentration in the host's haemolymph*. Experimental Parasitology, 31: 203–216.

LUKONG C.B., EZEBUO F.C., VERLA A.W. 2012. *Characterization of the major essential elements in the Haemolymph of the Giant African Land Snail (Achatina achatina) During Aestivation*. Biosciences Biotechnology Research Asia, 9(2): 577–584.

LUSTRINO D., SILVA C.M., ARAUJO G.I., TUNHOLI V.M., TUNHOLI-ALVES V.M., CASTRO R.N., CARVALHO D.P., PINHEIRO J., MARASSI M.P. 2017. *Evidence of the presence of thyroid hormones in Achatina fulica Snails*. Annals of the Brazilian. Academy of Sciences 89(3): 2181–2188.

LUSTRINO D., TUNHOLI-AVES V.M., TUNHOLI V.M., MARASSI M.P., PINHEIRO J. 2010. *Lipids analysis in haemolymph of African Giant Achatina fulica* (*Bowdich*, 1822) *exposed to different photoperiods*. Brazilian Journal of Biology, 70(1): 129–134.

MALEV O., SRUT M., MAGUIRE I., STAMBUK A., FERRERO E.A, LORENZON S., KLOBUCAR G.I. 2010. *Genotoxic physiological and immunological effects caused by temperature increase, air exposure or food deprivation in fresh water crayfish Astacus leptodachylus*. Comparative Biochemistry and Physiology, Part C. Toxicology and Pharmacology, 152: 433–443.

MANOHAR L., RAO P.V. 1977. *Physiological response to parasitism, Part II. Gluconeogenic precursor levels and related enzyme activity profiles in the snail host.* Indian Journal of Experimental Biology, 15: 264–267.

MEENAKSHI V.R., SCHEER B.T. 1968. *Studies on the carbohydrates of the slug Ariolimax columbianis with special reference to their distribution in the reproductive system*. Comparative Biochemistry and Physiology, 26: 1091–1097.

MEKA J.M., MCCORMICK S.D. 2005. *Physiological responses of wild rainbow trout to angling: impact of angling duration, fish size, body condition and temperature*. Fisheries Research, 72: 311–322.

MOHAMED A.M., ISHAK M.M. 1981. *Growth rate and changes in tissue carbohydrates during schistosome infection of the snail Biomphalaria alexandrina*, Hydrobiologia, 76: 17–21.

NICOLAI A., FILSER J., LENZ R., BERTRAND C., CHARRIER M. 2012. *Quantitative Assessment of Haemolymph Metabolites in two physiological states and two populations of the land snail H. pomatia*. Physiological and Biochemical Zoology, 85(3): 274–284.

OKHALE O.E., OMOYAKHI O., TAIWO E., AREMU O.T. 2018. *Hormonal Concentration of Controlled and Naturally Induced Aestivated Snails (Archachatina marginata) at Different Reproductive Phases*. *Journal of Applied Life Sciences International*, 16(1): 1–9.

PAILLARD C., ASHTON-ALCOX K.A., FORD S.E. 1996. *Changes in bacterial densities and hemocyte parameters in eastern oysters*, *Crassostrea virginica*, *affected by juvenile oyster disease*. Aquatic Living Resources, 9:145–158.

REJU M.K. 1990. *Studies on haemolymph constituents of pila virens (Lamarck) and the effects of pesticides on the activity pattern of selected enzymes. PhD thesis*, Faculty of Environmental Studies, Cochin University of Science and Technology.

RENWRANTZ L., SPIELVOGEL F. 2011. *Heart rate and haemocyte number as stress indicators in disturbed hibernating vineyard snails*, *Helix pomatia*. Comparative Biochemistry and Physiology. Part A: Molecular and Integrative Physiology, 160: 467–473.

ROBSON E.M., WILLIAMS I.C. 1971. *Relationships of some species of digenea with the marine prosobranch Littorina littorea* (L.) Ill. *The effect of larval digenea on the glycogen content of the digestive gland and foot of L. littorea*. Journal of Helminthology, 45: 381–401.

SALAMI M.I. 2010. *Study of the Circulatory System and effect of aestivation on heart rate of Archachatina marginata, Swainson*1821 *at different liveweights*. M. Agric. Thesis, department of Animal Physiology, Federal University of Agriculture, Abeokuta.

SCHEERBOOM J.E.M. 1978. *The influence of food quantity and food quality on assimilation, body growth and egg production in the pond snail Lymnaea stagnalis* (*L.*) *with particular reference to the hernolymph – glucose concentration*. Koninklijke Nederlands Akademic van Wetenschappen. Series C 81: 184–197

SODIPE O.G. 2011. *Comparative study of the haemolymph of the Giant African Land Snail, Archachatina marginata*. PhD Thesis, Department of Animal Physiology, Federal University of Agriculture, Abeokuta.

STANISLAWSKI E., BECKER W., MULLER G. 1979. *Alterations of the free amino acid content in the haemolymph of Biomphalaria glabrata* (Pulmonata) *in starvation and after infection with Schistosoma mansoni* (Trematoda). Comparative Biochemistry and Physiology, B 63B: 477–482.

STOCKHAM S.L., SCOTT M.A. 2002. *Fundamentals of Veterinary Clinical Pathology*. Iowa State Press, Ames, IA.

STOREY K.B. 2002. *Life in the low lane: molecular mechanisms of estivation.* Comparative biochemistry and Physiology, A 133(3): 733–754.

SUBRAMANYAM O.V. 1973. *Neuroendocrine control of metabolism of a pulmonate snail.* Ariophanta sp. Experientia, 29: 1150–1151.

SURESH P.G., MOHANDAS A. 1990. *Studies on haemolymph constituents of indoplanorbis exustus (Deshayes) and Lymnaea acuminata* (Larmarck) rufescens (*gray) and the effects of copper on the activity pattern of selected transaminases and phosphatases*. PhD thesis. School of Environmental Studies, Cochin University of Technology, Cochin.

SWAMI K.S., REDDY Y.S. 1978. *Adaptive changes to survival during aestivation in the gastropod snail, Pila globosa.* Journal of Science and Industrial Research, 37: 144–157.

Tensen C.P., Van Kasteren E.R., Planta R.J., Cox K.J., Burke J.F., Van Heerikhuizen H., Vreugdenhil E. 1994. *A G protein coupled receptor with low-density lipoprotein-binding motifs suggests a role for lipoproteins in G-linked signal transduction.* Proceedings of the National Academy of Sciences, 91: 4816–4820.

Ajiboye O.O., Abiona J.A., Onagbesan O.M., Durotoye V.L. 2022. *Effect of site of collection and liveweight on hemolymph volume and survival of Archachatina marginata*. Journal of Molluscan Research, 28: 97–106.

Vaidya D.P. 1979. *The pathological effects of trematodes on the biochemical components of hepatopancreas and blood glucose of freshwater snail Indoplanorbis exustus Riv.* Parasitology, 40: 267–272.

Webber H.H. 1970. *Changes in metabolic composition during the reproductive cycle of the abalone Haliotis cracheroidii* (*Gastropod: Prosobranchiata*). Physiological Zoology, 43(3): 213–231.

Wobeser G.A.1994. *Investigation and management of disease in wild animals*. Plenum Press, New York.

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(4): 217–247, Y. 2024

DOI: 10.31648/pjns.10554

MARINE HARMFUL ALGAL BLOOMS (HABs) IN WORLD'S TOURIST REGIONS

Bożena Jaworska

ORCID: 0000-0001-8843-6391
University of Warmia and Mazury in Olsztyn
Department of Tourism, Recreation and Ecology

Key words: harmful algal bloom, HAB, hazard, tourist region.

Abstract

Harmful algal blooms (HABs) include toxic and non-toxic blooms of microalgae and macroalgae that are detrimental to aquatic ecosystems, have negative impacts on human health or socio-economic interests. All of these aspects are important for tourism and recreation related to marine areas, coastal waters, shorelines and coastal areas. They reduce the attractiveness of the regions in which they occur and can be a determinant of directional preferences for tourism activities. The aim of this study is to analyse the occurrence of typical HABs in tourist regions of the world, taking into account the taxa that cause them and the threats they pose. The analysis is based on a review of knowledge on the subject. It outlines the magnitude of the problems associated with the occurrence of HABs and demonstrates their relationship to the tourism sector. It also indicates the need for the tourism sector to obtain information on HABs in order to verify the availability of safe destinations for tourism.

Introduction

An algal bloom is a rapid mass growth of one or more species of organisms living in an aquatic environment, which can be generally referred to by the name algae (ASSMY and SMETACEK 2009, SMAYDA 1997). Algae are a morphological-ecological group that includes organisms that have similar environmental requirements but different origins and features of cell structure and form of morphological organization. They are photosynthesizing eukaryotic organisms from several unrelated evolutionary lineages, constituting a polyphyletic group that includes, both microscopic unicellular and multicellular organisms, and macroscopic organisms with a molluscan structure (BARSANTI and GUALTIERI 2014, CHAPMAN 2013). The microscopic algae that form blooms are mostly planktonic, less frequently

Address: Bożena Jaworska, University of Warmia and Mazury in Olsztyn, e-mail: bozena.jaworska@uwm.edu.pl

benthic forms. The large macroscopic algae are the so-called seaweeds. The term algal bloom refers, most often, to the massive growth of microscopic phytoplankton algae rather than the rapid growth of macroscopic seaweeds. Photosynthesizing cyanobacteria as prokaryotes are not scientifically classified as algae, but the common name blue-green algae is still used synonymously with cyanobacteria (Barsanti and Gualtieri 2014, Castenholz 1992), and the term algal bloom often includes cyanobacterial blooms (Smayda 1997).

Algal blooms are not a new event. In the aquatic environment, the bloom effect is a natural phenomenon resulting from ecological succession, which is becoming increasingly common due to increasing anthropogenic eutrophication of waters and global climate warming. Blooms are becoming more frequent, more widespread and long-lasting, and their effects are increasingly affecting aquatic ecosystems directly, terrestrial ecosystems indirectly, as well as the economy, including tourism, and causing increasing losses (Kudela et al. 2017).

The global problem of blooms has led to the adoption of a separate definition of so-called harmful algal blooms. Harmful algal bloom (HAB) is a term that refers to toxic and non-toxic blooms of microalgae and macroalgae that are harmful to aquatic ecosystems, have negative impacts on human health or socio-economic interests (Kudela et al. 2017). The term harmful algal blooms (HABs) was introduced decades ago and is now preferred to the term 'red tide' because it covers all those varieties of algal blooms that are potentially harmful, including cyanobacterial blooms as CyanoHABs (Smayda 1997).

HABs can be harmful in two different ways. The first way in which HABs are harmful is through their high biomass accumulation, which can have a negative impact on the aquatic environment and consequently cause disturbance to aquatic ecosystems. Most often already in the bloom stage, massive algal growth can change the colour of the water, depending on the dominant species. The smell of the water also depends on the type of algal bloom. Already these visual and olfactory aspects are an adverse effect of the occurrence of a bloom and are indicative of a deterioration in water quality. During the duration of the bloom and during the decomposition phase, hypoxia of the water masses (anoxia) occurs, which can cause mortality of many marine animal species and consequently lead to the loss of natural marine resources. High mortality of marine animals also leads to negative changes in the coastal zone, where dead animal organisms discarded on the shore decompose, as does the mass of algae, emitting an unpleasant odour and sometimes also toxic gases (ammonia, hydrogen sulfide) (Sellner et al. 2003). A second way in which HABs are harmful is through the production and release of toxic compounds into the environment, which affect a variety of organisms, from plankton to humans (BIAŁCZYK et al. 2009). These compounds can be the direct cause of mass death in marine animals or can cause disease and death when the animals that have accumulated them are consumed by consumers in the food web. Accumulation of these compounds in organisms feeding on phytoplankton can cause numerous poisonings also in humans consuming so-called 'seafood'. Human poisoning induced by marine toxins has been divided into different types depending on the effects caused. These are: paralytic shellfish poisoning – PSP (the causative poison is saxitoxins), neurotoxic shellfish poisoning – NSP (the causative poison is brevetoxins and macrocyclic imines), amnesic shellfish poisoning – ASP (the causative poison is domoic acid), diarrheic shellfish poisoning – DSP (the causative poison is okadaic acid), ciguatera fish poisoning – CFP (the causative poisons are ciguatoxin and maitotoxin), azaspiracid shellfish poisoning (AZP) (the causative poison is azaspiracid) (VAN DOLAH 2000). In addition to toxins that accumulate in organisms at lower trophic levels and are passed up the food chain to higher trophic levels, there is a large group of toxins that have a direct lethal effect on marine organisms. These are mostly lipophilic and ichthyotoxin in nature, but the mechanism of action of many of them is not yet fully understood (MICHALSKI 2006, VAN DOLAH 2000).

The growing interest in HABs includes, concerns about public health safety and negative impacts on marine ecosystems Addresses the risks associated with the harvesting of fish and seafood and the potential to exploit the potential of natural marine natural resources and their attractiveness. All these aspects of HABs impacts are of interest to tourism and recreation related to marine areas, coastal waters, shorelines and coastal areas.

Materials and Methods

The paper is a review. Research articles on marine harmful algal blooms of the HABs type were used as the material for analysis. The search for articles required for the state of the art review was conducted using the ISI Web of Knowledge and Google Scholar databases of scientific publications. From the records obtained, a selection method was used to select all those articles that were thematically relevant and could be used to analyse general trends in the occurrence of HABs and the algal species that cause them. The species names used in the article follow the current taxonomic nomenclature adopted by AlgaeBase and refer to an entity that is currently taxonomically accepted. The division of the world into tourism regions used is consistent with UN Tourism (formerly UNWTO).

Results and Discussion

Harmful algal blooms cover various sea coasts in all tourist regions of the world. They occur on the Atlantic, Pacific and Indian Ocean coasts. Although all coastal regions experience the impact of harmful algal species, different HAB species live in different waters and cause different problems. Of the approximately 5,000 known species of marine algae, about 300 can occur in very high numbers, causing water blooms (Zohdi and Abbaspour 2019). Each of these species needs a unique set of environmental conditions for dynamic mass growth forming HABs. Other factors that affect populations of bloom-forming algal species, such as coastal structure, hydrographic regimes, oceanography and other water-dwelling organisms, can alter the extent and severity of HAB impacts (Sellner et al. 2021).

Americas region

The tourist region of the Americas includes both North America and South America, as well as Central America lying in between, which geographically belongs to North America. Harmful algal blooms pertaining to the Americas region occur in the western Adriatic and eastern Pacific waters (Table 1).

Table 1

Species forming HABs typical of the American tourist region, their taxonomic category and main toxins

Phylum	Class	Species	Toxins
1	2	3	4
Americas region: north-east coasts of North America			
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen & D.M. Anderson 2017	TBD*
Dinoflagellata	Dinophyceae	*Karlodinium veneficum* (D. Ballantine) J. Larsen 2000	carlotoxins
Heterokontophyta	Pelagophyceae	*Aureococcus anophagefferens* Hargraves & Sieburth 1988	TBD*

cont. Table 1

1	2	3	4
Americas region: south-east coasts of North America			
Dinoflagellata	Dinophyceae	*Karenia brevis* (C.C. Davis) Gert Hansen & Moestrup 2000	brevetoxins
Dinoflagellata	Dinophyceae	*Pyrodinium bahamense* L. Płyta 1906	saxitoxins
Heterokontophyta	Bacillariophyceae	*Pseudo-nitzschia australis* Frenguelli 1939	domoic acids
Dinoflagellata	Dinophyceae	*Gambierdiscus toxicus* R. Adachi & Y. Fukuyo 1979	ciguatoxins
Dinoflagellata	Dinophyceae	*Dinophysis ovum* F. Schütt 1895	okadaic acids
Haptophyta	Coccolithophyceae	*Prymnesium parvum* N. Carter 1937	prymnesins
Americas region: Caribbean coasts and the east coast of Central America			
Dinoflagellata	Dinophyceae	*Gymnodinium catenatum* H.W. Graham 1943	saxitoxins
Dinoflagellata	Dinophyceae	*Pyrodinium bahamense* L. Płyta 1906	saxitoxins
Dinoflagellata	Dinophyceae	*Gambierdiscus toxicuss* R. Adachi & Y. Fukuyo 1979	ciguatoxins
Dinoflagellata	Dinophyceae	*Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen & D.M. Anderson 2017	TBD*
Heterokontophyta	Phaeophyceae	*Sargassum natans* (Linnaeus) Gaillon 1828	biomass
Heterokontophyta	Phaeophyceae	*Sargassum fluitans* (Børgesen) Børgesen 1914	biomass
Americas region: north-west coasts of North America			
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Gymnodinium catenatum* H.W. Graham 1943	saxitoxins
Dinoflagellata	Dinophyceae	*Pyrodinium bahamanse* L. Płyta 1906	saxitoxins
Americas region: south-west coasts of North America			
Heterokontophyta	Bacillariophyceae	*Pseudo-nitzschia australis* Frenguelli 1939	domoic acids
Dinoflagellata	Dinophyceae	*Lingulaulax polyedra* (F. Stein) M.J. Head, K.N. Mertens & R.A. Fensome 2024	yessotoxins
Dinoflagellata	Dinophyceae	*Margalefidinium fulvescens* (M. Iwataki, H. Kawami & Matsuoka) F. Gómez, Richlen & D.M. Anderson 2017	TBD*

cont. Table 1

1	2	3	4
Dinoflagellata	Dinophyceae	*Akashiwo sanguinea* (K. Hirasaka) Gert Hansen i Moestrup 2000	TBD*
Heterokontophyta	Raphidophyceae	*Chattonella subsalsa* B. Biecheler 1936	TBD*
Americas region: west coasts of Central America			
Dinoflagellata	Dinophyceae	*Pyrodinium bahamanse* L. Płyta 1906	saxitoxins
Americas region: north-east coast of South America			
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids
Dinoflagellata	Dinophyceae	*Gymnodinium catenatum* H.W. Graham 1943	saxitoxins
Americas region: south-east coasts of South America			
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids
Dinoflagellata	Dinophyceae	*Dinophysis tripos* Gourret 1883	okadaic acids
Dinoflagellata	Dinophyceae	*Alexandrium tamarense* (Lebour) Balech 1995.	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Prorocentrum lima* (Ehrenberg) F. Stein 1878	okadaic acids
Americas region: north-west coasts of South America			
Heterokontophyta	Raphidophyceae	*Heterosigma akashiwo* (Hada) Hada ex Y. Hara & Chihara 1987	TBD*
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids
Americas region: south-west coasts of South America			
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Heterokontophyta	Bacillariophyceae	*Pseudo-nitzschia australis* Frenguelli 1939	domoic acids
Heterokontophyta	Dictyochophyceae	*Pseudochattonella verruculosa* (Y. Hara & Chihara) S. Tanabe-Hosoi, D. Honda, S. Fukaya, Y. Inagaki & Y. Sako 2007	TBD*

* to be determined/decided/declared – toxins associated with the mechanism of lethal action on aquatic organisms are yet to be determined

In the western Atlantic, on the coasts of northeastern North America, harmful algal blooms (HABs) are most commonly caused (for 100 years) by *Alexandrium catenella*. This toxic thecate dinoflagellate produces saxitoxins that accumulate in shellfish and can cause paralytic shellfish poisoning in humans (PSP). It occurs along the east coast of Canada and the USA, from Maine to New Jersey (ANDERSON et al. 2021, MCKENZIE et al. 2021). Other HABs species causing problems in the region include *Margalefidinium polykrikoides*, *Karlodinium veneficum* and *Aureococcus anophagefferens*. The first two are athecate dinoflagellates and the third belongs to the heteroconta. They all generate toxins that affect marine organisms in different ways, in effect causing their death. This applies to both wildlife and aquaculture. These species also cause high biomass blooms that turn the water brown or red and reduce its visual and recreational value (ANDERSON et al. 2021). HABs occur on the south-eastern coasts of North America, which are most commonly formed by the dinoflagellates *Karenia brevis* and *Pyroidinium bahamense* and the diatom *Pseudo-nitzschia australis*. All three produce neurotoxins that accumulate in molluscs and crustaceans. Brevetoxins of *Karenia brevis* can cause neurotoxic shellfish poisoning in humans (NSP) Saxitoxins of *Pyroidinium bahamense* pose a risk of paralytic shellfish poisoning (PSP) in humans. Neurotoxins (domoic acid) produced, by *Pseudo-nitzschia australis*, can cause amnesic shellfish poisoning (ASP). For this reason, aquaculture areas affected by these algal blooms are being closely monitored and seafood harvesting from them may be halted to protect public health. Restrictions on shellfish farming due to these HABs are common in Florida coastal waters (ANDERSON et al. 2021). In addition, recreational harvesting of fish is prohibited in some Florida estuaries due to the potential for human ciguatera poisoning (CFP). Ciguatera fish poisoning (neurotoxins) is a concern in South Florida due to toxins produced by *Gambierdiscus toxicus*, a furry fish associated with macroalgae on coral reefs. Such blooms in July 2016 led to the destruction of many businesses and even the closure of some. Loss of revenue was reported by restaurants and hotels in South Florida (HEIL and MUNI-MORGAN 2021). Losses to tourism-related businesses due to *Karenia brevis* blooms in 2018 were estimated at $2.7 billion, meaning that HABs and their impact on tourism in the region could be considered a potential 'billion-dollar disaster' (ALVAREZ et al. 2024, BECHARD 2020). The Gulf of Mexico is experiencing blooms of *Karenia brevis*, as are the coasts of Florida, but also many other HABs. Shellfish farm closures have occurred in Texas due to *Dinophysis ovum* blooms, which can cause diarrhetic shellfish poisoning (DSP). The routes by which the toxins can enter the human body are mainly seafood. The overall economic impact of these HABs is difficult to determine, but in 2003 alone, more than US$ 6 million in profit from sport fishing and tourism was lost in Texas due to a bloom towards *Prymnesium parvum*, a haptophyte species that produces phycotoxins (prymnesins) that are lethal to fish (LUNDGREN et al. 2015).

HAB blooms also affect the waters of the Caribbean Sea and the coastal areas of the Caribbean islands, on the one hand, and the coasts of Central American countries, on the other. The most common HAB-forming species there are *Gymnodinium catenatum*, *Pyrodinium bahamense*, *Gambierdiscus toxicus* and, in recent years, *Margalefidinium polykrikoides*. Blooms of these and other algae are increasingly common there, causing mass mortality of fish and invertebrates and a major threat to food security in the region. Paralytic shellfish poisoning (PSP) caused by *Gymnodinium catenatum* and *Pyrodinium bahamense* blooms and ciguatera fish poisoning occurring as a result of *Gambierdiscus* blooms are also a problem (SUNESEN et al. 2021). However, the biggest problem for Caribbean coasts is macroalgal blooms. These are algae from the brown algae cluster mostly *Sargassum natans* and *Sargassum fluitans* species, reaching over a metre in length and highly branched. Representatives of *Sargassum* spp. occupy vast spaces in warm seas (SUMANDIARSA et al. 2021). Among others, they are found in the Sargasso Sea, where they provide food and breeding grounds for many species of fish, turtles and other juvenile marine life. Normally they occur in the open ocean, but for some time they have been accumulating in the coastal zone of Caribbean islands to form blooms. There, the huge concentrations of algae have a detrimental effect on the aquatic ecosystem, blocking light, depleting oxygen, altering habitats and causing the death of many species of aquatic organisms, stranded ashore they accumulate, up to 3 meters high. During the decomposition phase, they emit an unpleasant odour and toxic gases (hydrogen sulfide and ammonia). The gases emitted by *Sargassum* spp. can cause respiratory, skin and nervous system symptoms in both residents and tourists (ROBLEDO et al. 2021). Tourists are disillusioned with the aesthetics of Caribbean beaches and residents find it difficult to go to sea for work. *Sargassum* spp. blooms pose a serious threat to the local economies of HABs-affected countries, negatively impacting tourism, and approximately 70% of territories in the Caribbean region are financially dependent on tourism. Island societies are affected by HABs materially, financially and in terms of health (RESIERE et al. 2023).

In the eastern Pacific, along the northern part of the west coast of North America, from Alaska to California, blooms are usually formed by *Alexandrium catenella, Gymnodinium catenatum*, *Pyrodinium bahamanse* or other species of these genera. These are thecate dinoflagellates that produce neurotoxins (mainly saxitoxins) that accumulate in invertebrates and, over time, in fish and other vertebrates, leading to disease and death in a variety of marine organisms (McKenzie et al. 2021). They also cause economic losses. The coasts of Alaska and Georges Bank are ideal areas for crustaceans fishing, but they are often so contaminated by the presence of toxic algae that no fishing can take place there, due to the risk of paralytic shellfish poisoning (PSP) in humans. The largest shellfish shoal, George Bank, has been closed since 1989 due to the massive year-round presence of toxins in the water. Alaska's shellfish resources, estimated at $50 million per year, do not provide this economic benefit through HABs (Levitus et al. 2012). On the coasts of south-western North America (in southern California and Mexico), the cause of blooms is most often the massive growth of *Pseudo-nitzschia australis* (Ekstrom et al. 2020, Lewitus et al. 2012). The consequences of blooms can be disease and mortality of marine life and humans, as well as economically damaging fishery closures required to protect public health. These diatoms are toxic, produce, neurotoxins (domoic acid) and can cause amnesic shellfish poisoning (ASP) in humans. During this HAB in 2015, the detection of toxins in marine mammals – including whales, dolphins, porpoises, seals and sea lions – had the largest geographical coverage ever recorded. Accumulation of toxins in shellfish has resulted in fishery closures and failures in commercial crab farming, and recreational and local harvesting of shellfish has been banned. In coastal areas, blooms have prevented access to beaches for recreation and leisure, contributing to the loss of local tourism and recreation activities (Ekstrom et al. 2020). Along the coasts of south-western North America, *Lingulaulax polyedra* has also made massive appearances. A large bloom of this species occurred in the summer and autumn of 2005 and extended from San Diego to Ventura. *Lingulaulax polyedra* is a dinoflagellate that can produce a toxin called yessotoxin. Yessotoxins are a group of lipophilic toxins that are related to ciguatoxins, but their mode of action is different. These toxins bioaccumulate in the edible tissues of bivalves, thus allowing them to enter the food chain. In the region in question, HABs can also cause other dinoflagellates, most commonly and *Akashiwo sanguinea*, which in 2007 led to seabird deaths in Monterey Bay, California, caused by surfactant-like proteins produced by this alga (Levitus et al. 2012). However, on Mexico's Pacific coast in the Gulf of California, it was a bloom of *Chattonella subsalsa* belonging to the raphidophytes that caused the mass death of tuna in aquaculture. These harmful species produce toxins that interfere with oxygen transport, ultimately leading to suffocation. The effect of HABs has been linked to changes in oceanographic and atmospheric environmental conditions resulting from ENSO processes (García-Mendoza et al. 2018).

On the Pacific coasts of Central America, the most common HABs are formed by *Pyrodinium bahamense* (El Salvador, Costa Rica and Guatemala). In 2013, around 200 sea turtles died in El Salvador, poisoned by the saxitoxin produced by this dinoflagellate. The ecosystem losses were probably much greater. Paralytic poisoning (PSP) can also occur in humans after eating seafood or fish. In Nicaragua in 2005, a *Pyrodinium bahamense* bloom caused several dozen poisonings in humans (Cuellar-Martinez et al. 2018).

HABs blooms are also present on the coasts of South America, in both Atlantic and Pacific waters.

In the Atlantic Ocean, which borders the eastern part of the continent, the most common species of HABs are *Alexandrium catenella* and *Alexandrium tamarense*, *Gymnodinium catenatum* and the *Dinophysis acuminata* and *Dinophysis tripos* complex (Sunesen et al. 2021). Blooms of the harmful alga *Dinophysis acuminata*, are becoming recurrent on the northeast coast, where most marine shellfish farms are located. *Dinophysis acuminata* is causing major losses to shrimp and clam farms in Brazil there. It produces okadaic acid, which is accumulated by molluscs, especially bivalves (mussels, oysters, scallops, cockles). Toxic molluscs can cause diarrhetic poisoning in humans (DSP) (Simões et al. 2021). In the coastal waters of Brazil, there are also frequent blooms of *Gymnodinium catenatum*, which are responsible for paralytic shellfish poisoning (PSP) (Proença et al. 2001). The south-eastern coasts of South America also have blooms of *Dinophysis acuminata*, in addition, HABs are often caused by *Dinophystis tripos* and *Prorocentrum lima*, but their detrimental effects (DSP) are less severe in this part of the coast (Sastre et al. 2018). A much greater threat of HABs is caused by the mass occurrence of *Alexandrium tamarense* and *Alexandrium catenella.* In the Argentine Sea, blooms of this furball have led to fish and bird deaths, as well as human deaths from paralytic shellfish poisoning (PSP) (Fabro et al. 2017).

In the Pacific, on the northwestern coasts of South America, the most common HABs are caused by *Heterosigma akashiwo* and *Dinophysis acuminata* (Cuellar-Martinez et al. 2023). *Heterosigma akashiwo* is a raphidophyte that threatens marine organisms at all trophic levels, including fish. It causes high mortality in fish, whose cause of death is gill damage leading to hypoxia. However, the mechanism of action of *Heterosigma akashiwo* is not yet fully understood. Four different mechanisms of fish death are being investigated: mucus secretion, endogenous production of reactive oxygen species, toxin production and hemolytic activity (Allaf

2023). Threats from *Dinophysis acuminata* can include aquaculture losses as well as human diarrhetic poisoning (DSP). Other toxic types of microalgae found in the region include *Alexandrium*, *Pseudo-nitzschia*, and *Prorocentrum*. All pose a risk of human poisoning from ingestion of bivalves contaminated with phycotoxins causing PSP, ASP or DSP, respectively (Cuellar-Martinez et al. 2023). In south-western South America, on the Pacific coast, harmful blooms of toxin-producing microalgae are mainly *Alexandrium catenella*, *Pseudo-nitzschia australis* and *Dinophysis* spp. These species produce toxins that accumulate in molluscs or marine crustaceans and can cause serious human illnesses described as paralytic (PSP), amnesic (ASP) and diarrhetic (DSP) shellfish poisoning (Barría et al. 2022). They therefore threaten the sustainable exploitation of seafood in intensive aquaculture sites, which are abundant in the region. In 2016 in Chile, due to a severe HAB event caused by *Alexandrium catenella*, the loss of molluscs production was estimated at around US$ 30–40 million. But it was not the most common species that caused the greatest losses in Chilean aquaculture. In the same year, the HAB *Pseudochattonela verruculosa* caused an ichthyotoxic event causing massive mortality in salmon farming (more than 40 000 tones) and caused losses in excess of US$ 500 million (Díaz et al. 2019).

East Asia and Pacific region

The East Asia and Pacific tourist region comprises the Asian mainland countries on the west coast of the Pacific Ocean and the island countries in this part of the Pacific, including Australia. Harmful algal blooms pertaining to this region occur in the western Pacific (Table 2).

Table 2

Species forming HABs typical of the East Asia and Pacific tourism region, their taxonomic category and main toxins.

Phylum	Class	Species	Toxins
1	2	3	4
East Asia and Pacific region: north-east coasts of Asia			
Heterokontophyta	Raphidophyceae	*Heterosigma akashiwo* (Hada) Hada ex Y. Hara & Chihara 1987	TBD*
Heterokontophyta	Raphidophyceae	*Chattonella marina* (Subrahmanyan) Y. Hara i Chihara 1982	TBD*
Dinoflagellata	Dinophyceae	*Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen & D.M. Anderson 2017	TBD*

cont. Table 2

1	2	3	4
Dinoflagellata	Dinophyceae	*Karenia mikimotoi* (Miyake & Kominami ex Oda) Gert Hansen & Moestrup 2000	gymnocins
Dinoflagellata	Noctilucophyceae	*Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921	TBD*
Haptophyta	Coccolithophyceae	*Phaeocystis globosa* Scherffel 1899	TBD*
Chlorophyta	Ulvophyceae	Ulva prolifera O.F. Müller 1778	biomass
East Asia and Pacific region: south-east coasts of Asia			
Dinoflagellata	Dinophyceae	*Pyrodinium bahamense* L. Płyta 1906	saxitoxins
Dinoflagellata	Dinophyceae	*Gymnodinium catenatum* H.W. Graham 1943	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium tamarense* (Lebour) Balech 1995.	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium tamiyavanichii* Balech 1994	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium ostenfeldii* (Paulsen) Balech & Tangen 1985	saxitoxins
Dinoflagellata	Noctilucophyceae	*Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921	TBD*
Dinoflagellata	Dinophyceae	*Gambierdiscus toxicus* R. Adachi & Y. Fukuyo 1979	ciguatoxins
East Asia and Pacific region: coasts of Australia			
Dinoflagellata	Dinophyceae	*Karlodinium veneficum* (D. Ballantine) J. Larsen 2000	carlotoxins
Dinoflagellata	Dinophyceae	*Karenia mikimotoi* (Miyake & Kominami ex Oda) Gert Hansen & Moestrup 2000	gymnocins
Haptophyta	Coccolithophyceae	*Prymnesium parvum* N. Carter 1937	prymnesins
Heterokontophyta	Coscinodiscophyceae	*Rhizosolenia chunii* Karsten 1905	TBD*
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium minutum* Halim 1960	saxitoxins
Dinoflagellata	Dinophyceae	*Gymnodiniu catenatum* H.W. Graham 1943	saxitoxins
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids

cont. Table 2

1	2	3	4
Dinoflagellata	Dinophyceae	*Dinophysis fortii* Pavillard 1924	okadaic acids
Cyanobacteria	Cyanophyceae	*Nodularia spumigena* Mertens ex Bornet & Flahault 1888	nodularins

* to be determined/decided/declared – toxins associated with the mechanism of lethal action on aquatic organisms are yet to be determined

The coasts of north-east Asia are an extensive zone of the north-west Pacific Ocean. In this region, raphidophyte blooms occur along Asian coasts, most commonly of the genera *Chattonella marina* and *Heterosigma akashiwo* as on the north-west coast of the Japanese islands. In the south-western coastal waters of Japan and off the coast of Korea, HABs cause *Margalefidinium polykrikoides* and *Karenia mikimotoi*. This is an athecate dinoflagellate that, unlike other species of the genus *Karenia*, does not produce brevetoxin, which is highly toxic to humans and marine fauna (BRAND et al. 2012). However, blooms of this species cause massive mortality of marine fauna. This is due to haemolytic and cytotoxic effects, but the mechanism of toxicity to marine organisms is not fully understood. (LI et al. 2019). *Margalefidinium polykrikoides* has similar effects, producing reactive oxygen species that are lethal to pelagic fish as well as echinoderm and crustacean molluscs, even at low concentrations. In 1995, it formed a huge bloom along the southern coast of Korea, causing severe economic losses to aquaculture estimated at around US$70 million (SAKAMOTO et al. 2021). In the waters off the east coast of China, *Karenia mikimotoi* is also the main cause of massive fish mortality, in addition to *Heterosigma akashiwo* and *Chattonella* spp. In 2012, a massive bloom of *Karenia mikimotoi* along China's coast, caused massive mortality of farmed seafood, causing economic losses of approximately US$ 300 million (SAKAMOTO et al. 2021). Toxic phytoplankton, responsible for poisoning crustaceans, molluscs and fish in aquaculture and beyond, can cause poisoning in humans (CORRALES and MACLEAN 1995). However, meticulous monitoring of farming means that fatal human poisoning cases from the consumption of commercially available seafood have become rare, although contamination of bivalves with paralytic toxins (PST) and diarrhetic toxins (DST) and the resulting trade restrictions are common (SAKAMOTO et al. 2021). In addition to the typically toxic HABs, algal blooms that are harmful due to the large biomass of the bloom are also common on the East Asian coast. These are the HABs *Noctiluca scintillans* and *Phaeocystis globosa*. Although *Noctiluca scintillans* is a species of dinoflagellate athecate that does not produce toxins that can kill marine organisms or threaten human health, massive blooms of this species have negative environmental impacts and can cause losses to aquaculture probably due to increased ammonia concentrations or low oxygen content during the degradation phase of the bloom (Xiaodong et al. 2023). *Phaeocystis globosa* belongs to the primnesiophytes and has the ability to form floating gelatinous colonies that can increase in size during blooms and, at the disappearance of the bloom, form bad-smelling clusters of algae and foam on beaches. This has a negative impact on coastal tourism. This effect can also have a negative impact on higher trophic levels in the marine ecosystem. *Phaeocystis globosa* blooms also cause massive mortality of aquacultured animals (Wang et al. 2021). Massive macroalgal blooms also occur in the same area (Yellow Sea). In the summer of 2008, the world's largest *Ulva prolifera* bloom took place here, and every year since then, this HAB covers an area of thousands of square kilometers and lasts for an average of 90 days, with significant inter-annual variability (Qi et al. 2016).

On the coasts of south-estern Asia (Philippines, Malaysia), common species forming HABs include *Pyrodinium bahamense*, *Gymnodinium catenatum* and *Alexandrium* spp. (*A. tamrense*, *A. catenella*, *A. tamiyavanichii*, *A. ostenfeldii*) (Azanza et al. 2024). The most common HABs are *Pyrodinium bahamense var. compressum* (*Pyrodinium bahamanse var. bahamense* occurs in the Central American and Caribbean region) (Usup et al. 2012). These are dinoflagellates that produce paralytic toxins (saxitoxins) that accumulate in marine crustaceans, as do *Gymnodinium* and *Alexandrium* species. By this, *Pyrodinium*, *Gymnodinium* and *Alexandrium* are the main cause of seafood toxicity and poisoning occurring in humans after consumption. Species causing paralytic shellfish poisoning (PSP) occur in the coastal waters of the Philippines and Malaysia annually at varying scales (Azanza et al. 2024). Bioaccumulation of toxins occurring at higher trophic levels, in marine mammals, birds and fish, can lead to massive mortality of these animals and contaminate beaches reducing the attractiveness of coastal areas for tourism. *Pyrodinium bahamense* is nevertheless seen as a tourist attraction, as it has the ability to bioluminesce and causes the water to glow spectacularly during a bloom (Usup et al. 2012). *Pyrodinium bahamense var. compressum* also forms blooms regularly in the Indonesian region, causing many negative impacts on fisheries, the aquatic environment and human health, including tourists. However, long-lasting HABs caused by *Chaetoceros* spp., *Noctiluca* spp. and *Skeletonema* spp. are most common in this region. Their harm lies primarily in the production of large biomass and the potential for hypoxia in coastal waters, resulting in the extinction of fish and marine invertebrates and damage to coral reefs (Sidabutar et al. 2024, Sidharta 2005). These blooms thus have a very negative impact on coastal tourism in the Indonesian region. Dangerous HABs in the region of both Indonesia and Malaysia and the Philippines are *Gambierdiscus toxicus* blooms, that have expanded their geographical range into the region. *Gambierdiscus* spp. produce ciguatoxins that accumulate in the muscles of some marine fish species. Ciguatoxins are a group of dangerous neurotoxins that cause ciguatera poisoning. The global spread of fish ciguatera poisoning (CFP) has meant that *Gambierdiscus* spp. and its toxins are considered a problem for the environment and human health worldwide. It is estimated that between 50,000 and 200,000 people worldwide contract CFP each year (Wang et al. 2022).

In Australia's coastal waters, HABs are formed by a variety of algal species whose mass growth varies in intensity, frequency and distribution. Their harmful effects also vary. High mortality of wild and farmed fish is associated with blooms of the dinoflagellates *Karlodinium veneficum* and *Karenia mikimotoi* and the haptophyte *Prymnesium parvum*. These species are capable of producing ichthyotoxic substances that have a pathological effect on the gills of fish, resulting in massive mortality (Hallegraeff 1992). Other HABs species found in the region are the diatom *Rhizosolenia chunii*, the dinoflagellates *Alexandrium catenella*, *Alexandrium minutum* and *Gymnodinium catenatum*. They all produce neurotoxins that accumulate in molluscs or crustaceans and can cause paralytic shellfish poisoning (PSP) (Parry et al. 1989). Less common are the HABs dinoflagellates *Dinophysis acuminata* and *Dinophysis fortii*, but their occurrence is associated with the risk of diarrhetic shellfish poisoning (DSP). On Australian coasts, blooms are also formed by *Gambierdiscus* spp. They are most abundant on the east coast, in the Great Barrier Reef region, and are the cause of frequent ciguatera fish poisoning (Kretzschmar et al. 2019). Poisoning of cattle and wildlife or contamination of drinking water supplies by blue-green toxins of the brackish water alga *Nodularia spumigena* is also a growing concern (Hallegraeff 1992). Australia's 2019 and 2020 wildfires also contributed to the magnification of blooms. Carried by wind over the Pacific, smoke and ash fertilized its waters, providing nutrients for algal blooms on a scale not seen in the region.

Middle East and South Asia region

The tourist region of the Middle East and South Asia comprises the western and southern parts of Asia located on the northern coast of the Indian Ocean. The blooms in the South Asian and Middle East coastal region are determined by the nature of the Indian Ocean waters (Table 3).

Table 3

Species forming HABs typical of the Middle East and South Asia tourism region, their taxonomic category and main toxins

Phylum	Class	Species	Toxins
Middle East and South Asia region: coasts of southern Asia			
Dinoflagellata	Noctilucophyceae	*Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921	TBD*
Cyanobacteria	Cyanophyceae	*Trichodesmium erythraeum* Ehrenberg ex Gomont 1892	TBD*
Cyanobacteria	Cyanophyceae	*Trichodesmium thiebautii* Gomont 1890	TBD*
Dinoflagellata	Dinophyceae	*Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen & D.M. Anderson 2017	TBD*
Dinoflagellata	Dinophyceae	*Karenia brevis* (C.C. Davis) Gert Hansen & Moestrup 2000	brevetoxins
Dinoflagellata	Dinophyceae	*Karenia mikimotoi* (Miyake & Kominami ex Oda) Gert Hansen & Moestrup 2000	gymnocins
Heterokontophyta	Raphidophyceae	*Chattonella marina* (Subrahmanyan) Y. Hara i Chihara 1982	TBD*
Middle East and South Asia region: coasts of the Middle East			
Dinoflagellata	Dinophyceae	*Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen i D.M. Anderson 2017	TBD*
Dinoflagellata	Dinophyceae	*Gonyaulax polygramma* F. Stein 1883	TBD*
Dinoflagellata	Dinophyceae	*Prorocentrum lima* (Ehrenberg) F. Stein 1878	okadaic acids
Dinoflagellata	Noctilucophyceae	*Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921	TBD*

* to be determined/decided/declared – toxins associated with the mechanism of lethal action on aquatic organisms are yet to be determined

In the South Asian region, along the west and east coasts of India and Pakistan, blooms are most commonly formed by the species *Noctiluca scintillans* and *Trichodesmium erythraeum* and *Trichodesmium thiebautii* (D'SILVA et al. 2012). *Noctiluca scintillans* is a translucent athecate dinoflagellate and can occur in green or red form. The species has the capacity for bioluminescence occurring when the cell is irritated and its blooms cause a glowing effect in the water. It is one of the tourist attractions in the Maldives. *Noctiluca scintillans* do not produce toxins, but are considered harmful to the marine environment. They can cause high mortality of fish and invertebrates due to ammonia accumulation and depletion of the oxygen in the water (GOMES et al. 2014). *Trichodesmium erythraeum* and

Trichodesmium thiebautii are species of filamentous cyanobacteria found in colonies named 'sea sawdust'. *Trichodesmium* is the only known diazotroph capable of fixing nitrogen in daylight under aerobic conditions without the use of heterocysts and accounts for almost half of nitrogen fixation in marine systems worldwide (Bergman et al. 2012). *Trichodesmium* spp. blooms typically last for a very long time causing reduced oxygen availability during bloom die-off, which can lead to the death of marine organisms (Padmakumar et al. 2010). However, massive fish mortality in Indian coastal waters has been linked more to blooms of *Margalefidinium polykrikoides*, *Karenia brevis*, *Karenia mikimotoi*, *Chattonella marina*, although blooms of these algae occur less frequently (D'Silva et al. 2012).

In the Middle East region, green *Noctiluca scintillans* and other dinoflagellates such as *Margalefidinium polykrikoides*, *Gonyaulax polygramma* and *Prorocentrum lima* have become the dominant HABs, partly replacing the previously dominant diatoms and red *Noctiluca scintillans* (Harrison et al. 2017). *Margalefidinium polykrikoides* is a species that can produce allelopathic chemicals that inhibit the growth of other phytoplankton taxa in the water depths, and can also produce reactive oxygen species that are lethal to pelagic fish as well as molluscs and crustaceans, even at low concentrations. *Margalefidinium polykrikoides* blooms are responsible for the majority of fish deaths in the Arabian Sea, although it is *Noctiluca scintillans* that causes about 50% of HABs events in the region. In late 2008–2009 (November–February) in the Gulf of Oman in the Arabian Sea, a massive bloom of *Margalefidinium polykrikoides* occurred, causing massive fish die-offs, damage to coral reefs and disruption to seawater desalination plants (Harrison et al. 2017). In the Gulf, the long-term occurrence of HABs *Margalefidinium polykrikoides* has led to massive economic, environmental and social damage (Esmaeili et al. 2021). The toxic *Gonyaulax polygramma*, whose blooms are becoming more frequent, is also becoming dangerous to the marine environment in the region (Dias et al. 2023). A characteristic species forming blooms in the Red Sea is *Trichodesmium* spp. It causes the red colouration of the water during a bloom and is responsible for the name of this sea. *Trichodesmium* spp. blooms have also started to appear in the eastern Mediterranean, along the coasts of Middle Eastern countries (Spatharis et al. 2012).

Africa region

Africa's coasts are also visited by species that cause harmful algal blooms, both on the east and west coasts of the continent, in the waters of the eastern Atlantic and western Indian Ocean (Table 4).

Table 4

Species forming HABs typical of the Africa tourism region, their taxonomic category and main toxins

Phylum	Class	Species	Toxins
Africa region: north-east coasts of Africa			
Heterokontophyta	Bacillariophyceae	*Pseudo-nitzschia pungens* (Grunow ex Cleve) Hasle 1993	domoic acids
Dinoflagellata	Dinophyceae	*Blixaea quinquecornis* (T.H. Abé) Gottschling 2017	TBD*
Dinoflagellata	Dinophyceae	*Alexandrium affine* (H. Inoue & Y. Fukuyo) Balech 1995	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium leei* Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium tamarense* (Lebour) Balech 1995	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium tamiyavanichii* Balech 1994	saxitoxins
Dinoflagellata	Noctilucophyceae	*Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921	TBD*
Cyanobacteria	Cyanophyceae	*Trichodesmium erythraeum* Ehrenberg ex Gomont 1892	TBD*
Africa region: south-east coasts of Africa			
Dinoflagellata	Dinophyceae	*Amphidinium carterae* Hulburt 1957	ciguatoxins
Dinoflagellata	Dinophyceae	*Gambierdiscus toxicus* R. Adachi & Y. Fukuyo 1979	ciguatoxins
Dinoflagellata	Dinophyceae	*Prorocentrum lima* (Ehrenberg) F. Stein 1878	okadaic acids
Dinoflagellata	Dinophyceae	*Ostreopsis ovata* Y. Fukuyo 1981	palytoxins
Africa region: south-west coasts of Africa			
Dinoflagellata	Dinophyceae	*Lingulaulax polyedra* (F. Stein) M.J. Head, K.N. Mertens & R.A. Fensome 2024	yessotoxins
Dinoflagellata	Dinophyceae	*Gonyaulax spinifera* (Claparède & Lachmann) Diesing 1866	yessotoxins
Dinoflagellata	Dinophyceae	*Prorocentrum lima* (Ehrenberg) F. Stein 1878	okadaic acids
Africa region: north-west coasts of Africa			
Dinoflagellata	Dinophyceae	*Dinophysis caudata* Kent 1881	okadaic acids
Dinoflagellata	Dinophyceae	*Dinophysis ovum* F. Schütt 1895	okadaic acids
Dinoflagellata	Dinophyceae	*Ostreopsis ovata* Y. Fukuyo 1981	palytoxins

* to be determined/decided/declared – toxins associated with the mechanism of lethal action on aquatic organisms are yet to be determined

On the eastern coasts of Africa (western Indian Ocean), HABs *Pseudo-nitzschia pungens*, *Blixaea quinquecornis* and *Alexandrium* spp. (*A. affine, A. leci, A. tamarense, A tamiyawanichii*) are found (Hansen et al. 2001). They can cause toxin accumulation in shellfish or marine molluscs and transmission to humans in the form of ASP or PSP poisoning. Mass occurrences of the athecate dinoflagellate *Noctiluca scintillans* and the cyanobacteria *Trichodesmium erythraeum* also occur there, but do not have a major impact on the economy and tourism in the region (Kiteresi et al. 2013). On the coasts of Madagascar and the Mascarene (Mauritus) archipelago, blooms of *Amphidinium carterae*, *Gambierdiscus toxicus*, *Prorocentrum lima* and *Ostreopsis ovata* occur and other species of these algal genera (Hansen et al. 2001). In southern Africa, dinoflagellate blooms of the genera *Gonyaulax*, *Lingulaulax*, *Prorocentrum*, *Protoceratium* and *Tripos* cause massive anoxia-induced mortality of marine organisms during the disappearance of the bloom.

The HAB species most commonly found in the south-west coastal region of Africa (eastern Atlantic) are *Lingulaulax polyedra* and *Gonyaulax spinifera* (Pitcher and Calder 2000). Both species belong to the dinoflagellates. *Lingulaulax polyedra* and *Gonyaulax spinifera* have heavily pigmented cells which, when present in mass numbers, gives the impression of staining the water various shades of red. Additionally, *Lingulaulax polyedra* has the ability to bioluminesce. Both species can also produce toxins from the yessotoxin group. These toxins bioaccumulate in the edible tissues of marine molluscs thus allowing the toxins to enter the food chain. These compounds become toxic to humans if concentrated in the food chain in large quantities. They also cause losses in aquaculture, such as on the south-west coast of Africa, where they caused the death of more than 250 tonnes of edible sea snails known as sea lugs, with an estimated value of US$ 33 million (Stephen and Hockey 2007). HABs caused by *Dinophysis caudata* and *Dinophysis ovum* and species of the genus *Alexandrium* also occur on the north-west coast of Africa (Akin-Oriola et al. 2006). HABs of *Ostreopsis ovata* also occur in this region (Morocco). They can reduce the oxygen concentration in the water and clog the gills of filter-feeding organisms. Some of these dinoflagellates contain toxic chemicals stored by the animals that eat them, which can threaten public health and cause economic damage to fisheries (Alkhatib et al. 2022). Coastal countries in the northern African region have blooms characteristic of the Mediterranean (Tsikoti and Genitsaris 2021).

Europe region

HABs events also occur in the oceanic and marine coastal area of the European region. These include the eastern Atlantic coasts and inland seas (Table 5).

Table 5

Species forming HABs typical of the European tourist region, their taxonomic category and main toxins

Phylum	Class	Species	Toxins
1	2	3	4
Europe region: southern coasts of Europe			
Dinoflagellata	Dinophyceae	*Alexandrium mediterraneum* U. John 2014	saxitoxins
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède i Lachmann 1859	okadaic acids
Dinoflagellata	Dinophyceae	*Ostreopsis ovata* Y. Fukuyo 1981	palytoxins
Heterokontophyta	Bacillariophyceae	*Pseudo-nitzschia calliantha* Lundholm, Moestrup & Hasle 2003	domoic acids
Dinoflagellata	Dinophyceae	*Gambierdiscus australes* Chinain & M.A. Faust 1999	ciguatoxins
Dinoflagellata	Dinophyceae	*Fukuyoa paulensis* F. Gómez, D.J. Qiu, R.M. Lopes & Senjie Lin 2015	ciguatoxins
Dinoflagellata	Dinophyceae	*Vulcanodinium rugosum* Nézan i Chomérat 2011	pinnatoxins
Dinoflagellata	Dinophyceae	*Azadinium poporum* Tillmann & Elbrächter 2011	azaspiracids
Europe region: south-east coasts of Europe			
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids
Dinoflagellata	Dinophyceae	*Dinophysis acuta* Ehrenberg 1839	okadaic acids
Dinoflagellata	Dinophyceae	*Ostreopsis ovata* Y. Fukuyo 1981	palytoxins
Dinoflagellata	Dinophyceae	*Lingulaulax polyedra* (F. Stein) M.J. Head, K.N. Mertens & R.A. Fensome 2024	yessotoxins
Dinoflagellata	Dinophyceae	*Alexandrium minutum* Halim 1960	saxitoxins
Dinoflagellata	Dinophyceae	*Gymnodinium catenatum* H.W. Graham 1943	saxitoxins
Dinoflagellata	Dinophyceae	*Pseudo-nitzschia australis* Frenguelli 1939	domoic acids

cont. Table 5

1	2	3	4
Dinoflagellata	Dinophyceae	*Azadinium spinosum* Elbrächter & Tillmann 2009	azaspiracids
Dinoflagellata	Dinophyceae	*Karenia mikimotoi* (Miyake & Kominami ex Oda) Gert Hansen & Moestrup 2000	gymnocins
Heterokontophyta	Raphidophyceae	*Heterosigma akashiwo* (Hada) Hada ex Y. Hara & Chihara 1987	TBD*
Cyanobacteria	Cyanophyceae	*Nodularia spumigena* Mertens ex Bornet & Flahault 1888	nodularins
Europe region: north-east coasts of Europe			
Haptophyta	Coccolithophyceae	*Prymnesium polylepis* (Manton & Parke) Edvardsen, Eikrem & Probert 2011	prymnesins
Haptophyta	Coccolithophyceae	*Chrysochromulina leadbeateri* Estep, Davis, Hargreaves & Sieburth 1984	TBD*
Dinoflagellata	Dinophyceae	*Dinophysis acuminata* Claparède & Lachmann 1859	okadaic acids
Dinoflagellata	Dinophyceae	*Prorocentrum lima* (Ehrenberg) F. Stein 1878	okadaic acids
Dinoflagellata	Dinophyceae	*Azadinium spinosum* Elbrächter & Tillmann 2009	azaspiracids
Dinoflagellata	Dinophyceae	*Alexandrium catenella* (Whedon & Kofoid) Balech 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium ostenfeldii* (Paulsen) Balech & Tangen 1985	saxitoxins
Dinoflagellata	Dinophyceae	*Alexandrium minutum* Halim 1960	saxitoxins
Europe region: north-west coast of Europe (Russia)			
Dinoflagellata	Dinophyceae	*Alexandrium tamarense* (Lebour) Balech 1995	saxitoxins

* to be determined/decided/declared – toxins associated with the mechanism of lethal action on aquatic organisms are yet to be determined

The marine coast of southern Europe is the Mediterranean Sea, whose waters border the tourist region of Africa and the Middle East. The main algal taxa responsible for the algal blooms in the Mediterranean Sea are the dinoflagellates, *Alexandrium mediterraneum*, *Dinophysis acuminata*, *Ostreopsis ovata* and the diatoms *Pseudo-nitzschia* calliantha. HABs *Alexandrium* spp. and *Dinophysis* spp. are common, but their impact on aquaculture is well monitored and paralytic or diarrhetic shellfish poisoning in humans is rare. *Pseudo-nitzschia* spp. blooms are common, but domoic acid in crustaceans rarely exceeds regulatory levels (ZINGONE et al. 2021).

In contrast, regularly occurring HABs caused by *Ostreopsis ovata* may be associated with health problems in humans. This algae contains palytoxin, which is considered one of the most toxic non-protein substances known. Direct contact with the cells or mucus of *Ostreopsis ovata* results in skin irritation. Respiratory problems, dizziness and headaches in the presence of a bloom are caused by marine aerosols. Poisoning episodes associated with toxic *Ostreopsis ovata* blooms have occurred during the summer in the western Mediterranean, e.g. on the Mediterranean coast of Italy (in 2005 and 2006), Spain (in 2006), France (2006–2009) and Algeria (in 2009), causing a number of health problems for surfers, swimmers, sailors and beachgoers (FERRANTE et al. 2013). HAB species in the Mediterranean whose occurrence is not regular but is increasing are *Gambierdiscus australes* and *Fukuyoa paulensis* (TUDÓ et al. 2020, ZINGONE et al. 2021). This raises concerns about the risk of ciguatera, a disease previously known only for subtropical and tropical areas. Ciguatera is the most common form of seafood poisoning caused by harmful algal blooms worldwide, and its incidence and extent appear to be spreading with the spread of the algal species causing it (MARAMPOUTI et al. 2021). Also of concern are the appearances of the dinoflagellates *Vulcanodinium rugosum*, which produces pinnatoxins and *Azadinium poporum*, an azaspiracid producer. These toxins accumulate in crustaceans and could be a potential source of poisoning in humans (JAUFFRAIS et al. 2013).

On the eastern shores of the Atlantic Ocean, in the European part of the Atlantic Ocean, HABs events are also recorded annually over a large geographical area from southern Spain to northern Scotland and Iceland and further north. There are regional differences in the causal species associated with HABs events. Only *Dinophysis acuminata* and *Dinophysis acuta* are common in the waters of most Atlantic coasts of Europe. On the Atlantic coasts of southern Portugal, Spain and France, there are mass occurrences of *Ostreopsis ovata*, which in 2021 caused health problems in approximately 700 people resting on the coast (CHOMÉRAT et al. 2022). Along the French Atlantic coast, blooms of *Lingulaulax polyedra* also occur. This species produces yessotoxins accumulated in clams, oysters and cockles. Poisoning has not been transmitted to humans despite the touristic nature of the region. These blooms also often cause hypoxia due to the large biomass and long bloom duration (MERTENS et al. 2023). In addition, on the coasts of Spain and Portugal, blooms are often formed by the furuncles *Alexandrium minutum* and *Gymnodinium catenatum* and the diatom *Pseudo-nitzschia australis*, whose range also extends to the coasts of France, England and southern Ireland. Mass occurrences of these algae lead to the accumulation of paralytic (*Dinopystis* spp. and *Alexan-*

drium spp.) or amnesic (*Pseudo-nitzschia* spp.) toxins in aquatic organisms, which can be a threat to human health. However, in this region, there is only an economic loss to wild-caught seafood or aquaculture (Bresnan et al.). In the coastal waters of Ireland, an additional threat is the presence of the toxic species the small dinoflagellate *Azadinium spinosum*, a producer of azaspiracids, which can accumulate in shellfish and cause disease in humans (McGirr et al. 2021). In contrast, the majority of aquaculture events and wild fish mortalities have been associated with blooms of the brucellosis *Karenia mikimotoi* and the raphidophyte *Heterosigma akashiwo*. These fish kills are rare but can cause significant mortality. Shellfish mortality has also been linked to *Phaeocystis* spp. blooms, particularly in the southern North Sea (Bresnan et al. 2021). In addition, the colonial stage of *Phaeocystis* spp. forms massive accumulations and can form periodically dense, very abundant, surface scum and cause threats to the safe use of seashores. In 2020, such scum was observed off the Dutch coast and resulted in drowning incidents (Smith and Trimborn 2024). The Baltic Sea is not free of blooms either. Its narrow connection to the open ocean makes it a low-salinity reservoir. For this reason, blooms in the Baltic Sea are caused by cyanobacteria (Paerl 1996, Palinska and Surosz 2014). These include *Nodularia spumigena*, *Aphanizomenon* spp. and *Dolichospermum* spp. *Nodularia spumigena* is a toxic cyanobacterial species, producing the toxin nodularin (Mazur-Marzec et al. 2007). *Dolichospermum* spp. and *Aphanizomenon* spp. are potentially toxic taxa. They have the potential to produce toxins, but only some strains are toxic (Olofsson et al. 2020). This happens during certain periods, as in 2006, when toxic cyanobacteria were observed in different parts of the Baltic Sea. In Sweden, this situation has led to clear restrictions on the use of coastal zones. As a result of the changed leisure and recreation patterns, the island of Gotland and Öland have lost revenue in the order of SEK 150–200 million (approximately €15–20 million) (Foghagen 2011, Nilsson and Gossling 2012). Harmful algal blooms (HABs) are also a recurrent phenomenon along the coast of the north-eastern Atlantic, in the waters of the North Sea, the Norwegian Sea and the Barents Sea. The main HAB taxa causing fish mortality in this region are the primnesiophytes of the genera *Prymnesium* (especially *P. polylepis*), *Chrysochromulina* (especially *Ch. leadbeateri*), the furuncles of the genera *Akashiwo*, *Karenia*, *Karlodinium* and the dictyochophytes of the genera *Dictyocha* and *Pseudochattonella*. Blooms of all of these algal genera cause huge economic losses to fish farmers in aquaculture. Shellfish farming and natural stocks are threatened by other HAB species. In northern Europe, diarrhetic shellfish poisoning (DSP) toxins are produced by several species of *Dinophysis* spp., dominated by *Dinophysis acuminata* and by the benthic *Prorocentrum lima*. Periodically, their concentrations in edible mussels, along the coasts of Norway, Denmark and the Swedish west coast, are above regulatory limits. *Azadinium spinosum* blooms have been unequivocally linked to the presence of azaspiracid toxins responsible for azaspiracid shellfish poisoning (AZP) in northern Europe. These toxins were detected in bivalves at concentrations above regulatory limits for the first time in Norway in mussels in 2005 and in Sweden in mussels and oysters in 2018 (KARLSON et al. 2021). However, among fur-browed mussels, *Alexandrium* species are the main source of toxins that often exceed regulatory limits. Several toxic *Alexandrium* species capable of producing toxins are common in northern European waters. Among these, *Alexandrium catenella*, *Alexandrium ostenfeldii* and *Alexandrium minutum* are the most significant producers of the neurotoxins responsible for paralytic shellfish poisoning (PSP) in this region. This is particularly important as the coastal and shelf regions of northern Europe provide a key supply of seafood (KARLSON et al. 2021).

The coasts of northern Russia, which belongs to the tourist region of Europe, are the Arctic belt and the north-western part of Pacific waters, including the Bering Sea and the Sea of Okhotsk In the Russian Far East seas, HABs are mostly formed by the diatom species *Pseudo-nitzchia spp.* or the *dinoflagellates Alexandrium* spp. and *Dinophystis* spp. The species present are toxic and can cause paralytic (PSP), amnesic (ASP) and diarrhetic (DSP) poisoning in humans. They are also detrimental to aquatic organisms causing high mortality, as occurred in the Bering Sea in Russia when a bloom of *Alexandrium tamarense* caused the death of cetaceans, fish and birds. Bloom species also pose a threat to aquaculture. Monitoring of ficotoxins in aquaculture was only introduced in Russia in 2007. Nevertheless, there is no effective government monitoring of HABs in Russia (VERSHININ and ORLOVA 2008).

Conclusions

Toxic algal blooms are an ever-growing problem in virtually every aquatic environment in the world. The number of HAB sites is still increasing. The reasons for this can be traced, on the one hand, to increasing eutrophication of waters related to anthropogenic activities and, on the other hand, to climate change also related to human activities (NWANKWEGU et al. 2019). Eutrophication of waters is caused by high nitrogen and phosphorus loads delivered by sewage discharges, industrial waste discharges, agricultural runoff and aquaculture activities and many other interrelated environmental factors (Davidson et al. 2014, Heisler et al. 2008). Climate change is proceeding in the direction of a warming climate and causing higher ocean water temperatures, which is a direct and indirect driver of the spread of algal blooms. Storms, winds, ocean currents, ocean circulations and other changing natural phenomena also enhance the formation of blooms (Gobler 2020).

All of these causes of HABs lead to negative effects through impacts on aquatic ecosystems and the human economy. The consequences of HABs for aquatic ecosystems include changes in their functioning, often combined with the death of marine organisms (Sellner et al. 2003). HABs also contribute to economic losses. The economic impacts of HABs arise from the costs of public health protection, commercial fishery closures and mass fish die-offs, decreased opportunities for coastal and marine recreation and tourism, and the costs of monitoring and managing HABs. The estimated economic impact of HABs in the United States is approximately US$ 100 million per year (Anderson et al. 2000). The comparable estimate for the European Union (EU) is an order of magnitude higher at US$ 1 billion per year (Hoagland and Scatasta 2006). Most other parts of the world report only ad hoc impact estimates resulting from extraordinary HABs events. An estimated rough breakdown of the costs associated with the impact of HABs on different economic sectors showed that 45% are costs incurred for public health protection, 37% of costs are due to closures and losses incurred by aquaculture and commercial fisheries, and 4% are the costs of monitoring and managing HABs. The economic loss incurred through lost recreation and tourism is 14% (Anderson et al. 2000).

The tourism and leisure industry loses directly through lower accommodation loads and fewer visitors to catering establishments and indirectly through a reduction in the staff needed to support tourism, which contributes to job losses. The reason for less tourism is the reduced attractiveness of the seashore under HABs conditions due to changes in water quality and coastal areas. The distinctive colour and unpleasant odour of the water, accompanying the blooms, significantly degrades water quality and its tourism and recreational value. In the case of toxic algal blooms, direct contact with the water is hazardous to health. The use of bathing and access to recreational water sports is restricted. Recreationally caught fish, crustaceans and molluscs are also a threat to human health. Recreational fishing grounds are closed, courses and cruises are cancelled. Commercial harvesting of fish and seafood is closely monitored to make sure it is safe, but the existing risk of poisoning causes fear of consumption. Coastal areas are also exposed to the negative effects of algal blooms. Decomposing micro or macro algae, dead aquatic organisms cast ashore, reduce the comfort of recreation in coastal areas. A threat to human health during coastal recreation (e.g. beach walks) are the compounds given off during algal decomposition (ammonia and hydrogen sulfide) or toxic algal compounds found in the air, in the form of aerosol. All of this has the effect of diminishing the attractiveness of coastal tourism under conditions where HABs are present and may be a determinant of preferences for the direction of tourism activities undertaken, which may influence the course of development of marine and coastal tourism in different tourist regions of the world.

In order to mitigate the detrimental effects of HAB events on human health, aquaculture, the tourism industry and coastal economies worldwide, it is essential to develop strategies to prevent, predict and control HABs. Several methods are available for monitoring and predicting HABs, including satellite surveys, laboratory studies, field observations and data sampling. A variety of techniques for monitoring, forecasting and early warning of HABs in coastal waters are being used, including space-based sensors, remote sensing, drones, biological identification, toxin analysis, molecular methods, modelling and citizen science programmes (ZAHIR et al. 2024). However, it is essential to develop an integrated effective monitoring and forecasting system for HABs that includes satellite observations, numerical modelling and machine learning algorithms with in-situ sensors and biosensors. Information extracted from such a system should be available to all economic sectors at risk of HABs, regardless of the region in the world (ALVAREZ et al. 2024). The tourism sector should be particularly interested in obtaining such information to be able to verify the availability of safe destinations for tourism.

Accepted for print 14.11.2024

References

AKIN-ORIOLA G.A., ANETEKHAI M.A., ORIOLA A. 2006. *Algal blooms in Nigerian waters: an overview*. Afr. J. Mar. Sci., 28(2): 219–224.

ALKHATIB H., BENNOUNA A., ABOUABDELLAH R., AMZIL Z., HERVE F., MOUSSAVOU-MOUITY C.A, ELAYOUBI S., BEKKALI M., FAHDE A. 2022. *Ostreopsis spp.: Morphology, proliferation and toxic profile in the North-West of Agadir (North Atlantic Ocean).* Reg. Stud. Mar. Sci., 56: 102713.

ALLAF M.M. 2023. *Heterosigma akashiwo, a Fish-Killing Flagellate*. Microbiol. Res., 14(1): 132–147.

ALVAREZ S., BROWN C.E., DIAZ M.G., O'LEARY H., SOLÍS D. 2024. *Non-linear impacts of harmful algae blooms on the coastal tourism economy*. Journal of Environmental Management, 351, 119811.

ANDERSON D.M., HOAGLAND P., KAORU Y., WHITE A.W. 2000. *Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States*. Technical Report WHOI-2000, 11: 1–101.

Anderson D.M., Fensinb E., Goblerc Ch.J., Hoeglund A.E., Hubbard K.A., Kulis D.M., Landsberg J.H, Lefebvre K.A., Provoost P., Richlen M.L., Smith J.L., Solow A.R., Trainer V.L. 2021. *Marine harmful algal blooms (HABs) in the United States: History, current status and future trends*. Harmful Algae, 102: 101975.

Assmy P., Smetacek V., 2009. *Algal Blooms,* In: Schaechter M. (eds) *Encyclopedia of Microbiology*, Elsevier Press, Oxford, pp. 27–41.

Azanza R.V., Yñiguez A.T., Benico G.A., Lim P.T., Leaw, Ch.P., Iwataki M. 2024. *Expansion of toxic algal blooms in coastal and marine areas in the Philippines and Malaysia: Is it climate change related?* Sustainability, 16(8): 3304.

Barría C., Vásquez-Calderón P., Lizama C., Herrera P., Canto A., Conejeros P., Beltrami O., Suárez-Isla B.A., Carrasco D., Rubilar I., Guzmán L., Durán L.R., Oliva D. 2022. *Spatial temporal expansion of harmful algal blooms in Chile: A review of 65 years records*. J. Mar. Sci. Eng., 10(12): 1868.

Barsanti L. Gualtieri P., 2014. *Algae: Anatomy, biochemistry and biotechnology*. CRC Press, Boca Raton, pp. 326.

Bechard A. 2020. *Harmful algal blooms and tourism: The economic impact to counties in Southwest Florida.* The Revive of Regional Studies, 50: 170–188.

Bergman B., Sandh G., Lin S., Larsson H., Carpenter E.J. 2012. *Trichodesmium – a widespread marine cyanobacterium with unusual nitrogen fixation properties.* FEMS Microbiol. Rev., 37: 286–302.

Białczyk J., Lechowski Z., Bober B. 2009. *Toksyny syntetyzowane przez morskie glony* [*Toxins synthesized by marine algae*], Wiad. Bot., 53(3/4): 31–51.

Brand L.E., Campbell L., Bresnan E. 2012. *KARENIA: The biology and ecology of a toxic genus*. Harmful Algae, 14: 156–178.

Bresnan E., Arévalo F., Belin C., Branco M.A.C., Cembella A.D., Clarke D., Correa J., Davidson K., Dhanji-Rapkova M., Lozano R.F., Fernández-Tejedor M., Guđfinnsson H., Carbonell D.J., Laza-Martinez A., Lemoine M., Lewis A.M., Menéndez L.M., Maskrey B.H., McKinney A., Pazos Y., Revilla M., Siano R., Silva A., Swan S., Turner A.D., Schweibold L., Provoost P., Enevoldsen H. 2021. *Diversity and regional distribution of harmful algal events along the Atlantic margin of Europe*. Harmful Algae, 102: 101976.

Castenholz, R.W. 1992. *Species usage, concept, and evolution in the cyanobacteria (blue-green algae).* J. Phycol., 28: 737–745.

Chapman R. 2013. *Algae: the world's most important "plants" – an introduction.* Mitig. Adapt. Strateg. Glob. Change, 18: 5–12.

Chomérat N., Antajan E., Gwenael Bilien I.A., Carpentier L., de Casamajor M.-N., Ganthy F., Hervé F., Labadie M., Méteigner C., Paradis C., Perrière-Rumèbe M., Sanchez F., Séchet V., Amzil Z. 2022. *First characterization of Ostreopsis cf. ovata (Dinophyceae) and detection of ovatoxins during a multispecific and toxic ostreopsis bloom on French Atlantic Coast.* Mar. Drugs, 20(7): 461.

Corrales R.A., Maclean J.L. 1995. *Impacts of harmful algae on seafarming in the Asia-Pacific areas*. J. Appl. Phycol., 7: 151–162.

Cuellar-Martinez T., del Rocío Huanca Ochoa A., Sánchez S., Aguirre-Velarde A., Ocas E.O. M., Velasquez A.M.R., Querevalú R.I.S., Colas F., Tam J., Gutiérrez D. 2023. *Abundance and distribution of potentially toxic phytoplankton in aquaculture sites along the Peruvian coast.* J. Mar. Sys., 240: 103865.

Cuellar-Martinez T., Ruiz-Fernández A.C., Alonso-Hernández C., Amaya-Monterrosa O., Quintanilla R., Carrillo-Ovalle H.L., Arbeláez N.M., Díaz-Asencio L., Méndez S.M., Vargas M., Chow-Wong N.F., Valerio-Gonzalez L.R., Enevoldsen H., Dechraoui Bottein M.-Y. 2018. *Addressing the problem of harmful algal blooms in Latin America and the Caribbean. A regional network for early warning and response.* Front. Mar. Sci., 5(409): 1–7.

D'Silva M.S., Anil A.C., Naik R.K., D'Costa P.M. 2012. *Algal blooms: a perspective from the coasts of India.* Nat. Hazards, 63: 1225–1253.

Davidson K., Gowen R.J., Harrison P.J., Fleming L.E., Hoagland P., Moschonas G. 2014. *Anthropogenic nutrients and harmful algae in coastal waters*. J. Env. Man., 146: 206–216.

Dias A.B., Kurian S., Vijayan N.T., Gauns M., Khichi R., Pratihary A.K., Borker S.G., Shenoy D.M. 2023. *Recurrence of Gonyaulax polygramma bloom in the southeastern Arabian Sea.* Environ. Monit. Assess., 195: 635.

Díaz P.A., Álvarez G., Varela D., Pérez-Santos I., Díaz M., Molinet C., Seguel M., Aguilera-Belmonte A., Guzmán L., Uribe E., Rengel J., Hernández C., Segura K., Figueroa R. I. 2019. *Impacts of harmful algal blooms on the aquaculture industry: Chile as a case study*. PiP, 6(1–2): 39–50.

Ekstrom J.A., Moore S.K., Klinger T. 2020. *Examining harmful algal blooms through a disaster risk management lens: A case study of the 2015 U.S. West Coast domoic acid event.* Harmful Algae, 94: 101740.

Esmaeili F.M., Mortazavi M.S., Banadaki A.D., Saraji F., Laili S., Nozar M. 2021. *Algal blooms historical outbreaks in the northern coastal waters of the Persian Gulf and Oman Sea (1980–2015).* Environ. Monit. Assess., 193(10): 648.

Fabro E., Almandoz G.O., Ferrario M., John U., Tillmann U., Toebe K., Krock B., Cembella A. 2017. *Morphological, molecular and toxin analysis of field populations of Alexandrium genus from the Argentina Sea.* J. Phycol., 53(6): 135–138.

Ferrante M., Conti G.O., Fiore M., Rapisarda V., Ledda C. 2013. *Harmful algal blooms in the Mediterranean Sea: Effects on human health.* EMBJ, 8(6): 25–34.

Foghagen C. 2011. *Algae blooms and their consequences on camping tourism destinations: The case of Öland, Sweden.* Tourism: An International Interdisciplinary Journal, 59(4): 411–426.

García-Mendoza E., Cáceres-Martínez J., Rivas D., Fimbres-Martinez M., Sánchez-Bravo Y., Vásquez-Yeomans R., Medina-Elizalde J. 2018. *Mass mortality of cultivated Northern bluefin Tuna Thunnus thynnus orientalis associated with chattonella species in Baja California, Mexico.* Front. Mar. Sci., 5: 00454.

Gobler C.J., 2020. *Climate change and harmful algal blooms: Insights and perspective.* Harmful Algae, 101731.

Gomes H.R., Goes J., Matondkar S.G.P., Buskey E., Basu B., Parab S., Thoppil P. 2014. *Massive outbreaks of Noctiluca scintillans blooms in the Arabian Sea due to spread of hypoxia*. Nat. Commun., 5(1): 4862.

Hallegraeff G.M. 1992. *Harmful algal blooms in the Australian region*. Mar. Pollut. Bull., 25 (5–8): 186–190.

Hansen G., Turquet J., Quod J.-P., Ten-Hage L., Sabatier P., Lugomela Ch., Kyewalyanga M.S., Hurbungs M., Wawiye P., Ochieng' Ogongo B., Tunje S., Rakotoarinjanahary H. 2001. *Potentially harmful microalgae of the Western Indian Ocean – a guide based on a preliminary survey*. Intergovernmental Oceanographic Commision UNESCO, 41: 1–108.

Harrison P.J., Piontkovski S., Al-Hashmi K. 2017. *Understanding how physical-biological coupling influences harmful algal blooms, low oxygen and fish kills in the Sea of Oman and the Western Arabian Sea*. Mar. Pollut. Bull., 114(1): 25–34.

Heil C.A., Muni-Morgan A.L. 2021. *Florida's harmful algal bloom (HAB) Problem: Escalating risks to human, environmental and economic health with climate* change. Front. Ecol. Evol., 9: 646080.

Heisler J., Glibert P.M., Burkholder J.M., Anderson D.M., Cochlan W., Dennison W.C., Dortch Q., Gobler C.J., Heil C.A., Humphries E., Lewitus A., Magnien R., Marshallm H.G., Sellner K., Stockwell D.A., Stoecker D.K., Suddleson M. 2008. *Eutrophication and harmful algal blooms – A scientific consensus*. Harmful Algae, 8: 3–13.

Hoagland P., Scatasta S. 2006. *The economic effects of harmful algal blooms*. In: Granéli E., Turner J.T. (eds), *Ecology of harmful algae. Ecological studies*. Springer, Berlin, Heidelberg, 189: 391–402.

Jauffrais T., Séchet V., Herrenknecht Ch., Truquet P., Véronique S., Tillmann U., Hess P. 2013. *Effect of environmental and nutritional factors on growth and azaspiracid production of the dinoflagellate Azadinium spinosum*. Harmful Algae, 27: 138–148.

Karlson B., Andersen P., Arneborg L., Cembella A., Eikrem W., John U., West J.J., Klemm K., Kobos J., Lehtinen S., Lundholm N., Mazur-Marzec H., Naustvoll L., Poelman M., Provoost P., Derijcke M., Suikkanen S. 2021. *Harmful algal blooms and their effects in coastal seas of Northern Europe*. Harmful Algae, 102: 101989.

Kiteresi L., Ochieng O.E., Mwangi S. Mkonu M. 2013. *Potentially Harmful Algae along the Kenyan Coast: A Norm or Threat*. J. Environ. Earth Sci., 3(9): 1–12.

Kretzschmar A.L., Larsson M.E., Hoppenrath M., Doblin M.A., Murray S.A. 2019. *Characterisation of Two Toxic Gambierdiscus* spp. *(Gonyaulacales, Dinophyceae) from the Great Barrier Reef (Australia): G. lewisii* sp. *nov. and G. holmesii* sp. *nov*. Protist, 170(6): 125699.

Kudela R.M., Berdalet E., Enevoldsen H., Pither G., Raine R., Urban E. 2017. *GEOHAB – The Global Ecology and Oceanography of Harmful Algal Blooms Program: motivation, goals, and legac*. Oceanography, 30(1): 12–21.

Lewitus A.J., Horner R.A., Caron D.A., Garcia-Mendoza E., Hickey B.M., Hunter M., Huppert D. D., Kudela R.M., Langlois G.W., Largier J.L, Lessard E.J., RaLonde R., Rensel J.E.J., Strutton P.G., Trainer V.L., Tweddle J.F. 2012. *Harmful algal blooms along the North American west coast region: History, trends, causes, and impacts*. Harmful Algae, 19: 133–159.

Li X., Yan T., Yu R., Zhou M. 2019. *A review of Karenia mikimotoi: Bloom events, physiology, toxicity and toxic mechanism*. Harmful Algae, 90: 101702.

Lundgren W., Roelke D.L., Brooks B.W., Granéli E., Davis S., Baty T., Scott W.C. 2015. *Prymnesium parvum invasion success into coastal bays of the Gulf of Mexico: Galveston Bay case study*. Harmful Algae, 43: 31–45.

Marampouti C., Buma A.G.J., de Boer K.M. 2021. *Mediterranean alien harmful algal blooms: origins and impacts*. Environ. Sci. Pollut. Res., 28: 3837–3851.

Mazur-Marzec H., Tymińska A., Szafranek J., Pliński M. 2007. *Accumulation of nodularin in sediments, mussels, and fish from the Gulf of Gdańsk, southern Baltic Sea*. Environ. Toxicol., 22(1): 101–111.

McGirr S., Clarke D., Kilcoyne J., Salas R., Koehler H., SilkeJ., Touzet N., 2021. *Insights into the discrepancy between Azadinium spp. and azaspiracid toxins near strategically important aquaculture operations in the west and southwest of Ireland*. Estuar. Coast. Shelf Sci., 262: 107622.

McKenzie C.H., Bates S.S., Martin J.L., Haigh N., Howland K.L., Lewis N.I., Locke A., Peña A., Poulin M., Rochon A., Rourke Wade A., Scarratt M.G., Starr M., Wells T. 2021. *Three decades of Canadian marine harmful algal events: Phytoplankton and phycotoxins of concern to human and ecosystem health*. Harmful Algae, 102: 101852.

Mertens K.N., Retho M., Manach S., Zoffoli M.L., Doner A., Schapira M., Bilien G., Séchet W., Lacour T., Robert E., Duval A., Terre-Terrillon A., Derrien A., Gernez P. 2023. *An unprecedented bloom of Lingulodinium polyedra on the French Atlantic coast during summer 2021*. Harmful Algae, 125: 102426.

Michalski M.M. 2006. *Biotoksyny morskie – występowanie i metody analizy* [*Marine biotoxins – occurrence and methods of analysis*]. ŻNTJ, 3(48): 16–22.

Nilsson J.H., Gossling S. 2013. *Tourist responses to extreme environmental events: The case of Baltic Sea algal blooms*. TPD, 1(1): 32–44.

Nwankwegu A.S., Li Y., Huang Y., Wei J., Norgbey E., Sarpong L., Lai Q., Wang K. 2019. *Harmful algal blooms under changing climate and constantly increasing anthropogenic actions: the review of management implications*. 3 Biotech, 9: 449.

Olofsson M., Suikkanen S., Kobos J., Wasmund N., Karlson B. 2020. *Basin-specific changes in filamentous cyanobacteria community composition across four decades in the Baltic Sea*. Harmful Algae, 91: 101685.

Padmakumar K.B., Smitha B.R., Thomas L.C., Fanimol C.L., SreeRenjima G., Menon N.R. Sanjeevan V.N. 2010. *Blooms of Trichodesmium erythraeum in the South Eastern Arabian Sea during the onset of 2009 summer monsoon*. Ocean Sci. J., 45: 151–157.

Paerl H. W. 1996. *A comparison of cyanobacterial bloom dynamics in freshwater, estuarine and marine environments*, Phycologia 35: 25–35.

PALINSKA K.A., SUROSZ W. 2014. *Taxonomy of cyanobacteria: a contribution to consensus approach*, Hydrobiologia, 740: 1–11.

PARRY G.D., LANGDON J. S., HUISMAN J.M. 1989. *Toxic effects of a bloom of the diatom Rhizosolenia chunii on shellfish in Port Phillip Bay, Southeastern Australia*. Mar. Biol., 102(1): 25–41.

PITCHER G.C., CALDER D. 2000. *Harmful algal blooms of the southern Benguela current: A review and appraisal of monitoring from 1989 to 1997*. S. Afr. J. Mar. Sci., 22: 255–271.

PROENÇA L.D.O., TAMANAHA M.S., SOUZA N.P. 2001. *The toxic dinoflagellate Gymnodinium catenatum Graham in southern Brazilian waters: occurrence, pigments and toxins*. Atlântica, 23: 59–65.

QI L., HU C., XING Q, SHANG S. 2016. *Long-term trend of Ulva prolifera blooms in the western Yellow* Sea, Harmful Algae, 58: 35–44.

RESIERE D., KALLEL H., FLORENTIN J., BANYDEEN R., COMPTON K., GUEYE P., MEHDAOUI H., NEVIERE R. 2023. *Sargassum seaweed in the Caribbean: A major public health problem still unsolved*. J. Glob. Health, 13: 03017.

ROBLEDO D., VÁZQUEZ-DELFÍN E., FREILE-PELEGRÍN Y., VÁSQUEZ-ELIZONDO R.M., QUI-MINET Z.N., SALAZAR-GARIBAY A. 2021. *Challenges and Opportunities in Relation to Sargassum Events Along the Caribbean Sea*. Front. Mar. Sci., 8: 699664.

SAKAMOTO S., LIM W.A., LU D., DAI X., ORLOVA T., IWATAKI M. 2021. *Harmful algal blooms and associated fisheries damage in East Asia: Current status and trends in China, Japan, Korea and Russia*. Harmful Algae, 102: 101787.

SASTRE A.V., SANTINELLI N.H., SOLÍS M.E., PÉREZ L.B., OVEJERO S.D., VILLALOBOS L.G., CADAILLÓN A., D'AGOSTINO W.C., 2018. *Harmful marine microalgae in coastal waters of Chubut (Patagonia, Argentina)*. In: *Plankton ecology of the Southwestern Atlantic*, (eds.) Hoffmeyer M.S., Sabatini M., Brandini F., Calliari D., Santinelli N., Springer, Cham: 495–515.

SELLNER K.G., DOUCETTE G.J. KIRKPATRICK G.J., 2003. *Harmful algal blooms: causes, impacts and detection*. J. Ind. Microbiol. Biotechnol., 30: 383–406.

SIDABUTAR T., SUNARWATI SRIMARIANA E., CAPPENBERG H.A.W., WOUTHUYZEN S. 2024. *Comprehensive analysis of harmful algal blooms in Indonesia: from occurrence to impact*. BIO Web of Conferences ICFAES-2023, 87(10): 02003.

SIDHARTA B.R. 2005. *The current status of research on harmful algal bloom (HAB) in Indonesia*. J. Coast. Dev., 8(2): 75–88.

SIMÕES E., VIEIRA R.C., SCHRAMM M.A., MELLO D.F., DE ALMEIDA PONTINHA V., DA SILVA P.M., BARRACCO M.A. 2014. *Impact of harmful algal blooms (Dinophysis acuminata) on the immune system of oysters and mussels from Santa Catarina, Brazil*, JMBA, 95(04): 773–781.

SMAYDA T.J. 1997. *What is a bloom? A commentary*. Limnol. Oceanogr., 42(5/2): 1132–1136.

SMITH JR. W.O., TRIMBORN S. 2024. *Phaeocystis: A Global Enigma*, Annu. Rev. Mar. Sci., 16: 417–441.

SPATHARIS S., SKLIRIS N., MEZITI A., KORMAS K. A. 2012. *First record of a Trichodesmium erythraeum bloom in the Mediterranean Sea*. CJFAS, 69(8): 1444–1455.

STEPHEN V.C., HOCKEY P.A.R. 2007. *Evidence for an increasing incidence and severity of Harmful Algal Blooms in the southern Benguela region*. S. Afr. J. Sci., 103: 223–231.

SUMANDIARSA I.K., BENGEN D.G., SANTOSO J., JANUAR H.I. 2021. *The relationship between seasonal and environmental variations with morphometric characteristics of Sargassum polycystum (C. Agardh. 1824) from Tidung, Sebesi and Bintan islands waters, Indonesia*, Pol. J. Natur. Sc., 36(1): 37–57.

SUNESEN I., MÉNDEZ S.M., MANCERA-PINEDA J.E., DECHRAOUI BOTTEIN M.-Y., ENEVOLDSEN H. 2021. *The Latin America and Caribbean HAB status report based on OBIS and HAEDAT maps and databases*. Harmful Algae, 102: 101920.

TSIKOTI CH., GENITSARIS S. 2021. *Review of harmful algal blooms in the Coastal Mediterranean Sea, with a focus on Greek waters*. Diversity, 13(8): 396.

TUDÓ À., TOLDRÀ A., REY M., TODOLÍ I., ANDREE K.B., FERNÁNDEZ-TEJEDOR M., CAMPÀS M., SUREDA F.X., DIOGÈNE J. 2020. *Gambierdiscus and Fukuyoa as potential indicators of ciguatera risk in the Balearic Islands*. Harmful Algae, 99, 101913.

USUP G., AHMAD A., MATSUOKA K., LIM P.T., LEAW C.P. 2012. *Biology, ecology and bloom dynamics of the toxic marine dinoflagellate Pyrodinium bahamense*. Harmful Algae, 14: 301–312.

VAN DOLAH F.M. 2000. *Marine algal toxins: origins, health effects, and their increased occurrence*. Environ. Health Perspect., 108 (Suppl. 1): 133–141.

VERSHININ A.O., ORLOVA T.Y., 2008. *Toxic and harmful algae in the coastal waters of Russia*. Oceanology, 48: 524–537.

WANG D.Z., XIN Y.H., WANG M.H., 2022. *Gambierdiscus and its associated toxins: A Minireview*. Toxins, 14(7): 485.

WANG K., CHEN B., GAO Y., LIN H. 2021. *Harmful algal blooms caused by Phaeocystis globosa from 1997 to 2018 in Chinese coastal waters*. Marine. Mar. Pollut. Bull., 173A: 112949.

XIAODONG L., WEIJING L., FAN J., ZIQIN CH., YANG CH., ZIYANG W., TAN Y., JING L., WEICHENG W., XINHUA CH. 2023. *The dinoflagellate Noctiluca scintillans in China: A review of its distribution and role in harmful algal blooms*. Mar. Pollut. Bull., 194B: 115415.

ZAHIR M., SU Y., SHAHZAD M.I., AYUB G., RAHMAN S.U., IJAZ J. 2024. *A review on monitoring, forecasting, and early warning of harmful algal bloom*. Aquaculture, 593: 741351.

ZINGONE A., ESCALERA L., ALIGIZAKI K., FERNÁNDEZ-TEJEDOR M., ISMAEL A., MONTRESOR M., MOZETIČ P., TAŞ S., TOTTI C. 2021. *Toxic marine microalgae and noxious blooms in the Mediterranean Sea: A contribution to the Global HAB Status Report*, Harmful Algae, 102: 101843.

ZOHDI E., ABBASPOUR M. 2019. *Harmful algal blooms (red tide): A review of causes, impacts and approaches to monitoring and prediction*. Int. J. Environ. Sci. Technol., 16: 1789–1806.

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(4): 249–263, Y. 2024

DOI: 10.31648/pjns.9141

VALUES OF THE MEDICINAL BATH PLACE ENVIRONMENT: THE IMPORTANCE OF MEDICINAL BATH PLACE CHARACTERISTICS AMONG HUNGARIANS

***Ágnes Erzsébet Hojcska*[1], *Zoltán Szabó*[2], *Zoltán Bujdosó*[3]**

[1] ORCID: 0000-0003-2201-0659
[2] ORCID: 0000-0002-1088-8416
[3] ORCID: 0000-0002-5023-074X
[1] Department of Health Tourism, Faculty of Health and Social Sciences
Gál Ferenc University, Gyula, Hungary
[2,3] Institute for Rural Development and Sustainable Economy,
Department of Sustainable Tourism
Hungarian University of Agriculture and Life Sciences, Georgikon Campus, Keszthely[2],
Károly Róbert Campus, Gyöngyös[3], Hungary

Key words: attitude, consumer, environment, medicinal bath place, value offer.

Abstract

The main topic of our research is the examination of the environmental values of Hungarian medicinal bath place from the demand side, which can significantly contribute to the preservation of people's health and the improvement of their quality of life. The actuality of our research is due to the fact that in our society, people pay more and more attention to health presevation and their personal well-being. The water usually attracts people, so the medicinal bath place environment appears as a defining element of the offer among tourists.

The main goal of our research is to map out, with the help of consumer attitudes and preferences, the expectations of tourists regarding the characteristics of medicinal bath place. To achieve the goal of our research, we conducted primary research and a questionnaire survey. Data collected among the Hungarian middle-aged middle class (n = 200) were processed with univariate descriptive statistics and bivariate analyses.

In the course of our research, we came to the results that the Hungarian middle-aged middle class clearly detects the medicinal bath place characteristics, and that the main medicinal bath place characteristics can be divided into characteristically different ways of thinking. In the opinion of the respondents, among the features of the spa, the silence and tranquility, the quality of the accommodation, the beautiful environment, the wide range of treatments, as well as the quality of the gastronomy and medicinal care significantly contribute to a successful stay in a medicinal bath place. We also determined the three main ways of thinking of spa visitors: environment-oriented way of thinking, medicinal-oriented way of thinking, culture-oriented way of thinking, which is most characteristic of a satisfied guests.

Address: Zoltán Szabó, Hungarian University of Agriculture and Life Sciences, Georgikon Campus Keszthely, Hungary, e-mail: Szabo.Zoltan.dr@uni-mate.hu

Introduction

Nowadays, the issue of health-related consumption is topical, because the appreciation of health can be seen worldwide, as a result of which the prevailing megatrend has become health awareness. The development of health-related tourism offers is characterized by the combination of nature conservation and sustainable tourism development (SZÉCHY and SZERÉNYI 2023, BUJDOSÓ et al. 2019, STOJANOVIĆ et al. 2018). Can be experienced the transformation of the health market, the expansion and dynamic growth of health tourism (KOŠIĆ et al. 2011).

In the case of Hungary, a special service within health tourism is medicinal bath tourism based on internationally unique medicinal water (PRINTZ-MARKÓ et al. 2020). The basis for this was created in Hungary by the reputation gained in medicinal bath tourism based on centuries-old traditions, the availability of natural resources in quantity and quality, and the services related to them (SZABÓ and HOJCSKA 2020). Hungary is a country of water, as almost 4/5 of it is covered with water. Most of the water is not visible, because unlike surface water, it is located below the earth's surface. In Hungary, the temperature of the rocks inside the earth and the incoming water gradually rises as it goes down, which is why the country has favorable thermal water resources. This temperature change is expressed by the geothermal gradient. In Hungary, waters with a water temperature above 30°C can be called thermal water, in contrast to surface water in other areas of Europe, where this value is 20°C. In the case of medicinal waters, the chemical (macroelement content) and physical properties (buoyancy, hydrostatic pressure, temperature) of water are utilized during their use in healing. There are 1370 thermal wells and 238 thermal water deposits in Hungary, the largest number of which are used for bathing, and to a lesser extent for agricultural, waterworks, communal and industrial use. In Hungary, there are 270 qualified medicinal waters, of which a large number are found in individual medicinal bath place (HOJCSKA and SZABÓ 2021). In Hungary, primarily based on thermal waters, numerous health tourism developments, including medicinal tourism, were realized with state contributions (SZABÓ et al. 2013), which were supplemented by local and regional infrastructure developments, such as regional railway development in Western Hungary (BALI 2014). During spa development, the construction or renovation of a medicinal bath means attraction and service development at the same time (STARCZEWSKI et al. 2018). Thanks to the developments, the new and renovated medicinal baths have become the most important tourist attractions of the medicinal bath places (MILORADOV and EIDLINA 2018).

The healing effects of Hungarian thermal waters have been known for centuries and have been widely used in the treatment of various diseases. Due to their composition, i.e. their dissolved components and their quantity, each water is meant to treat different diseases. Those thermal and/or mineral waters with medically proven medicinal effects are registered as medicinal waters in Hungary. The chemical composition of medicinal waters plays an important role in shaping the physiological effects on the body during medicinal treatments (HOJCSKA et al. 2022, MAYER and HOJCSKA 2018). Based on the latest research, value-creating people are becoming more and more important in knowledge-based societies (FARKAS 2021), for whom health is more and more valued, and for an increasing number of them, its preservation appears as one of the most important value. It is everyone's own responsibility to shape the state of health, because health behavior (harmful or beneficial) can contribute to the development respectively prevention of many diseases (MAGYAR 2017). The probability of occurrence of diseases that can be treated with medicinal services increases as the number of years of life increases, it is 6.8% in the young age group, while it is already 48.6% among the middle-aged. Therefore, the consumers of medicinal bath tourism are primarily the middle-age group in the broad sense (SZABÓ 2021). From the point of view of the family life cycle, the consumers of medicinal baths are adults living without children, with their own income, and pensioners. Most of this segment is characterized by a traditional way of life, a conservative outlook on life, a moderate sense of status and price sensitivity. Based on these, the demand for medicinal bath tourism is generally influenced by several factors. One of them is an aging population with increasing health problems and discretionary income and leisure time. The other is health behavior changes, which emphasize the prevention of diseases. It is also influenced by the search for the experience of health on the part of tourists through the assumed positive change of the expected environmental change. The medicinal bath tourism demand is also influenced by medicinal baths places with their active marketing activities (POLISCHCHUK and BUJDOSÓ 2022, MUHI and ĐURKOVIĆ 2021). Nowadays, platforms and applications optimized for smartphones are increasingly used by potential consumers when making travel decisions (MORABI et al. 2023). According to prognoses, an ever-increasing proportion of the Hungarian population recognizes that good health is the basis of work productivity, emotional, intellectual and physical development.

In Hungarian medicinal bath tourism, the basic condition for the sustainable use of opportunities and the achievement of international competitiveness is the predictability and security of the domestic market

(NAVARRO et al. 2020, BRAMWELL et al. 2017). Within tourism, medicinal bath tourism is one of the fastest growing market segments, yet researchers still pay little attention to it. In the globalized offer of tourism, the Hungarian medicinal bath placses can be an increasingly important player in the spa tourism market due to the appreciation of health and the utilization of the spa water resources (KELLER et al. 2021). This possibility can only be used if the characteristics that contribute to the successful stay of medicinal bath tourists in a medicinal bath are known. To explore this important issue, we defined two research goals. Our first goal is to establish whether the Hungarian middle-aged middle class, who mostly visit medicinal baths, clearly perceive the medicinal bath place's characteristics. Our second goal is to explore, whether the main features of medicinal bath places, among Hungarians, can be divided from each other into characteristically different ways of thinking. Getting to know these basic issues can help the medicinal bath places's planners and decision-makers to better satisfy guest needs.

Materials and Methods

In order to achieve our research goals, we used the questionnaire survey among the quantitative research methods (TAKÁCS 2016). The assertions of the questionnaire measured the importance of Hungarian medicinal bath place characteristics among the Hungarian adult population, the other questions related to the socio-demographic characteristics of the respondents. The assertions of the questionnaire were selected based on relevant international and domestic literature. As a means of data collection, we used a paper-based questionnaire, which was delivered to the interviewees through intermediaries. The respondents were selected randomly (BABBIE 2017) in different settlements in Hungary. The requirements for respondents was adulthood and Hungarian citizenship. Data collection took place until the planned 200 evaluably completed questionnaires were reached. The socio-demographic characteristics of the 200 people who in an evaluable manner completed the questionnaires, taking into account distribution ratios it was possible to reach the middle-aged Hungarian middle class in the broad sense (Table 1).

Table 1

Socio-demographic characteristics of the respondents (N = 200)

Specification	Level	Count	Proportion	p
Gender	female	116	0.580	0.028
	male	84	0.420	0.028
Age	18–39 years	46	0.230	<.001
	40–59 years	98	0.490	0.832
	60+ years	56	0.280	<.001
Economic activity	worker, entrepreneur	131	0.655	<.001
	pensioner	55	0.275	<.001
	inactive (student, unemployed, other)	14	0.070	<.001
Educational attainment	elementary	16	0.080	<.001
	secondary education	141	0.705	<.001
	higher education	43	0.215	<.001
Residence	city	111	0.555	0.137
	village	89	0.445	0.137
Family status	living alone	74	0.370	<.001
	living in a relationship	126	0.630	<.001
Income level	below average	13	0.065	<.001
	average	165	0.825	<.001
	above average	22	0.110	<.001
Note. H_a is proportion ≠ 0.5				

Source: Own calculation and editing

Based on the age of those who completed the questionnaire (42% male, 58% female), 23% were 18–39 years old, 49% were between 40–59 years old, and 28% were older than 60 years. In terms of highest education, 8% had primary education, 70.5% had secondary education, and 21.5% had higher education, in terms of their economic activity, 65.5% were employed, 27.5% were pensioner and 7% were unemployed. According to their marital status, 37% live alone, 63% in a relationship, 55.5% live in a city, and 44.5% live in a village. Based on their perception of income, 6.5% have below average income, 82.5% have average income, and 11.0% have above average income.

To measure the characteristics of medicinal bath place features, we used a sophisticated five-point Likert scale, where 1 means „not at all", 2 means „to a small extent", 3 means „to a moderate extent" 4 means „to a great extent" and 5 meant "completely" agree. The obtained data were processed using the statistical analysis program Jamovi version 2.3.21 of the Windows 10 program package. Among the data processing methods, we used univariate descriptive statistical analyzes (mean, median, mode, standard deviation, minimum, maximum) and multivariate analysis (Takács 2017). Among the multivariate methods, principal component analysis and factor analysis were used in order to explore Hungarians' ways of thinking about medicinal bath place characteristics.

Results

Our investigation concerned how important the respondents consider the values of the medicinal bath place environment to be. In this part of our investigations, we looked for the answer to how the Hungarian population evaluates the importance of the characteristics of the medicinal bath places. A significant proportion of those interviewed had a favorable opinion of the characteristics of the medicinal bath place. Among them, a significant degree (4.02) of acceptance of a medicinal bath place environment. The standard deviation of the responses to the statements is below 1 with one exception. It follows that the respondents perceive the factors of the values of the medicinal bath place environment (Table 2).

Table 2

Average order of importance of the medicinal bath place features (N = 200)

Specification	N	Mean	95% confidence interval		Mode	SD	Minimum	Maximum
			lower	upper				
1	2	3	4	5	6	7	8	9
Silence and calme	200	4.56	4.44	4.68	5.00	0.860	1	5
Quality of accomodation	200	4.28	3.87	4.11	4.00	0.715	2	5
Beautiful environment	200	4.21	4.03	4.25	4.00	0.708	2	5
Wide range of treatments	200	4.20	4.03	4.26	4.00	0.831	1	5
Gastronomy quality	200	4.14	3.90	4.14	4.00	0.757	2	5
Quality of medicinal service and treatment	200	4.14	3.97	4.21	4.00	0.817	1	5
The cleanliness and charm of the medicinal bath park	200	4.09	4.12	4.31	4.00	0.828	1	5
Favorable cost of accomodation	200	4.07	3.76	4.02	4.00	0.802	2	5

cont. Table 2

1	2	3	4	5	6	7	8	9
Transportation (accessibility, parking)	200	4.07	4.08	4.31	4.00	0.830	1	5
Medicinal bath and the safety of the settlement (low crime rate)	200	4.02	3.95	4.19	4.00	0.839	1	5
Cleanliness of streets	200	4.00	3.36	3.67	4.00	0.833	2	5
A wide selection of cultural attractions in the spa settlement	200	3.99	3.95	4.18	4.00	0.880	2	5
Wide selection of tourist attractions in the settlement	200	3.92	4.18	4.37	4.00	0.878	1	5
Treatment cost are low	200	3.89	3.44	3.71	3.00	0.939	1	5
Mass events, concert, festivals, etc.	200	3.63	3.79	4.04	4.00	0.931	1	5
Entertainment (cinema, dance, etc.)	200	3.58	3.51	3.76	4.00	0.974	1	5
Opportunity to get to know other medicinal bath visitors	200	3.52	3.88	4.12	4.00	1.103	1	5

Source: Own calculation and editing

For the respondents, the silence and calme (4.56), the quality of the accommodation (4.28), the beautiful environment (4.21), the wide range of treatments (4.20) and the quality of the gastronomy (4.14) the most important. The most important characteristics also received the lowest standard deviation values, which proves the significant agreement. We have to emphasize all of this because it draws attention to the increased importance of the mdicinal bath place milieu.

For the respondents, the least important are the possibilities of using the services provided by the cultural and entertainment facilities provided by the medicinal bath place, which also received the highest standard deviation. For the respondents, it is less important to be able to get to know each other at the medicinal bath place (3.52), have fun, go to the cinema, dance (3.58), or participate in larger events, such as concerts and festivals (3.63).

The system of medicinal bath place characteristics were examined with a cluster analysis prepared and substantiated by factor analysis. During the factor analysis, the initial variables were examined using the Bartlett test. The result of the test is: $\chi^2 = 1294$; df = 136; $p < 0.001$, which means that the variables are suitable for factor analysis. Using this procedure, we determined three pincipal components based on the professional aspects and the main values of the medicinal bath place characteristics. The selection also meets the Scree-test rule of thumb criterion, because after the third factor the value of the explained variance significantly deteriorates. At the fourth factor number that is the rule of thumb, which is relevant due to the explained variance. The break at the fourth factor number confirms the choice of the three-factor solution.

These criteria gave us the number, of principal components considered justified for the investivation. As can be seen from the presented figure, the examination of a total of three principal components became justified (Table 3).

Table 3

Explained variance of medicinal bath place characteristics

Component	SS loadings	% of variance	Cumulative [%]
1	3.49	20.5	20.5
2	2.76	16.2	36.7
3	2.48	14.6	51.3

Source: Own calculation and editing

The three principal components isolated in the examinations explain a total of about 51.3% of the variance of the tested sample, which is a good value, but does not reach the 60% threshold accepted as a rule of thumb. This also confirms that the proportion of factors that could not be taken into account even with the use of principal component analysis is relatively large. In other words, this should be seen as a warning sign from the point of view that these principal components explain, interpret, a little more than half of the variance of the examined sample. Furthermore, it also means that in the case of medicinal bath place characteristics, there is a significant difference in opinions in the sample. The medicinal bath place characteristics are explained by the first principal component in 20.5%, the second principal component in 16.2%, and the third principal component in 14.6%. In the three principal components, the principal component weights show relatively large differences, as a result of which these three principal components are suitable for revealing three well-separated ways of thinking with their help.

From the component matrix, it can be read which variable best characterizes which factor based on its largest absolute values (Table 4).

Table 4

Component-matrix system of medicinal bath place characteristics

Specification	Component			Uniqueness
	1	2	3	
The cleanliness and charm of the medicinal bath park	0.766	–	–	0.390
Transportation (accessibility, parking)	0.757	–	–	0.362
Favorable cost of accomodation	0.722	–	–	0.408
Quality of accomodation	0.663	–	–	0.544
Beautiful environment	0.594	0.311		0.538
Gastronomy quality	0.323	–	–	0.793
Quality of medicinal service and treatment	–	0.768	–	0.401
Wide range of treatments	–	0.656	–	0.499
Medicinal bath and the safety of the settlement (low crime rate)	–	0.618	–	0.544
Treatment cost are low	0.495	0.584	–	0.402
Silence and calme	–	0.532	–	0.692
A wide selection of cultural attractions in the spa settlement	–	0.498	0.450	0.544
Mass events, concert, festivals, etc.	–	–	0.836	0.274
Entertainment (cinema, dance, etc.)	–	–	0.782	0.360
Wide selection of tourist attractions in the settlement	0.474	–	0.616	0.395
Opportunity to get to know other medicinal bath visitors	–	0.371	0.509	0.538
Cleanliness of streets	0.398	–	0.421	0.593
Note. 'Varimax' rotation was used				

Source: Own calculation and editing

In order to make the component matrix easier to interpret, three factors were defined using Varimax rotation. As a result of the rotation, the variables were classified to the individual principal components and factors. Based on these, we separated the medicinal bath place characteristics according to three main dimensions and ways of thinking.

In the first principal component, the factors related to the spa environment, such as the cleanliness and charm of the medicinal bath park and accessibility, parking, or the beautiful environment, received high factor loading values. The ratio of the component values also significant for those, wich are related to the other services of the medicinal bath place, such as accomodation and gastronomy. Overall, this dimension can be considered as one that includes very favorable opinions about the medicinal bath place environment.

In the second principal component, the opinions related to the quality of medicinal service and treatment, wide range of treatments and low-cost medical treatments appear with significant principal component factor loading. These factors lend a kind of „expert" character to this dimension. It is noteworthy that in this principal component, the opinion regarding the medicinal bath and the safety of the settlement, as well as the low crime rate, received a high value. Overall, this dimension can be considered as one that includes very favorable opinions about the medicine of the medicinal bath place.

The basic factors of the third main component are mass events, concerts, festivals, entertainment such as cinema, dance, and wide selection of tourist attractions in the settlement. Interestingly, the cleanliness of the streets was included in this dimension, which reflects the environmental culture of the locals. Overall, this dimension can be considered as one that includes very favorable opinions about the culture of the medicinal bath place. Based on these, we separated three main dimensions and lines of thinking from the point of view of the medicinal bath place characteristics (Table 5).

Table 5

The factor system of medicinal bath place – characteristics

Factor	Indicator	Estimate	SE	95% confidence interval		*Z*	*p*
				lower	upper		
1	2	3	4	5	6	7	8
Factor 1	the cleanliness and charm of the medicinal bath park	0.599	0.0550	0.492	0.707	10.89	<.001
	transportation (accessibility, parking)	0.618	0.0540	0.512	0.724	11.45	<.001
	favorable cost of accomodation	0.544	0.0549	0.436	0.652	9.90	<.001
	quality of accomo-dation	0.403	0.0508	0.304	0.503	7.94	<.001
	beautiful environ-ment	0.462	0.0486	0.367	0.558	9.52	<.001
	gastronomy quality	0.307	0.0557	0.198	0.416	5.51	<.001

cont. Table 5

1	2	3	4	5	6	7	8
Factor 2	quality of medicinal service and treatment	0.426	0.0609	0.307	0.545	7.00	<.001
	wide range of treatments	0.556	0.0586	0.441	0.671	9.48	<.001
	medicinal bath and the safety of the settlement (low crime rate)	0.444	0.0623	0.322	0.566	7.12	<.001
	treatment cost are low	0.738	0.0639	0.612	0.863	11.54	<.001
	silence and calme	0.392	0.0641	0.267	0.518	6.12	<.001
Factor 3	a wide selection of cultural attractions in the spa settlement	0.394	0.0662	0.264	0.524	5.95	<.001
	mass events, concert, festivals, etc.	0.618	0.0669	0.487	0.749	9.24	<.001
	entertainment (cinema, dance, etc.)	0.657	0.0697	0.520	0.793	9.42	<.001
	wide selection of tourist attractions in the settlement	0.649	0.0608	0.530	0.768	10.68	<.001
	opportunity to get to know other medicinal bath visitors	0.330	0.0878	0.158	0.502	3.76	<.001
	cleanliness of streets	0.470	0.0613	0.350	0.590	7.67	<.001

Source: Own calculation and editing

In the first dimension, the factors related to the medicinal bath place environment were given a very high factor loading value. In the second dimension, factors related to medicinal bath place medicine were given a very high factor loading value. In the third dimension, the factors related to the medicinal bath place culture were given a very high factor loading value. The three ways of thinking thus formed are the environment-oriented way of thinking, the medicine-oriented way of thinking and the culture-oriented way of thinking. On the basis of the three examined schools of thought, we were able to determine significant differences in almost every single case, which support the fact that the triple grouping, which was established during the creation of the schools of thought, is valid.

The differences are clearly visible based on the average values obtained for the degree of identification with certain statements examined in the lines of thinking. In the environment-oriented direction of thinking, as we expected, all indicators received a very high acceptance value. The highest acceptance value was the opinion that the beautiful environment is an important attribute of a medicinal bath place (4.21), and the cleanliness and charm of the medicinal bath park (4.09) as well as the accessibility of the medicinal bath place and the parking conditions (4.07) are also important. In terms of medicine-oriented thinking, the most important characteristic of a medicinal bath place is silence and calme (4.56), wide range of treatments (4.20) and the quality of medicinal service and treatment (4.14). Interestingly, the treatment costs are the least significant in the medicine-oriented way of thinking (3.89). The culture-oriented way of thinking has the lowest average indicators. In the direction of culture-oriented thinking, the cleanliness of the streets (4.00), the wide selection of cultural attractions in the spa settlement (3.99) and teh wide selection of tourist attractions in the settlement (3.92) are included. In this way of thinking, the least important thing is to have the opportunity to get to know other medicinal bath visitors (3.52).

Discussion

The present study deals with the significant issue of tourism management as an interdisciplinary scientific field, the significance of the characteristics of medicinal bath place in Hungary among Hungarian consumers. By preparing this study, we aimed to contribute to the understanding of the importance of medicinal bath place characteristics among the Hungarian population and to expand the limited research on the topic so far.

Based on the socio-demographic characteristics of the 200 Hungarian respondents who completed the questionnaire, we managed to reach the middle-aged middle class in the broad sense, who are currently and are expected to be visitors to the medicinal bath places in the future. 49% of those filling out the questionnaire are middle-aged, 92% have a secondary education or higher, 93.5% have an average or above-average income. So the sample is limitedly representative as the base population is not known. In the primary study, using modern mathematical and statistical methods, consumers' opinions on the features that contribute to a successful medicinal bath place stay were examined.

From the test results obtained with the help of a survey based on the objective of the research, two conclusions regarding the importance of the characteristics of medicinal bath place follow, which can be considered as new, scientifically proven results. As a first finding, it was proven that the Hungarian middle-aged middle class perceives the characteristics of the medicinal bath place. It was proven because the interviewees perceived the importance of medicinal bath place characteristics, but the opinions differed. The standard deviation of the answers was below 1 with one exception, which is acceptable. It follows from all of this that the respondents perceive the characteristics of the medicinal bath place and believe that some of them play a significant role in a successful stay at the medicinal bath place. These are the silence and calme, the quality of the accommodation, the beautiful environment, the wide range of treatments, the quality of the gastronomy, and the quality of medicinal service and treatment. The mass events, concerts, festivals, entertainment such as cinema, dancing, and the opportunity to get to know other medicinal bath visitors play the least role in a successful medicinal bath place stay. As a second finding, it was proven that among Hungarians, the main characteristics of medicinal bath places can be divided into characteristically different ways of thinking. It was proven because we identified three groups of principal components, taking into account the test criteria, using sophisticated mathematical-statistical data processing methods. One of the principal component groups defined the indicators that clearly included a positive and favorable opinion about the medicinal bath place environment. The other is the one that favorably evaluated the characteristics related the medicinal of the bath place and showed its importance. And the third included those indicators that mainly focused on cultural factors in the medicinal bath place area. As a result, three clearly distinguishable ways of thinking were identified, the environment-oriented way of thinking, the medicine-oriented way of thinking and the culture-oriented way of thinking, which contribute to a successful medicinal bath place stay.

Comparing our results with similar studies from other countries, we conclude that, like domestic spa guests, the availability and development of medical services is also important for the majority of Greek spa guests (Papageorgiou and Beriatos 2011). Compared to the characteristics of spas in Vojvodina, the characteristics of Hungarian spas can be better assessed and provide users with more complex and advanced medical tourism opportunities (Košić et al. 2011, Vörös and Szabó 2024). According to a survey conducted in neighboring Romania (SWOT analysis), the proper use of their country's outstanding natural resources for medical tourism requires the modernization of accommodation and catering facilities, as well as the development of recreation and leisure facilities (Neacsu and Platon 2019). The results of foreign researchers confirm our position that for the development of a suitable medicinal bath place, a scientific assessment of the features and user needs of the given tourist region is essential, with the results of these analyzes the necessary development directions can be determined for a more effective medicinal bath place stay.

These new, scientifically proven results can help medicinal bath place planners and decision makers to better satisfy guest needs, medicinal tourism planners, tourism marketing professionals to better utilize new market opportunities, and medicinal bath managers to better meet guest needs, thereby contributing to a successful medicinal bath place stay for guests.

Translated by Ágnes Erzsébet Hojcska, Zoltán Bujdosó

Accepted for print 10.10.2024

References

BABBIE E. 2017. *The practice of social science research.* Balassi Publishing House, Budapest.

BALI L. 2014. *The role of the railway in regional development in austro-hungary and in hungarian-croatian relations today, especially with regard to the availability of Rijeka (Fiume).* Central European Papers, 2(1): 160–166. DOI: 10.25142/cep.2014.011

BRAMWELL, B., HIGHAM, J., LANE, B., MILLER, G. 2017. *Twenty-five years of sustainable tourism and the Journal of Sustainable Tourism: looking back and moving forward.* Journal of Sustainable Tourism, 25(1): 1–9. DOI: 10.1080/09669582.2017.1251689

BUJDOSÓ Z., GYURKÓ Á., BENKŐ B. 2019. *Tourism development in Hungary on the example of Northern Hungary Region.* Folia Geographica, 61(2): 86–103.

FARKAS T. 2021. *The role of the social capital in rural development. Case study analysis of village research camps in Romania and Hungary.* European Countryside, 13(3): 584–598. DOI: https://doi.org/10.2478/euco-2021-0033

HOJCSKA Á.E., SZABÓ Z., BUJDOSÓ Z. 2022. *Multi-aspect overview of mineral-water-based therapies of musculoskeletal disorders in Hungary.* Ecocycles, 8(2): 23–36. DOI: https://doi.org/10.19040/ecocycles.v8i2.235

HOJCSKA Á.E., SZABÓ Z. 2021. *Investigating natural treatment factors and inequalities of medicinal water institutions in the aspect of tourism in Hungary.* Geojournal of Tourism and Geosites, 36(2spl): 555–562. DOI: https://doi.org/10.30892/gtg.362spl01-683

KELLER V., GULYÁS G., MOLNAR E.I., PRINTZ-MARKÓ E. 2021. *The future of the hungarian spa sector (thermal and medicinal baths).* In: SZABÓ Z., HOJCSKA Á.E., BUJDOSÓ Z. (eds*.). Spa town inspiration: 3rd Science Papers of the Spa Towns*, pp. 61–94. Hajdúszoboszló.

KOŠIĆ K., PIVAC T., ROMELIĆ J., LAZIĆ L., STOJANOVIĆ V. 2011. *Characteristics of thermal–mineral waters in Backa region (Vojvodina) and their exploitation in spa tourism.* Renewable and Sustainable, Energy Reviews, 15(1): 801–807. DOI: https://doi.org/10.1016/j.rser.2010.09.004

MAGYAR M. 2017. *Animation-entertainment service value in the Hungarian wellness hotels.* In: SZABÓ Z. (ed.). *The values of spa towns.* Magyar Fürdővárosok Szövetsége: 90–113., Szentes.

MAYER Á., HOJCSKA Á.E. 2018. *The role of evidence-based balneo- and hydrotherapy treatments in the treatment of knee osteoarthritis.* In: SZABÓ Z. (ed.). *Development of spa towns.* Magyar Fürdővárosok Szövetsége: 147–168., Túrkeve.

MILORADOV K., EIDLINA, G. 2018. *Analysis of tourism infrastructure development projects in the context of "Green economy".* European Research Studies Journal, 21(4): 20–30. DOI: 10.35808/ersj/1100

Morabi Jouybari H., Ghorbani A., Mousazadeh H., Golafshan A., Akbarzadeh Almani F., Dávid L.D., Ritter K. 2023. *Smartphones as a platform for tourism management dynamics during pandemics: A case study of the Shiraz metropolis, Iran.* Sustainability, 15(5) Paper: 4051. DOI: https://doi.org/10.3390/su15054051

Muhi B., Đurković J.V. 2021. *Smart city solutions as city marketing and city branding tools – Case study of Novi Sad.* Tourism and Rural Development Studies, 6(3): 109–123. DOI: https://doi.org/10.15170/TVT.2021.06.03.07

Navarro J., Martínez M., Jiménez J. 2020. *An approach to measuring sustainable tourism at the local level in Europe.* Current Issues in Tourism, 23(4): 423–437. DOI: 10.1080/13683500.2019.1579174

Neacsu M. N., Platon O.E. 2019. *Using SWOT analysis to substantiate marketing strategies for balneo-tourism.* New Trends and Issues Proceedings on Humanities and Social Sciences [Online], 6(8): 030–038. Available from: www.prosoc.eu

Papageorgiou M., Beriatos E. 2011. *Spatial planning and development in tourist destinations: A survey in a Greek spa town.* Int. J. Sus. Dev. Plann., 6(1): 34–48. DOI: 10.2495/SDP-V6-N1-34-48

Polischchuk E., Bujdosó, Z. 2022. *Theoretical connections between behavioral economics and tourism.* Acta Carolus Robertus, 12(1): 75–83. DOI: https://doi.org/10.33032/acr.2870

Printz-Markó E., Molnar E.I. 2020. *Health tourism – a new system-model based on the four basic elements.* In: Fotea S.L., Fotea I.Ş., Văduva S.A. (eds.). *Challenges and opportunities to develop organizations through creativity,* Technology and Ethics, Cham, pp. 253–258. DOI: 10.1007/978-3-030-43449-6_14

Starczewski K., Affek-Starczewska A., Rymuza, K., Bombik A. 2018. *Analysis of tourist attractiveness of communes situated on the Krzna river.* Polish Journal of Natural Sciences, 33(1): 171–182.

Stojanović V., Lazić L., Dunjić J. 2018. *Nature protection and sustainable tourism interaction in selected Ramsar sites in Vojvodina (Northern Serbia).* Geographica Pannonica, 22(3): 201–207. DOI: 10.5937/gp22-16637

Szabó Z., Hojcska Á.E. 2020. *Recreational tourist spa services and the correlation of their use at a SPA service provider.* Recreation, 10(1): 36–39. DOI: 10.21486/recreation.2020.10.1.4

Szabó Z. 2021. *Attitudes Relating to Making Use of Spa Services in Hungary.* Selye E-Studies, 12(1): 16–23.

Szabó Z., Kocsondi J., Lakner Z. 2013. *Role of thermal-tourism in regional development – a case study from Hungarian side of the Hungarian-Croatian border: Uloga termalnog turizma u regionalnom razvoju – studija slucaja s Madarske Strane Madarsko-Hrvatske Granice.* Podravina: Casopis za Multidisciplinarna Istrazivanja, 12(23): 70–76, https://hrcak.srce.hr/107190, access: 10.06.2024.

Széchy A., Szerényi Z.S. 2023. *Valuing the recreational services provided by Hungary's Forest Ecosystems.* Sustainability, 15(5) Paper: 3924, DOI: https://doi.org/10.3390/su15053924

Takács S.Z. 2016. *Introduction to mathematical statistics.* Antrész Publishing House, Budapest.

Vörös A., Szabó Z. 2024. *A vajdasági turizmus változásai és egészségturisztikai lehetőségei.* In: Csákvári, T; Varga, Z (eds.). *VII. Zalaegerszegi Nemzetközi Egészségturizmus Konferencia Tanulmánykötet.* Pécsi Tudományegyetem Egészségtudományi Kar (PTE ETK): 195–206, Pécs.

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(4): 265–279, Y. 2024

DOI: 10.31648/pjns.10719

USE OF HERBAL PLANTS IN THE OFFER OF AGRITOURISM FARMS

Bożena Jaworska

ORCID: 0000-0001-8843-6391
University of Warmia and Mazury in Olsztyn
Department of Tourism, Recreation and Ecology

Key words: words: herbs, herbal plants, offer, agritourism farm.

Abstract

The aim of the study was to assess the activities of agritourism farms in the use of herbal plants. The basis for the assessment was an analysis of the agrotourism offer proposed in this respect on the websites of the surveyed farms. The offer of 25 agrotourism farms from different regions of Poland was analysed, which concerned the use of herbs in ornamental, utilitarian, cosmetic-therapeutic and educational aspects. The use of herbal plants in individual aspects varied considerably. All farms used herbs for ornamental and nutritional purposes. The use of herbs in the commercial and cosmetic-therapeutic aspects was on offer in every fourth farm. The educational aspect of the use of herbs was offered by three quarters of the farms. The educational offer was mostly carried out in the form of workshops. The topics of the classes varied. Most often, workshops were offered on learning about medicinal plants and their properties. Less frequently, workshops were offered on cooking, growing herbs, making herbal cosmetics and herbal therapies. The fewest workshops were offered on making herbal decorations. In general, the offer of using herbal plants in the activities of agritourism farms was well integrated into the agritourism context, and at the same time it fitted well into the cultural heritage of the Polish countryside.

Introduction

Agrotourism is one of the forms of rural tourism, which includes various types of services related to spending holidays in the countryside, ranging from accommodation, through partial or full-day meals, to a very diverse package of accompanying services. An important element of running an agritourism business is skillful communication of its services to all those interested in spending their leisure time in the countryside. The offer, which each agritourism farm can present to potential recipients of its services, serves this purpose. Expectations of service recipients and

Address: Bożena Jaworska, University of Warmia and Mazury in Olsztyn, e-mail: bozena.jaworska@uwm.edu.pl

competitiveness on the market, make agritourism farms strive to have the widest possible offer and the highest possible quality of services (Łukasiewicz 2018, Matlegiewicz 2015, Przeorek 2018). This also applies to the offer related to the possibilities of using the potential of herbal plants in the activities of agritourism farms.

Herbal plants (herbs) are a large group of botanically and usefully diverse plants. They belong to many botanical families, genera and species. In Polish, the name herbs is not very precisely defined and has a rather broad meaning because it refers to all plants containing in their composition active biological compounds that can influence physiological processes in human and animal organisms (Szempliński 2017).

For centuries, man has inhabited areas rich in plant life. Through contact with them, he has discovered the nutritional, poisonous and healing properties of plants. From generation to generation, knowledge of herbal plants and their properties has developed through experience and observation. Initially passed on orally, it was later written down. On this basis, skills in the use of herbal plants grew and knowledge of them increased. The oldest records of herbal plants, how they were harvested, processed and used, date back five thousand years (Drozd 2012, Makarska-Białokoz 2019, 2020a, 2020b).

All accumulated knowledge about herbal plants has been verified by scientific research. Thanks to the original intuitive attempts to use herbal plants and their subsequent scientific confirmation, it is now possible to use them in a fully informed and responsible manner (Kuźnicka and Dziak 1984). Herbal plants are used in many fields of human activity. Among the herbal plants are species that, due to their active substances, can only be used under controlled conditions (Bacler-Żbikowska and Stebel 2023, Rivera et al. 2013). There are also herbal plants whose use in conventional medicine is limited, but they are of importance as plants used in non-conventional (alternative) medicine, in various types of therapies (Ewansiha et al. 2022, Pal and Shukla 2003). In addition to medicinal use, herbal plants are widely used in the food industry. Among other things, they are used to enrich the taste of food and beverages as so-called spice plants (Kudełka 2008). Areas that benefit from the properties of herbal plants also include the cosmetic and perfume industry (Jankowiak and Schaschner 2013). There are also those herbaceous plants that provide tannins for the tanning industry, fibres for the textile industry or dyes used in artistic weaving (Newerli-Guz 2016).

Some of the uses of herbal plants have been applied in various forms of agro-tourism activities (Chaiyakot and Visuthismajarn 2012, Firmino 2010, Hakim et al. 2016, Sala 2021, Widayati et al. 2024). On agritourism farms, herbs are used in various aspects. This is reflected in the offer created based on herbal plants and their place both in the tradition and culture of the village and in the contemporary agritourism farm. One of the interesting areas of research in the context of the development of agritourism farm activities is the potential of their use of herbal plants and the associated offer. The aim of this study is to assess the activities of agritourism farms in terms of the use of herbal plants.

Materials and Methods

The research material was obtained from information posted on the websites of agritourism farms as part of an offer concerning the use of herbal plants in their activities. The information presented on the single electronic address of agritourism farms was preliminarily analysed in order to establish classification criteria suitable for the study. Only agritourism farms with their own website were analysed. The condition for qualifying an agritourism farm for the study was to have its own website, accommodation and catering offer and to include at least two activities related to the use of herbal plants in the offer. The criteria were defined so that at least one farm from each province qualified for the study. The research covered the entire area of Poland, broken down by voivodeship. The search for agrotourism farms was conducted taking into account their location. Objects in each voivodship were searched for successively. If the number of facilities meeting the criteria set out for the study was less than three, all agritourism farms were taken into account. If the number was higher than three, further selection criteria were based on the diversity of agrotourism services offered, in terms of the use of herbal plants, and those with the widest offer were classified. Finally, 25 agrotourism farms from different regions of Poland were selected for the study. Their characteristics were drawn up on the basis of a thorough analysis of the data found on the websites of these facilities. If a farm belonged to a network of educational homesteads, the offer offered there was also included in the general offer of the farm with regard to the use of herbal plants.

The methods of analysing the collected data consisted in selecting agrotourism farms meeting the assumed criteria, analysing the full offer of selected agrotourism farms, extracting data on the use of herbal plants in each of the facilities, and grouping these data, depending on the way the herbs were used, into the following aspects: ornamental, utilitarian (nutritional), therapeutic-cosmetic, commercial and educational. For the educational aspect, the workshops on offer were grouped according to their subject matter. The data were compiled using Microsoft Excel and then analysed and interpreted in terms of the research topic.

Results and Discussion

The use of herbal plants in the activities of agritourism farms is based on the centuries-old tradition of herbalism and herbal medicine in the Polish countryside (Ciechomska 2018, Kuźnicka and Wysakowska 1993). Herbal plants and their properties have been known and valued by the rural community there for centuries. They were sought after, extracted, processed and used, and the skills to use them were passed down from generation to generation. Herbal plants were initially extracted from clumps growing naturally in meadows and forests. Later, they also began to be cultivated on peasant homesteads (Nowiński 1980). Herbs became common in village gardens at the turn of the 18th and 19th centuries (Iwaniuk and Kowalik 2014). They were present in all parts of the village garden, depending on the function they served. In the 'fore-garden', herbs used primarily for medicinal or ceremonial purposes grew among ornamental plants. In the 'vegetable garden' herbs used in the village kitchen were grown. Within the homestead, under the fences, in the grove and in the orchard between the trees, grew wild herbaceous plants used for healing and rituals, i.e. the so-called 'weeds that heal' (Szot-Radziszewska 2017). Herbaceous plants were valued for their ornamental qualities, medicinal, spice and honey-giving properties, as well as their oil, dye, fibre and insecticide properties (Szempliński 2017). They were also used in traditional folk ceremonies and in the celebration of many church festivals. In addition, they were attributed magical powers that were reflected in folk beliefs (Szot-Radziszewska 2005).

Agritourism farms have become the refuge of herbal traditions in the Polish countryside, and the development of rural tourism has resulted in the use of herbal plants as part of agritourism activities. The offer of agritourism farms for the use of herbal plants can be very rich (Klepacka-Dunajko and Kalużna 2015, Sala 2021, Woś 2017). It can be based on garden or field cultivation of herbaceous plants. All surveyed agritourism farms (25) base their offer for the use of herbal plants on their cultivation in the garden (Table 1). Gardens in relation to agrotourism farms are areas with a specified use, with recreational and leisure, didactic and educational, utilitarian and aesthetic purposes (Kałużny and Hanus-Fajerska 2016). Additionally, 7 farms (28%) still cultivate herbs in the field (Table 1).

Table 1

Aspects of the use of herbal plants in the offer of agritourism farms

Order number	Name of agritourism farm	Voivodship	Garden/field cultivation of herbs	Use of herbal plants				
				Decorative aspect	Nutritional aspect	Therapeutic-cosmetic aspect	Commercial aspect	Educational aspect
1	'Chata Morgana'	Lower Silesia	g/f	+	+	-	-	+
2	'Lovenda Kujawska'	Kuyavia-Pomerania	g/f	+	+	-	+	+
3	'Ekogościniec Pachotówko'	Kuyavia-Pomerania	g	+	+	-	-	+
4	'Wiedźminowo'	Lublin	g	+	+	-	-	+
5	'Koziołek Suchodołek'	Lubusz	g	+	+	-	+	+
6	'Leśne Zacisze'	Lubusz	g	+	+	-	-	+
7	'Synowcówka'	Lodz	g	+	+	-	-	-
8	'Łopusze'	Lesser Poland	g	+	+	-	-	+
9	'Willa Jasna'	Lesser Poland	g	+	+	-	-	+
10	'Pod Dębem'	Masovia	g	+	+	-	-	+
11	'Uroczysko'	Opole	g	+	+	-	-	+
12	'Zadnie Łuki'	Subcarpathian	g	+	+	-	-	-
13	'Ziołowy Zakątek'	Podlasie	g	+	+	+	+	+
14	'Czar Podlasia'	Podlasie	g	+	+	+	-	+
15	'Lawendowa Osada'	Podlasie	g/f	+	+	+	-	+
16	'U Lawendowej Wiedźmy'	Silesia	g/f	+	+	-	-	-
17	'Oaza Zdrowia'	Holycross	g	+	+	+	+	+
18	'Siedlisko Orzechowe Wzgórze'	Warmia-Masuria	g	+	+	+	-	+
19	'Ziołowa Dolina'	Warmia-Masuria	g/f	+	+	-	+	+
20	'Ziołowy Dzbanek'	Warmia-Masuria	g	+	+	+	-	+
21	'Lawendowe Pole'	Warmia-Masuria	g/f	+	+	+	+	+
22	'Zagroda u Kuski'	Greater Poland	g	+	+	-	-	+
23	'Zielone Zacisze'	Greater Poland	g/f	+	+	+	+	+
24	'Knieja'	West Pomerania	g	+	+	-	-	+
25	'Piotrogródek'	West Pomerania	g	+	+	-	-	-
All [numer]		–	–	25	25	8	7	21
All [%]		–	–	100	100	32	28	84

In field cultivation, lavender is the most commonly grown herb. Only one farm cultivates herbs in the field for the extraction of herbal raw material other than lavender. The range of uses of herbal plants can include ornamental, utilitarian (nutritional), therapeutic-cosmetic, commercial and educational aspects of these plants.

Herbal plants can only be present in the garden with an ornamental function (KOWALIK and KOWALSKA 2013). They can be a great enrichment of flower beds Thanks to their varied colours, shapes and textures, they add variety to plant compositions and, by emitting pleasant aromas, stimulate the senses (MARWICKA et al. 2015). This way of using herbs is included in the offer of all surveyed agritourism farms (Table 1).

The utilitarian aspect of herbal plants is based on their extraction for various purposes within the farm business. Herbs can be used in agro-tourism food offerings as an ingredient in traditional regional products and dishes (ORŁOWSKI 2018, 2022). They enrich the taste and aroma of dishes, traditionally made cheeses, pickles, hams or sausages. Herbs also work well as an addition to sauces, salads and various drinks. They can be used to prepare infusions, juices, syrups and wines and liqueurs, which can enhance the offer of the agritourism farm. All the farms surveyed offer the use of herbs for food purposes (Table 1).

Herbal plants can also be used for therapeutic and cosmetic purposes. This type of activity is on offer at 32% of the surveyed agrotourism farms (Table 1). The offer in this respect can be very diverse (PRZEZBÓRSKA 2010). Many herbs are suitable for the preparation of natural cosmetics, which can be used on an agritourism farm. Wellness, physiotherapy and cosmetology treatments using herbal plants can also be offered (GEDIYA et al. 2011, JANKOWIAK and SCHASCHNER 2013). These include various types of baths, massages, rituals and other treatments aimed at addressing health, regeneration and also well-being needs. The 'Ziołowy Zakątek' and 'Lawendowa Osada' farm have a wide range of activities in this area. The treatments offered there are performed using various herbs at 'Ziołowy Zakątek', on the basis of lavender at 'Lawendowa Osada'. Agrotourism farms 'Czar Podlasia' 'Siedlisko Orzechowe Wzgórze', 'Ziołowy Dzbanek' 'Lawendowe Pole', 'Zielone Zacisze', also offer the use of herbs in the therapeutic-cosmetic aspect, but to a lesser extent. The therapeutic aspect of the use of herbs can also be realised in the offer of phytotherapy. Phytotherapy, i.e. treatment with herbs, is one of the oldest methods of natural medicine and also one of the branches of unconventional medicine, but it requires knowledge and experience (BAHMANI et al. 2016). Typical phytotherapy is only offered by the 'Oaza Zdrowia'. A centre for dietetics and phytotherapy, it is run there by a certified phytotherapist and nutritionist. Her dietary recommendations and product selection for chronic health problems are particularly appreciated. Offerings using herbs for therapeutic purposes can also be quite different from others. Herbal plants are involved in horticotherapy (CAPUCHO et al. 2023). Hortitherapy is a non-conventional therapeutic method that involves influencing a person's overall condition through their contact with plants in the garden. It can be passive or active hortiterapy. Passive hortiterapy is primarily walking and observing plants to stimulate the senses in order to achieve tranquillity, peace and relaxation. Active hortiterapy, on the other hand, takes place through physical work in the garden. Gardens designed for hortiterapy activities are so-called sensory gardens, which are designed to stimulate the senses of hearing, touch, smell, sight and taste. Such gardens must therefore be specifically designed to achieve the goal of the therapy conducted there (LATKOWSKA and MIERNIK 2012). This type of use of herbal plants is offered by the 'Ziołowy Dzbanek' agrotourism farm and 'Siedlisko Orzechowe Wzgórze'.

Another way of using herbs in the activities of agro-tourism farms is by offering to sell them. The sale concerns both medicinal raw materials usually in the form of dried or oil, as well as culinary or cosmetic products made from the processing of medicinal plant raw materials. Handicraft items made from herbs are also often available. This way of using herbal plants is offered by 28% of the surveyed agro-tourism farms (Table 1).

An agrotourism offer based on the use of herbal plants may also concern educational activities thematically related to these plants (WIŚNIEWSKA and SZYMAŃSKA 2020). The offer in this respect is most often based on proposals for thematic workshops organised by the farms, but can also be implemented in a completely different way. 84% of the surveyed agritourism farms have an educational offer on herbaceous plants (Table 1).

The cognitive aspect of herbs can also be realised through workshops on the identification of herbal plants, learning about the raw herbal material, its properties and possible uses. The herbal raw material is not always the whole plant, often only a part of it (leaves, flowers, fruits, seeds, rhizomes or other parts of the plant), and the extraction of herbal raw materials follows strict rules (SZEMPLIŃSKI 2017). Workshop participants learn to recognise different species of herbs, how to obtain herbal raw material from them, their properties and purpose. This type of workshop is offered by 76% of the surveyed farms (Table 2). On the farm 'Ziołowy Zakątek' it is implemented on the basis of the Podlaski Herb Garden with the status of a botanical garden (KLEPACKA-DUNAJKO and KAŁUŻA 2015). Each plant in the garden here has a plaque with its name and description. A mini garden of herbaceous, utilitarian and forgotten plants bearing identifiers also has a farm called ‘Lawendowe Pole’.

Table 2

Types of workshops using herbal plants on offer at agritourism farms.

Types of work-shops	Order number of agritourism farms according to Table 1																									Number	Share [%]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
Workshop to learn about herbal plants, their properties and uses	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	-	+	-	19	76
Herbal plant cultivation workshop	+	+	+	-	+	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	9	36
Workshop on the culinary use of herbs	-	+	-	-	+	-	-	+	+	+	+	-	+	-	+	-	+	-	-	-	+	-	-	-	-	10	40
Workshop on making herbal cosmetics and applying herbal therapies	+	+	-	+	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-	+	+	+	+	+	-	11	44
Workshops for creating decorations with herbs	-	+	+	-	-	-	-	+	-	-	-	-	+	-	+	-	-	-	-	+	-	-	+	-	-	7	28

Agri-tourism farms can also offer workshops to enrich knowledge and practice in the cultivation and care of herbs. Herbs are quite a diverse group of plants. The conditions for their cultivation must meet the environmental requirements associated with where they are found in natural plant communities. They most often have high light requirements, low moisture requirements and variable soil requirements. Most common herbs can be grown in an agro-garden. However, not all herbs are suitable for traditional cultivation; some can only survive in container cultivation (GAWŁOWSKA 2014). Workshop participants create their own small herb crops, preparing plots, sowing, planting, tending and fertilising the plants. This type of workshop is offered by 36% of the surveyed farms (Table 2) and these are: ‘Chata Morgana’, ‘Lovenda Kujawska’, ‘Ekogościniec Pachotówko’, ‘Koziołek Suchodołek’, ‘Leśne Zacisze’, ‘Willa Jasna’, ‘Lawendowa Osada’, ‘Siedlisko Orzechowe Wzgórze’, ‘Lawendowe Pole’.

Another form of workshop on the offer of agritourism farms based on herbal plants can be their use for culinary purposes. Herbs are an essential component of dishes in any agritourism kitchen. Products and preparations based on herbs are also (KUŹNICKA and DZIAK 1984). The ability to use them in traditional regional cuisine can be taught in culinary workshops (ORŁOWSKI 2016, ORŁOWSKI and WOŹNICZKO 2016). Workshop participants take part in the process of preparing dishes with herbs, gaining the ability to make herbal infusions, juices, syrups and preserves, as well as vinegars and oils with the addition of specific herbs. They can also learn how to make herbal tinctures. Workshops on culinary topics are offered by 40% of agritourism farms (Table 2). Most of them base their workshops on the preparation of beverages, infusions and herbal preserves. These include 'Lovenda Kujawska', 'Koziołek Suchodołek', 'Leśne Zacisze', 'Pod Dębem', 'Uroczysko'. Composing herbal mixtures to make infusions or spices is on offer at 'Ziołowy Zakątek'. Workshops on the principles of using herbal spices in various dishes, using them in meat marinades and vegetable and fruit preparations, adding them to salads and salads are offered by 'Willa Jasna'. 'Lawendowa Osada' has on offer the preparation of dishes with the addition of lavender. Baked goods with herbs are offered by the 'Lawendowe Pole' and the 'Oaza Zdrowia'.

The theme of the workshop can also be based on the use of herbal plants for cosmetic or therapeutic purposes. Herbs are often used in cosmetics for their healing and care properties. Natural herbal raw materials can be used in personal care as an ingredient in creams, masks and body wraps, but often their use also has a therapeutic effect. The possibilities for producing natural cosmetics based on herbal plants and treatments using them are extensive (GEDIYA et al. 2011, JANKOWIAK and SCHASCHNER 2013, PRZEZBÓRSKA 2010). Workshop participants most often compose herbal cosmetics on their own, and less often learn the use of herbs in phytotherapy. Cosmetic-therapeutic workshops are offered by 44% of the farms (Table 2). Workshops on the cosmetic use of herbal plants take place in most lavender agro-tourism farms ('Chata Morgana', 'Lovenda Kujawska', 'Lawendowa Osada', 'Lawendowe Pole', 'Zielone Zacisze'). These include workshops for the production of bath balls, soaps, hydrolats, lavender oils and creams. The agritourism farms 'Ziołowy Zakątek', 'Ziołowy Dzbanek', 'Wiedźminowo', 'Knieja' base this type of workshop on the composition of various herbal ingredients other than lavender. Only two farms offer workshops on typical phytotherapy and these are 'Oaza Zdrowia' and 'Zagroda u Kuski'.

Handicraft workshops using herbs can also be an interesting proposition in the offer of agritourism farms. Herbs are a very versatile material for artistic inspiration (MAGOWSKA 2014). They are often a decorative element of agritourism interiors, dried, arranged in bouquets, enclosed under glass in the form of paintings, or embedded in wax. Workshop participants make a variety of objects from herbs themselves. 28% of the surveyed agritourism farms offer this type of workshop (Table 2). Most of them offer workshops on weaving herbal/lavender garlands ('Zielone Zacisze', ‘Lovenda Kujawska’, ‘Ekogościniec Pachotówko’, ‘Lawendowa Osada’). In the field of handicrafts, workshops are also offered for weaving herbal macchiatos, making flower compositions on a tambourine, creating flower compositions on canvas (‘Ziołowy Zakątek’), making herbal handmade paper or candles (‘Ziołowy Dzbanek’, ‘Zielone Zacisze’, ‘Łopusze’) or lavender/herbal fusetek (‘Lovenda Kujawska’).

The agritourism offer for the use of herbal plants presents diverse proposals and indicates the most common practices related to their use. It is directly correlated with the demand observed on the tourist market It was created on the basis of the needs signalled by tourists interested in the traditional use of herbs and all kinds of regional products made with their participation (WOŚ 2017). Agritourism farms, observing the interest in the offer regarding the use of herbal plants, meet the expectations of its recipients and try to satisfy their various preferences. The great diversity of the offer makes it an important element in increasing the attractiveness of agritourism farms.

Conclusions

The agro-tourism offer regarding the use of herbal plants is a return to the centuries-old traditions of the Polish countryside. The creation of an offer based on traditional patterns is evident in all the ways in which herbs are used.

The use of herbs in the decorative aspect favours the preservation of the idyllic character of a country garden in an agro-tourism farm. This type of garden is inscribed in the traditional landscape of the Polish countryside (ZĄTEK 2003). Shaping the greenery of agrotourism farms based on traditional compositional assumptions creates the possibility of restoring or, in some cases, preserving traditional gardens in rural areas (KAŁUŻNY and HANUS-FAJERSKA 2016, MARKS et al. 2003, POŁUCHA and MARKS 2011).

The use of herbs in the utilitarian aspect, and more specifically in the nutritional aspect, allows the cultivation of the traditions of the regional culinary heritage of the countryside within the framework of agro-tourism activities. Culinary practices are the basis of culinary heritage, which is a fundamental component of cultural heritage constituting one of the elements of cultural identity of social groups. It is a wealth of culinary history usually differentiated at the local or regional level being a reflection of their past (JAWORSKI and DOMINIK 2017, KRUPA 2010, PRZYBYŁO-KISIELEWSKA et al. 2019).

The use of herbs in the therapeutic-cosmetic aspect can be seen as an extension of the tradition of using them to make natural cosmetics and in folk herbalism. The use of herbs in folk medicine and cosmetology was not a matter of chance, but was linked to extensive knowledge of their properties and effects. This knowledge, as well as customs, rituals and magical rituals in their use are part of the cultural heritage of the Polish countryside (CIECHOMSKA 2018).

The use of herbs in the educational aspect is connected with passing on, in agrotourism activities, those values which are connected with the tradition and culture of the Polish countryside to a larger number of interested parties. Tradition, understood as behaviours, customs, beliefs and rituals handed down from generation to generation that are considered by a community to be important for its present and future, is, in addition to the material aspects of a culture, part of the intangible cultural heritage (KHAMUNG 2015).

The use of herbaceous plants in each aspect indicates that these plants are present in all zones of the agritourism garden, performing different functions in them (POŁUCHA and MARKS 2011). The presence of herbal plants in different parts of the garden is consistent with the pattern of traditional village gardens (SZOT-RADZISZEWSKA 2005, 2017), as is the use of them in different aspects in agrotourism activities.

The offer of using herbaceous plants in the activities of agritourism farms is well integrated into the agritourism context, and at the same time fits well into the cultural heritage of the Polish countryside. It is not only an important element of the general agrotourism offer, but also a space where tradition and innovation can intermingle. Encouraging the development of agrotourism related to the use of herbal plants is the general trend of 'slow live', which motivates people to relax in the countryside. Agritourism farms focused on herbal plant activities are fully in line with existing trends regarding healthy eating, living in harmony with nature and caring for the environment. In this way, they can fit in not only with the principles of agrotourism, but also ecotourism and sustainable tourism (GAWLIK and WOŚ 2021, ZAREMBA 2013, 2015).

The multifaceted possibilities of using herbal plants in agro-tourism activities make them a base for developing different types of tourism due to the main motive of the trip. Depending on the aspect of herbs used, they can influence not only the development of typical herbal tourism, but also health tourism and even culinary tourism (ÇALIŞKAN 2020, TORABI FARSANI et al. 2016, VASILJEVIĆ et al. 2012, WOŚ 2017). Herbal tourism based on learning about and using herbs, through herbal medicine, is directly linked to health tourism (ATAL and ATAL 2024, NÉMETHY et al. 2020).

Health tourism is a fast-growing form of tourism that allows leisure combined with the possibility of health treatments. Its idea is in line with the global trend of combining treatment with relaxation (ŁOŚ 2012, WIDARINI et al. 2022). The same is true of culinary tourism. There is a worldwide trend of seeking regional national culinary traditions during tourist travel, and the local culinary heritage is an additional motivation in undertaking tourist activities, both to distant places in the world and to those close by, in one's own country or region as part of the offer of agritourism farms (NAIR and MOHANTY 2021, ORŁOWSKI D. 2018, PEHIN DATO MUSA and CHIN 2022).

All this gives rise to the conclusion that agro-tourism farm activities based on the use of herbal plants have multifaceted potential and can be a key element in the perspective of developing different forms of tourism in the natural and cultural rural landscape.

Accepted for print: 20.11.2024

References

ATAL N., ATAL C.K. 2024. *Healing Potential of Herbs and Herbal Tourism*. In: *Sustainable Development and Resilience of Tourism*. Ed. D. Chhabra, N. Atal, A. Maheshwari, Springer, Cham, Switzerland: 39–61.

BACLER-ŻBIKOWSKA B., STEBEL A. 2023. *Katalog roślin leczniczych aktualnie dopuszczonych do stosowania w medycynie konwencjonalnej w Polsce* [*Catalogue of medicinal plants currently approved for use in conventional medicine in Poland*]. Press SUM, Katowice, Poland.

BAHMANI M., EFTEKHARI Z., SAKI K., FAZELI-MOGHADAM E, JELODARI M., RAFIEIAN-KOPAEI M. 2016. *Obesity Phytotherapy: Review of Native Herbs Used in Traditional Medicine for Obesity*. J. Evid. Based. Complementary Altern. Med., 21(3): 228–234.

CAPUCHO J., PAÇO A., GASPAR P.D. 2016. *Tourism Related to Aromatic and Medicinal Plants: Some Practical Evidence*. Sustainability, 15(22): 15966.

ÇALIŞKAN G., YILDIRIM G., ŞENKARDEŞ İ. 202). *A study on herbs used in food in Rize province within the context of gastronomy tourism*. J. Res. Soc. Sci. Humanit., 7(51): 573–583.

CHAIYAKOT P. VISUTHISMAJARN P. 2012. *Herbal Garden Tourism Development in Thailand: A Case Study*. J. Bus. Case Stud., 8(2): 237–240.

CIECHOMSKA A. 2018. *Ziołolecznictwo ludowe w Polsce* [*Folk herbalism in Poland*]. In: *Wieloaspektowość antropologii kulturowej*, Red. Łukomiak K., ArchaeGraph, Łódź: 7–38.

DROZD J. 2012. *Wczoraj i dziś ziołolecznictwa* [*Herbal medicine yesterday and today*]. Prz. Med. Uniw. Rzesz. Inst. Leków, 2: 245–251.

EWANSIHA J.U., ADELEKE A.J., ORJI L.S., KOLAWOLE I.D. 2022. *Therapeutic potency of lemon-scented gum (Eucalyptus citriodora) leaf extract for the development of antibacterial drug*. Pol. J. Natur. Sc., 37(3): 311–344.

FIRMINO A. 2010. *New challenges for the organic farmers in India – tourism, spices and herbs*. Revija za geografijo – Journal of Geography, 5–1: 101–113.

GAWLIK A. WOŚ B. 2021. 7. *Agritourism and Ekotourism as an Innovative Direction for Sustainable Rural Development*. In: *Poverty and Development: Problems and Prospects*, Ed. M. Apollo, P. Moolio, Channel View Publications.

GAWŁOWSKA A. 2014. *Uprawa ziół* [*Cultivation of herbs*]. Wyd. SBM, Warszawa.

Gediya S.K., Mistry R.B., Patel U.K., Blessy M., Jain H.N. 2011. *Herbal plants: Used as a cosmetics.* J. Nat. Prod. Plant Resour., 1(1): 24–32.

Hakim L., Soemarno S., Yanuwiyadi B. 2016. *Identifying and assessing Spice and herbs resources for tourism attractions: A case study from Banyuwangi, East Java.* Res. J. Life Sci., 3(3): 154–159.

Iwaniuk A., Kowalik E. 2014. *Polski ogród wiejski* [*Polish country garden*]. Wyd. Bellona, Warszawa.

Jankowiak W., Schaschner K. 2013. *Surowce roślinne w kosmetyce – fitokosmetyki* [*Plant materials in cosmetics – phytocosmetics*]. Kosmet. Estet., 4 (2): 239–242.

Jaworski M., Dominik P. 2017. *Kontekst przyrodniczy powstawania tradycyjnych produktów kulinarnych jako wartość dla turystyki kulturowej* [*Natural context of the emergence of traditional culinary products as a value for cultural tourism*]. Zesz. Nauk. Ucz. Vistula; 54 (3): 55–73.

Kałużny K., Hanus-Fajerska E. 2016. *Tereny zieleni gospodarstw agroturystycznych szansą na zachowanie tradycyjnych ogrodów wiejskich* [*Green spaces for agritourism farms as an opportunity to preserve traditional rural gardens*]. Topiarius, Stud. Krajobraz., 1: 87–96.

Khamung R. 2015. *A Study of Cultural Heritage and Sustainable Agriculture Conservation as a Means to Develop Rural Farms as Agritourism Destinations.* J. Soc. Sci., 15(3): 1–35.

Klepacka-Dunajko I., Kałużna H. 2015. *Agro-ekoturystyka zielarska przykładem markowego produktu turystycznego w Polsce* [*Herbal agro-ecotourism as an example of a branded tourism product in Poland*]. Europa Regionum, 24: 21–28.

Kowalik E., Kowalska M. 2013. *Kolorowe zagrody* [*Colourful enclosures*]. Press Stow. Wiej. „Zielona Przestrzeń", Grabowo, 102 pp.

Krupa J. 2010, *Dziedzictwo kulinarne elementem atrakcyjności turystycznej regionu* [*Evaluation of green spaces on agritourism farms*]. Probl. Ekologii Kraj., 17: 451–455.

Kudełka W. 2008. *Składniki przypraw i ziół przyprawowych determinujące ich funkcjonalne właściwości oraz ich rola w żywieniu człowieka i zapobieganiu chorobom* [*Constituents of spices and seasoning herbs determining their functional properties and their role in human nutrition and disease prevention*]. Zesz. Nauk. UE Kraków, 781: 83–111.

Kuźnicka B., Dziak M. 1984. *Zioła i ich stosowanie. Historia i współczesność* [*Herbs and their use. History and the present day*]. Press Lek. PZWL, Warszawa.

Kuźnicka B., Wysakowska B. 1993. *Comparative study on the use of medicinal plants in Poland (16th century and today).* Médicaments et Aliments: approche ethnopharmacologique [Medicines and foods: ethnopharmacological approach]: 149–153.

Latkowska M.J., Miernik M. 2012. *Ogrody terapeutyczne – miejsce biernej i czynnej „zielonej terapii"* [*Therapeutic gardens – a place for passive and active 'green therapy'*]. Czas. Techn., Architektura, 109, (8–A): 245–251.

Łoś A. 2012. *Turystyka zdrowotna – jej formy i motywy : czynniki rozwoju turystyki medycznej w Polsce* [*Health tourism – its forms and motives : factors in the development of medical tourism in Poland*]. Ekonomiczne Problemy Usług, 84: 569–578.

Łukasiewicz K. 2018. *Znaczenie kategoryzacji gospodarstw agroturystycznych w podnoszeniu poziomu jakości usług* [*Importance of categorisation of agritourism farms in improving the quality of services*]. Rocz. Nauk. SERiA, XX (6): 161–166.

Magowska A. 2014. *Discovering herbalism through art. Plants in Polish symbolic painting* (1890–1914). Herba Polon., 60(3): 89–100.

Makarska-Białokoz M. 2019. *History and significance of phytotherapy in the human history 1. Phytotherapy in ancient times.* Arch. Phys. Glob. Res., 23 (2):15–17.

Makarska-Białokoz M. 2020a. *History and significance of phytotherapy in the human history. 2. Phytotherapy in ancient Greece and ancient Rome.* Arch. Phys. Glob. Res., 24 (1): 21–23.

Makarska-Białokoz M. 2020b. *History and significance of phytotherapy in the human history 3. The development of phytotherapy from the Middle Ages to modern times.* Arch. Phys. Glob. Res., 24 (2): 17–22.

Marks E. Młynarczyk K., Połucha I., Jaszczak A. 2003. *Ocena terenów zieleni w gospodarstwach agroturystycznych* [*Evaluation of green spaces on agritourism farms*]. Folia Hort. Supl., 2: 93–106.

MARWICKA J., NIEMYSKA K., PODRAZA S. 2015. *Terapeutyczne właściwości aromaterapii* [*Therapeutic qualities of aromatherapy*]. Kosmet. Estet., 4: 525–531.

MATLEGIEWICZ M. 2015. *Agroturystyka – pozarolniczy biznes polskiej wsi* [*Agrotourism – the non-agricultural business of the Polish countryside*]. Ekonomia i Środ., 4(55): 221–234.

NAIR B.B., MOHANTY P.P. 2021. *Positioning spice tourism as an emerging form of special interest tourism: perspectives and strategies*. J. Ethn. Food, 8(10): 1–8.

NEWERLI-GUZ J. 2016. *Uprawa roślin zielarskich w Polsce* [*Cultivation of herbal plants in Poland*]. Rocz. Nauk. SERiA, 18, 3: 268–274.

NÉMETHY S., TAKÁCS T., SZEMETHY L., LAGERQVIST B., BARÓCSI Z., DINYA A., PÉTERFFY NÉMETHY I. 2020. *Collection, cultivation and processing of medical plants, herbs and spices in the Balaton Ecomuseum – herbal medicine as intangible cultural heritage*. Ecocycles, 6(1): 52–87.

NOWIŃSKI M. 1980. *Dzieje upraw i roślin leczniczych* [*History of cultivation and medicinal plants*]. Press PWRiL, Warszawa, 336 pp.

ORŁOWSKI D. 2016. *Edukacja kulinarna w gospodarstwach agroturystycznych* [*Culinary education in agri-tourism farms*]. In: *Turystyka wiejska. Zagadnienia przyrodnicze i kulturowe* [*Rural tourism. Natural and cultural issues*], Ed. S. Graja-Zwolińska, A. Spychała, K. Kasprzak, Press Wieś Jutra Sp. z o.o, Poznań; 2: 107–121.

ORŁOWSKI D. 2018. *Polskie kuchnie regionalne i ich miejsce w turystyce kulinarnej na obszarach wiejskich* [*Polish regional cuisines and their place in culinary tourism in rural areas*]. Tur. Kultur., 7: 132–157.

ORŁOWSKI D. 2022. *Praktyki kulinarne związane z wyrobem tradycyjnych produktów żywnościowych jako element rozwoju turystyki kulinarnej* [*Culinary practices related to the production of traditional food products as an element of culinary tourism development*]. Tur. Kultur., 3(124): 145–181.

ORŁOWSKI D., WOŹNICZKO M. 2016. *Turystyka kulinarna w Polsce – wstępne badania nad fenomenem zjawiska* [*Culinary tourism in Poland – preliminary studies of the phenomenon*]. Tur. Kultur., 5: 60–100.

PAL S.K., SHUKLA Y. 2003. *Herbal medicine: Current status and the future*. Asian Pacific J. Cancer Prev., 4: 281–288.

PEHIN DATO MUSA S.F., CHIN W.L. 2022. *The role of farm-to-table activities in agritourism towards sustainable development*. Tour. Rev., 77 (2): 659–671.

POŁUCHA, I., MARKS, E. 2011. *Zasady kreowania przestrzeni ogrodowej w gospodarstwach agroturystycznych* [*Principles of garden space creation on agritourism farms*]. Folia Pomer. Univ. Technol. Stetin. Oeconomica, (64): 203–213.

PRZEOREK R. 2018. *Produkty gospodarstw agroturystycznych* [*Products of agritourism farms*]. Prace Nauk. AE Wrocław, 535: 152–160.

PRZEZBÓRSKA L. 2010. *Produkty terapeutyczne i lecznicze w agroturystyce i turystyce wiejskiej*. [*Therapeutic and curative products in agri-tourism and rural tourism*]. Stud. Periegetica, 5: 233–251.

PRZYBYŁO-KISIELEWSKA K., KRUCZEK Z., KNEFEL M. 2019. *Znaczenie regionalnych produktów kulinarnych w turystyce* [*Importance of regional culinary products in tourism*]. Zesz. Nauk. WSTiE; 1(15): 32–49.

RIVERA J.O., LOYA A.M., CEBALLOS R. 2013. *Use of herbal medicines and implications for conventional drug therapy*. Altern. Integ. Med., 2(6): 1–6.

SALA K. 2021. *The attractiveness of the rural tourist product on the example of the trail "Lesser Poland Village Fragrant with Herbs"*. Zesz. Nauk. MWSE Tarnów, 50(2): 53–64.

SZEMPLIŃSKI W. 2017. *Rośliny zielarskie* [*Herbal plants*]. Wyd. UWM, Olsztyn, 379 pp.

SZOT-RADZISZEWSKA E. 2005. *Sekrety ziół. Wiedza ludowa, magia, obrzędy, leczenie* [*Secrets of Herbs. Folk knowledge, magic, rituals, healing*]. Press TRIO, Warszawa, 300 pp.

SZOT-RADZISZEWSKA E. 2017. *Ogródki wiejskie na Kielecczyźnie jako ozdoba, apteka i spiżarnia* [*Rural gardens in the Kielce region as decoration, pharmacy and larder*]. Kielecka Teka Skansen., III(6): 105–122.

Torabi Farsani N., Zeinali H., Moaiednia M. 2016. *Food heritage and promoting herbal medicine-based niche tourism in Isfahan, Iran.* J. Herit. Tour., 13(1): 77–87.

Vasiljević D., Lesjak M., Beara I., Mimica-Dukić N., Vujičić M., Radivojević G. 2012. *Herbal tourism – A new approach to special-interest eco-travels: Lessons and initiative from Serbia,* Planta Med., 78 (11): 1288–1289.

Widayati A., Winanta A., Widada H., Pratiwi N.H. 2024. *Initiating a sustainable community-based agritourism model of herbal garden in a rural area of Indonesia: perspectives from community members.* Cogent Soc. Sci., 10(1): 347049.

Wiśniewska A., Szymańska W. 2020. *Educational Activity of Agritourism Farms In Poland (On Examples From The Pomeranian Region).* GeoJ. Tour. Geosites, 28(1): 140–150.

Widarini P.S.I., Wijaya M., Naini A.M.I. 2022. *Wellness and Herbal Tourism Based on Local Wisdom as an Alternative to 'New Normal' Tourism.* Jurnal Komunikasi, 14(2), 299–321.

Woś B. 2017. *Turystyka zielarska i uwarunkowania jej rozwoju* [*Herbal tourism and the determinants of its development*]. Prace i Studia Geogr. WGiSR UW Warszawa, 62 (3): 141–156.

Zaremba D. 2013, *Ekoturystyka* [*Ecotourism*], Press Nauk. PWN, Warszawa, 232 pp.

Zaremba D. 2015. *Rozwój ekoturystyki w Polsce – przykłady dobrych praktyk* [*Development of ecotourism in Poland – examples of good practice*], In: *Ekoturystyka wobec globalnych wyzwań – idee, trendy, dobre praktyki* [*Ecotourism in the face of global challenges – ideas, trends, good practices*]. Ed. Zientek-Varga J., Społeczny Instytut Ekologiczny, Warszawa: 12–21.

Ządek W. 2003. *Przydomowy ogród wiejski – dawniej i dziś* [*The domestic country garden – past and present*]. Zesz. Nauk. AR Krak. Sesja Nauk., 402(90): 271–276.

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 39(4): 281–292, Y. 2024

DOI: 10.31648/pjns.10812

EFFECT OF RECREATION ON DIVERSITY OF LITTORAL BENTHIC MACROINVERTEBRATES IN LAKES

Jacek Koszałka

ORCID: 0000-0003-3434-2036
Department of Tourism, Recreation and Ecology
University of Warmia and Mazury in Olsztyn

Key words: recreation ecology, biodiversity, zoobenthos, water-based recreation, lake.

Abstract

Water-based recreation making use of the assets offered by the lakes. The impact of recreational activities on the macroinvertebrate communities in the littoral zone was investigated by comparing sites that had been altered for recreational purposes with sites that had not been used for this purpose. The study was conducted on fourteen lowland lakes situated in the north-eastern region of Poland. A semi-quantitative method was used to sample the infralittoral macroinvertebrates at the recreationally used site and two reference sites. The results obtained indicate that the development of recreational facilities has a moderate impact on macroinvertebrate assemblages. Significant differences (Wilcoxon test, $p < 0.05$) were identified in the macroinvertebrate assemblages of the compared sites in eight of the fourteen studied lakes. The observed biodiversity was predominantly lower compared to the reference sites, and the differences in community structure may be the result of the homogeneity of the littoral habitats. In part of the lakes surveyed, macroinvertebrate communities were found to be similar between those used for recreation and sites that had been transformed for recreational functions.

Introduction

Recreational opportunities are a primary reason people choose to visit lakes and the fact that people benefit from access to natural and manmade water bodies is well documented (Doi et al. 2013, Venohr et al. 2018, Schafft et al. 2021). Inland waters are a popular destination due to their greater accessibility compared to marine waters for the majority of people (Meyer et al. 2021). The impact of recreation on aquatic ecosystems is variable and depends on a number of factors, including the species involved, the location, and the way in which recreation is managed. In general, the

Address: Jacek Koszałka, University of Warmia and Mazury in Olsztyn, Oczapowskiego 5, 10-957 Olsztyn, Poland, e-mail: jacko@uwm.edu.pl

effects of water-based activities have been found to be negative, particularly concerning their influence on plants (O'Toole et al. 2009, Meyer et al. 2021), aquatic invertebrates (Schmitt et al. 2007), fish (Meyerhoff et al. 2019) and birds (Yalden 1992, Mcfadden et al. 2017). It has been demonstrated that water-based recreational activities can cause stress to aquatic ecosystems, which in turn affects the diversity, composition and abundance of freshwater organisms (Venohr et al. 2018). The effects of water-based recreational activities have been particularly well-documented for boating (Smith et al. 2019, Houser et al. 2021), swimming (Schafft et al. 2021) and angling (Lewin et al. 2006, O'toole et al. 2009, Nikolaus et al. 2021).

The shores of lakes play an important role in the functioning of lake ecosystems and are characterised by high biodiversity. Littoral zones are distinguished by a complex spatial structure and variable environmental conditions, which provide habitats for a diverse range of water invertebrate species (Strayer and Findlay 2010). The impact of human activity on the littoral zone has significant implications for the diversity of lake ecosystems, with the unique assemblage of benthic organisms in this zone being particularly vulnerable to disruption (Brauns et al. 2007). Macroinvertebrates play a crucial role in the littoral zone of lakes, and the composition of the benthos community is closely linked to the prevailing habitat conditions. Unfortunately, there is a limitation in the available information concerning the impact of recreational sites on the habitat and the diversity of the fauna at the lake's shoreline (Brauns et al. 2007, Smith et al., 2019, Spyra and Strzelec 2019, Arva et al. 2021).

The aim of this study was to assess the impact of water-based recreation on the richness, abundance and composition of the littoral macroinvertebrate communities in lowland lakes. In particular, my objective was to respond to the following questions: 1. Does recreational alteration of the littoral influence the taxonomic richness, abundance and composition of macroinvertebrate assemblages? 2. Does the littoral zone, as a site for water recreation, affect the taxonomic diversity of macroinvertebrates?

Material and Method

Study area

The investigation was conducted on 14 lakes situated in the northeastern region of Poland (Figure 1). The majority of the lakes under survey were situated within the Vistula River catchment basin (11 lakes), with a further three located within the Pregola River catchment basin. In accordance with the typology proposed by SOLON et al. (2018), four lakes are situated within the macroregion of the Masurian Lake District, while those located in the Wel River basin are within the macroregion of the Chełmińsko-Dobrzyńskie Lake District, and Lake Płaskie is within the macroregion of the Iławska Lake District. Of the lakes under investigation, this is the largest, with a surface area of 620 ha. A part of the Lake Płaskie area is protected under the European environmental protection network Natura 2000 and the Iława Lake District Landscape Park. The surface areas of Lakes Majcz Wielki and Ławki range from 100 to 200 ha. The surface areas of Lakes Kuc and Stryjewskie are less than 100 ha. The largest of the lakes situated within the Wel River catchment area is Lake Dąbrowa Wielka, which has a surface area of 615 ha. The surface areas of lakes Rumian, Dąbrowa Mała, Tarczyńskie, Grądy and Lidzbarskie range from 100 to 200 ha, while the remaining lakes are smaller than 100 ha (i.e., lakes Hartowieckie, Kiełpińskie and Zarybinek). Five of the lakes are situated within the boundaries of the Welski Landscape Park. The lakes were selected to represent a range of water-based recreational activities.

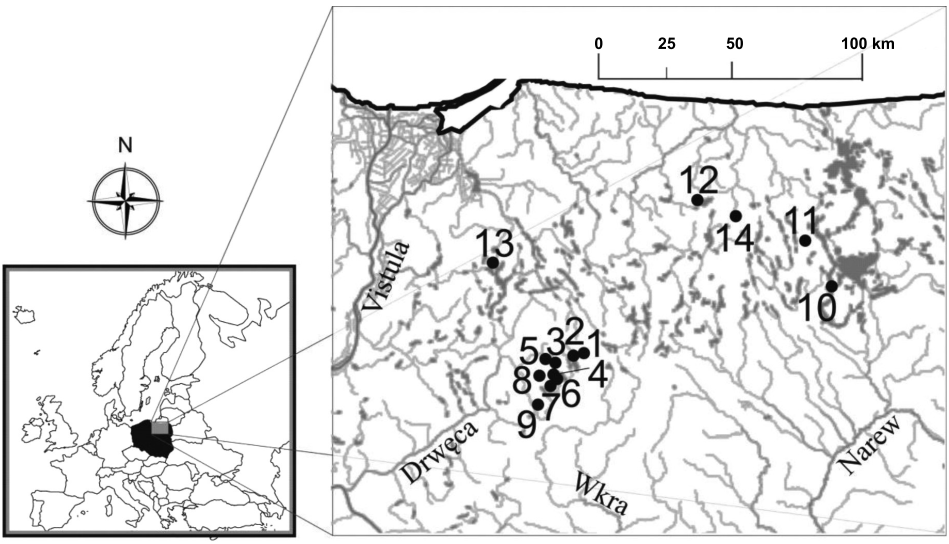

Fig. 1. The study area showing location of lake sampling sites 1 – Dąbrowa Wielka; 2 – Dąbrowa Mała; 3 – Rumian; 4 – Zarybinek; 5 – Hartowieckie; 6 – Tarczyńskie; 7 – Grądy; 8 – Kiełpińskie; 9 – Lidzbarskie; 10 – Majcz Wielki; 11 – Kuc; 12 – Ławki; 13 – Płaskie; 14 – Stryjewskie

Methodology

The impact of recreational activities on the littoral macrozoobenthos was assessed by comparing areas that were subject to high levels of trampling or physical disturbance with those that were less intensively used in the infralittoral zone of selected lowland lakes. In order to provide a representative sample of the range of impacts induced by recreational use, three sites were selected within each lake. One site has been designated in a location that has been modified for recreational purposes. Two reference stations were located at the boundaries between the sandy impacted area and the natural vegetated shoreline, which was dominated by reed and rush. Sampling points with and without recreational transformation were selected in close proximity to one another, taking into account the substratum and riparian vegetation, as these factors have the potential to influence the distribution of aquatic fauna. The bottom fauna were sampled in autumn (October 2009 – lakes 1–9, October 2011 – lakes 10–14, Figure 1) using a semiquantitative method, with samples taken at a depth of between 0.5 and 0.75 m. The material was sampled using a Surber sampler. The specimens were then picked from the sediments and identified in the laboratory to the lowest possible taxonomic level, with the exception of lakes 10–14, in which the chironomids were determined to the subfamily level.

Statistical analysis

The benthic macroinvertebrate community was first analysed by calculating abundance, taxonomic richness, the Shannon diversity index (H′) and the Pielou evenness index (E) for each site. Data were analyzed using the MultiVariate Statistical Package 3.13 (Kovach 2007).

The Wilcoxon non-parametric rank-sum test was used to check for significant differences between values of taxa abundances of macroinvertebate assemblages at sampling site turned into recreational place as compared to the other sites at each lake. Comparison of benthos assemblages was conducted only within stations at different impact level. All possible pairs of elements (sites within one lake, not mixed) were tested. The statistical evaluation of the data was carried out with Statistica 13.1 statistical package (TIBCO Software Inc., 2017).

Results

A lower infralittoral species richness was observed at 40% of the surveyed lakes (Figure 2), indicating a potential impact on the biodiversity of these coastal ecosystems. In two cases, the number of taxa at the impacted site and the taxonomically poorer reference site were found to be non-significantly different. The highest number of taxa was identified at the site situated within the bathing area of Lake Dąbrowa Wielka.

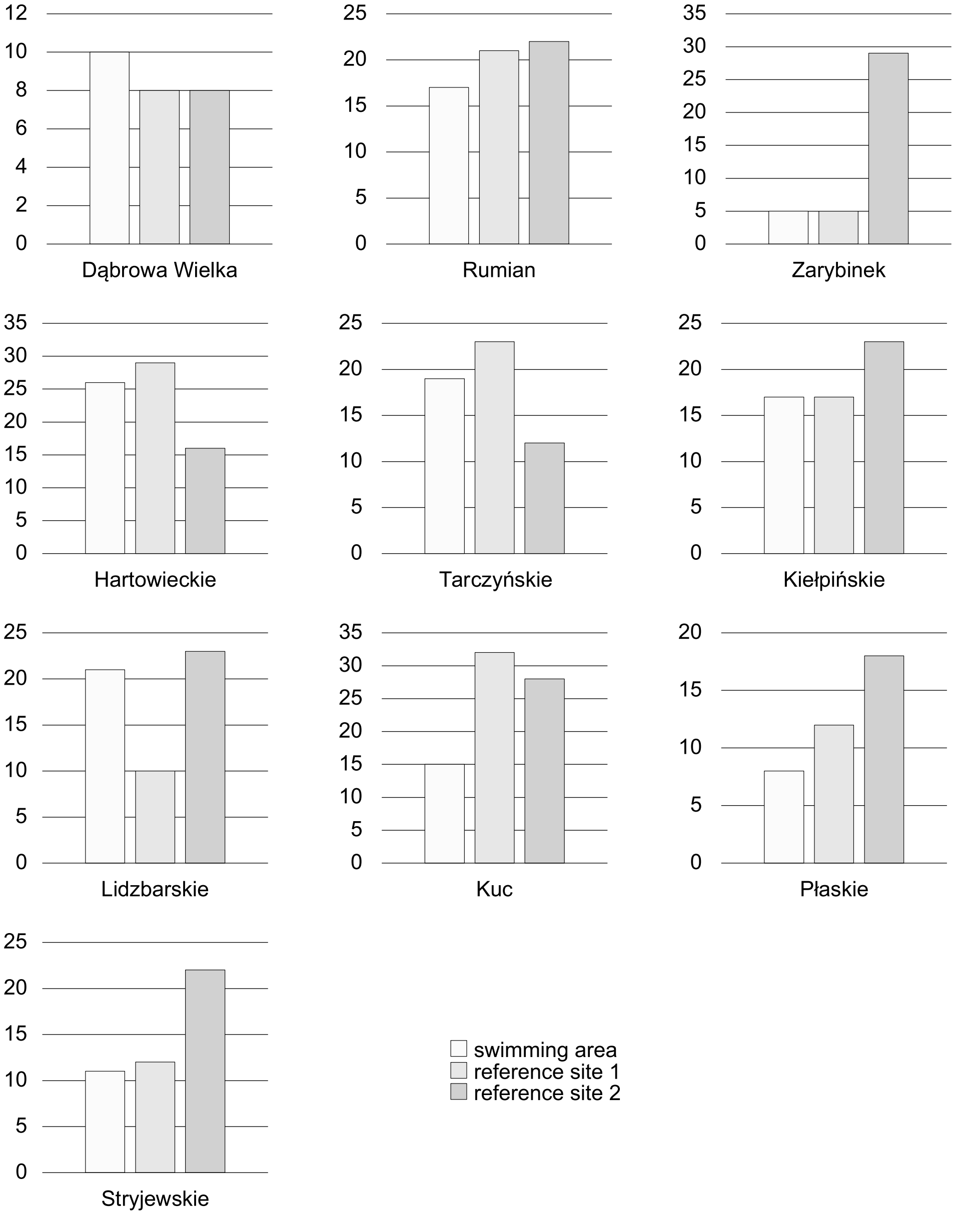

Fig. 2. Comparison of taxa richness (S) among sites within studied lakes with swimming area

Similarly, a comparison of the taxonomic richness of the lakes with boat ramp sites revealed that in half of the lakes, the fewest taxa of littoral fauna were observed at impacted sites (Figure 3). The greatest number of taxa were observed in Lake Dąbrowa Mała at boat ramp sites.

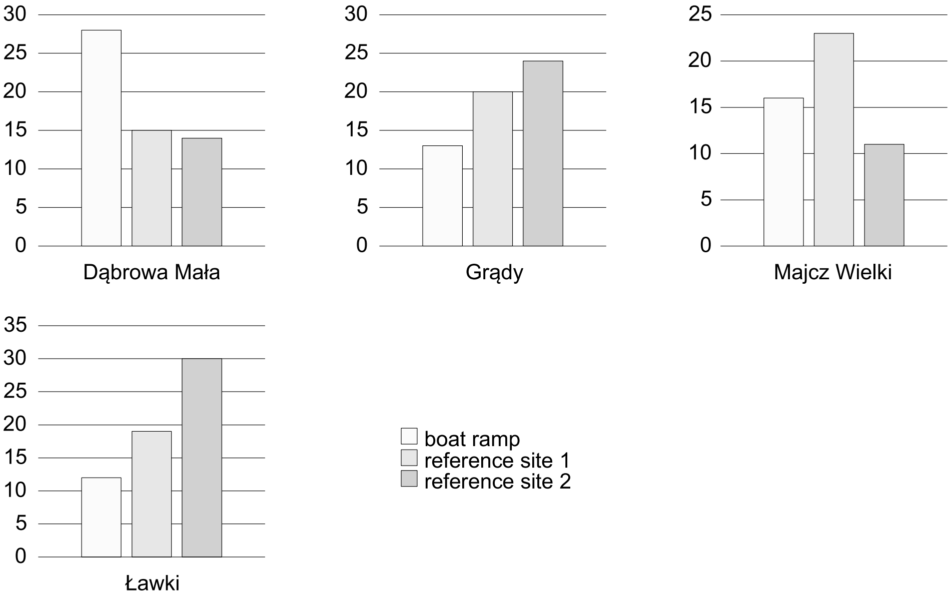

Fig. 3. Comparison of taxa richness (S) among sites within studied lakes with boat ramp

A comparison of the structure of macroinvertebrate assemblages based on taxon abundances revealed statistically significant differences between impacted and reference sites for eight of the fourteen lakes under study (Table 1). Significant differences were observed in the faunal assemblages of lakes Kuc and Dąbrowa Mała when the impacted site was compared with both reference sites.

The Shannon diversity index values of macroinvertebrate assemblages in the lakes under investigation ranged from 0.25 at the site with recreational activities in Lake Tarczyńskie to 1.33 at one of the reference sites in Lake Kuc. The diversity of bottom fauna was lowest at the site located in the bathing area for five lakes (Figure 4). In the case of Lakes Hartowieckie and Lidzbarskie, the highest biodiversity was recorded at the impacted site. Among the four lakes with boat ramps, the value of the Shannon diversity index was lowest on impacted sites for three of them; the opposite was the case for Lake Dąbrowa Mała (Figure 5).

Table 1

Results of Wilcoxon sign rank test for differences between macroinvertebrate assemblages at stations where a recreation activity takes place and in the reference area. Statistically significant rows are bold

Lake	Recreation impact	Reference site	*N*	Wilcoxon test (Z)	*p* value
Dąbrowa Wielka	swimming area	1	14	0.628	0.530
		2	9	1.599	0.110
Rumian	swimming area	1	26	0.952	0.341
		2	22	0.503	0.615
Zarybinek	swimming area	1	9	0.296	0.767
		2	**30**	**3.898**	**<0.001**
Hartowieckie	swimming area	1	36	0.652	0.514
		2	**26**	**2.159**	**0.031**
Tarczyńskie	swimming area	1	24	0.400	0.689
		2	21	1.164	0.244
Kiełpińskie	swimming area	1	24	0.929	0.353
		2	33	1.483	0.138
Lidzbarskie	swimming area	**1**	**26**	**2.781**	**0.005**
		2	38	0.109	0.913
Kuc	swimming area	**1**	**38**	**3.009**	**0.003**
		2	**31**	**2.312**	**0.021**
Płaskie	swimming area	1	16	0.103	0.918
		2	21	1.286	0.198
Stryjewskie	swimming area	1	19	0.402	0.687
		2	**24**	**3.457**	**0.001**
Dąbrowa Mała	boat ramp	**1**	**28**	**4.179**	**<0.001**
		2	**27**	**3.676**	**<0.001**
Grądy	boat ramp	1	22	1.542	0.123
		2	**25**	**3.054**	**0.002**
Majcz Wielki	boat ramp	1	29	1.438	0.150
		2	20	0.747	0.455
Ławki	boat ramp	1	24	0.629	0.530
		2	**36**	**2.129**	**0.033**

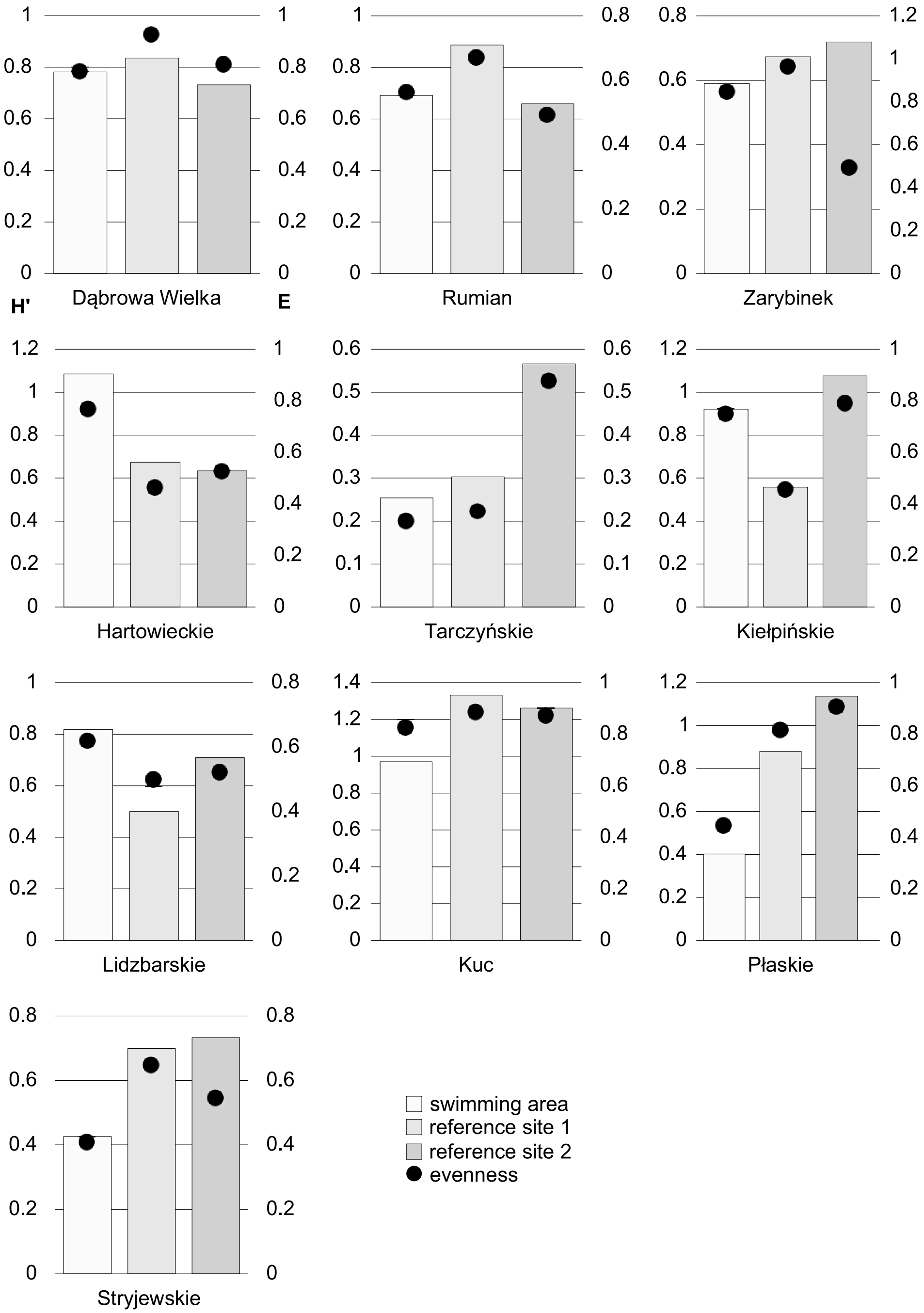

Fig. 4. Results of Shannon-Weaver index (H') and Evenness (E) for the studied stations in the lakes with swimming area

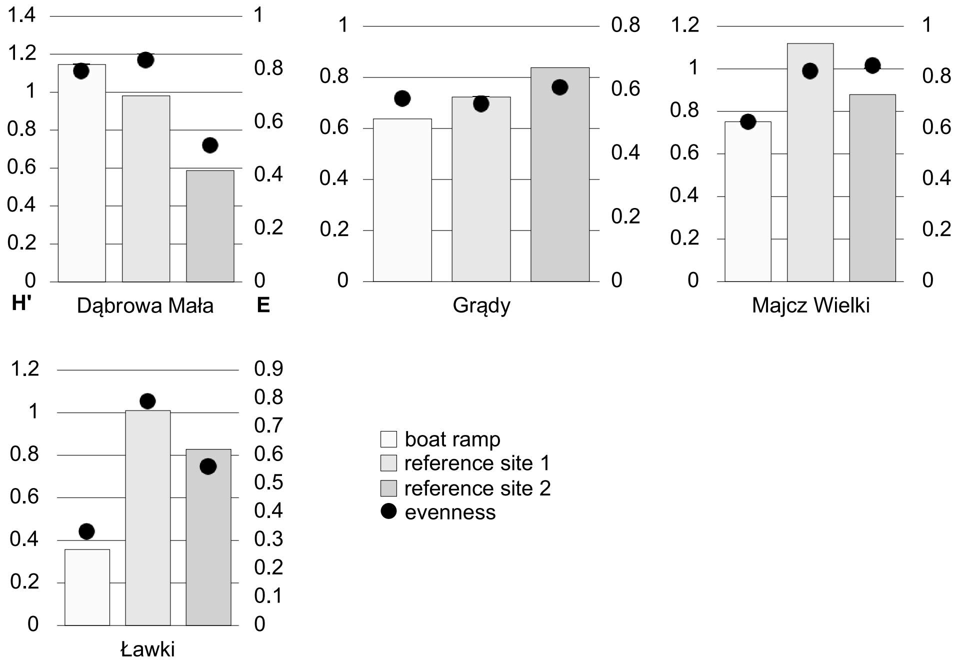

Fig. 5. Results of Shannon-Weaver index (H') and Evenness (E) for the studied stations in the lakes with boat ramp

Discussion

Despite observing a general reduction in the taxonomic diversity of species at sites where recreational activities were taking place, this decline was not evident in all lakes. This may be the result of a number of factors. The conversion of shoreline to beach results in the absence of riparian trees. Furthermore, the presence of a boat ramp on the shoreline has an additional impact, as it eliminates the vegetation that would otherwise facilitate boat launching. This restricts access to plant litter, which would otherwise provide a food source for the habitat and a food base for shredders (SOLIMINI et al. 2006). Consequently, the infralittoral species richness and abundance of Ephemeroptera, Trichoptera and shredders were markedly reduced on the beaches in comparison to the natural shorelines (BRAUNS et al. 2007). Macrophytes provide shelter for the fauna and serve to compensate for the influence of water movements on invertebrate fauna (TOLONEN et al. 2001). The mosaic of habitat types present in the littoral zone of lakes creates a high spatial heterogeneity. However, the annual timing of strong macrophyte development often coincides with the summer months, when water recreation peaks (VERHOFSTAD and BAKKER

2019). The impact of recreational activities on lake ecosystems is generally less significant than other environmental factors (SCHAFFT et al. 2024). A lake shore used during the season for recreational activities such as bathing or for boat access is subject to repeated disruption from human activity, including trampling and increased wave action (SOLIMINI et al. 2006). The present study demonstrates that in more than half of the lakes surveyed, the lowest levels of taxonomic diversity were observed in areas that have been altered for recreational use.

SMITH et al. (2019) reports that littoral macroinvertebrate assemblages occurring in large but relatively shallow lakes were not significantly influenced by boating-related activity. However, the results of the present study demonstrated greater differences between the results obtained for the impacted and reference sites for the boat ramp lakes. In addition to wave stress, increased turbidity and light limitations have been identified as factors that disturb the water environment by ramp boats (SOLIMINI et al. 2006, SMITH et al 2019).

The highest value of the Shannon diversity index at one of the reference sites in Lake Kuc can be attributed to the highest number of taxa observed across all the studied lakes (KOSZAŁKA and JABŁOŃSKA-BARNA 2020). Furthermore, diversity at both other sites was also relatively high. Additionally, the high evenness values at all sites in this lake indicate a very equal share of taxa in the community.

The situation in which the greatest number of taxa were identified at induced sites in both lakes Dąbrowa, which are situated in close proximate locations, would indicate a need for further investigation.

This study attempted to assessing the impact of transforming the littoral habitat for zoobenthos. Although differences in taxa diversity and composition as well as in richness were detected for benthic invertebrates, translating these observations as strong response to water-based recreation effects should be interpreted with caution. The present study has some limitations. For instance, due to insect life cycles, it is not possible to carry out the survey in summer during the high tourist season. Survey coverage of more lakes would be needed to more fully assess the impact of the shoreline altered into a bathing area and boat ramp on macroinvertebrate communities.

Conclusions

The present study has demonstrated that the development of recreational areas has a moderate impact on macroinvertebrate assemblages.

The observed biodiversity was predominantly lower in comparison to reference sites, and the differences in community structure are attributable to the homogeneity of littoral habitats. In some of the lakes surveyed, macroinvertebrate communities exhibited similarities between areas with low and high recreational use.

Accepted for print 4.12.2024

References

Arva D., Mozsar A., Barta B., Specziar A., Toth M., Bohus A., Gal B., Schmera D. 2021. *Effects of recreational beaches on chironomid assemblages in a large, shallow lake*. Ecol. Indic., 125: 107469.

Brauns M., Garcia X.F., Walz N., Ousch M. T. 2007. *Effects of human shoreline development on littoral macroinvertebrates in lowland lakes*. Journal of Applied Ecology, 44(6): 1138–1144.

Doi H., Katano I., Negishi J.N., Sanada S., Kayaba Y. 2013. *Effects of biodiversity, habitat structure, and water quality on recreational use of rivers*. Ecosphere 4(8): 1–11.

Houser C., Smith A., Lilly J. 2021. *Relative importance of recreational boat wakes on an inland lake*. Lake and Reservoir Management, 37(3): 227–234.

Koszałka J., Jabłońska-Barna I. 2020. *Aquatic Macroinvertebrate Biodiversity in Freshwaters in Northeastern Poland*. [In]: *Polish River Basins and Lakes – Part II. The Handbook of Environmental Chemistry,* 87. Eds. E. Korzeniewska, M. Harnisz, Springer, Cham, pp. 103–125.

Kovach W.L. 2007. *MVSP. A multivariate statistical package for Windows, ver. 3.1*. Kovach Computing Services, Pentraeth, Wales, U.K.

Lewin W.C., Arlinghaus R., Mehner T. 2006. *Documented and potential biological impacts of recreational fishing: insights for management and conservation*. Rev. Fish. Sci. 14: 305–367.

McFadden T.N., Herrera A.G. Navedo J.G. 2017. *Waterbird responses to regular passage of a birdwatching tour boat: Implications for wetland management*. Journal for Nature Conservation, 40: 42–48.

Meyer N., Schafft M., Wegner B., Wolter C., Arlinghaus R., Venohr M., von Oheimb G. 2021. *A day on the shore: Ecological impacts of non-motorised recreational activities in and around inland water bodies*. Journal for Nature Conservation, 64, 126073.

Meyerhoff J., Klefoth T., Arlinghaus R. 2019. *The value artificial lake ecosystems provide to recreational anglers: Implications for management of biodiversity and outdoor recreation*. Journal of Environmental Management, 252: 109580.

Nikolaus R., Schafft M., Maday A., Klefoth T., Wolter C., Arlinghaus R. 2021. *Status of aquatic and riparian biodiversity in artificial lake ecosystems with and without management for recreational fisheries: Implications for conservation*. Aquatic Conservation: Marine and Freshwater Ecosystems, 31(1): 153–172.

O'Toole A.C., Hanson K.C., Cooke S.J. 2009. *The effect of shoreline recreational angling activities on aquatic and riparian habitat within an urban environment: Implications for conservation and management*. Environmental Management, 44: 324–334.

Schafft M., Wegner B., Meyer N., Wolter C., Arlinghaus R. 2021. *Ecological impacts of water-based recreational activities on freshwater ecosystems: a global meta-analysis*. Proceedings of the Royal Society B, 288: 20211623.

Schafft M., Nikolaus R., Matern S., Radinger J., Maday A., Klefoth T., Wolter C., Arlinghaus R. 2024. *Impact of water-based recreation on aquatic and riparian biodiversity of small lakes*. Journal of Nature Conservation, 78: 126545.

Schmitt C., Oetken M., Dittberner O., Wagner M., Oehlmann J. 2008. *Endocrine modulation andntoxic effects of two commonly used UV screens on the aquatic invertebrates Potamopyrgus antipodarum and Lumbriculus variegatus*. Environ. Pollut., 152: 322–329.

SMITH B.J., CHIPPS S.R., GROTE J.D., MECHAM J., STEVENS T.M., RAPP T. 2019. *Comparison of aquatic invertebrate communities in near-shore areas with high or low boating activity*. Journal of Freshwater Ecology, 34(1): 189–198.

SOLIMINI A.G., FREE G., DONOHUE I., IRVINE K., PUSCH M., ROSSARO M., SANDIN L., CARDOSO A.C. 2006. *Using benthic macroinvertebrates to assess ecological status of lakes. current knowledge and way forward to support WFD implementation*. Institute for Environment and Sustainability, Luxembourg.

SOLON J., BORZYSZKOWSKI J., BIDŁASIK M., RICHLING A.,BADORA K., BALON J., BRZEZIŃSKA-WÓJCIK T., CHABUDZIŃSKI Ł., DOBROWOLSKI R., GRZEGORCZYK I., JODŁOWSKI M., KISTOWSKI M., KOT R., KRĄŻ P., LECHNIO J., MACIAS A., MAJCHROWSKA A., MALINOWSKA E., MIGOŃ P., MYGA-PIĄTEK, U., NITA J., PAPIŃSKA E., RODZIK J., STRZYŻ M., TERPIŁOWSKI S., ZIAJA W., PAUL J. 2018. *Physico-geographical mesoregions of Poland: verification and adjustment of boundaries on the basis of contemporary spatial data*, Geographia Polonica, 91: 143–170.

SPYRA A., STRZELEC M. 2019. *The implications of the impact of the recreational use of forest mining ponds on benthic invertebrates with special emphasis on gastropods*. Biologia, 74(8): 981–992.

STRAYER D.L., FINDLAY S.E.G. 2010. *Ecology of freshwater shore zones*. Aquatic Sciences, 72: 127–163.

TIBCO SOFTWARE INC. 2017. *Statistica (data analysis software system), version 13*. http://statistica.io.

TOLONEN K.T., HÄMÄLÄINEN H., HOLOPAINEN I.J, KARJALAINEN J. 2001. *Influences of habitat type and environmental variables on littoral macroinvertebrate communities in a large lake system*. Archiv für Hydrobiologie, 152: 39–67.

VENOHR M., LANGHANS S.D., PETERS O., HÖLKER F., ARLINGHAUS R., MITCHELL L., WOLTER C. 2018. *The underestimated dynamics and impacts of water-based recreational activities on freshwater ecosystems*. Environmental Reviews, 26(2), 199–213.

VERHOFSTAD M.J.J.M., BAKKER E.S. 2019. *Classifying nuisance submerged vegetation depending on ecosystem services*. Limnology, 20: 55–68.

YALDEN D.W. 1992. *The influence of recreational disturbance on common sandpipers Actitis hypoleucos, breeding by an upland reservoir, in England*. Biological Conservation, 61: 41–49.

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