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Biodiversity in the Context of Biodiversity Mental Health Research

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Abstract

In this chapter the concept of biodiversity and its measurement and use in biodiversity mental health research is discussed, as well as access to and contact with biodiverse nature. It is pointed out that biodiversity is an ecological concept that originated in the context of nature conservation. It has evolved without consideration of its potential role in mental health promotion. In studying the latter, the concept of biodiversity is frequently adapted. Such adaptations are likely to occur at the expense of its relevance for nature conservation. Using the concept of biodiversity as originally intended may be fruitful for a different type of research question, focusing more on multi-functionality issues: can the same nature constitute a healthy, biodiverse ecosystem and enhance mental health simultaneously? By pointing out this and related issues, this chapter aims to support researchers and students in future research, and help both scientists and policy-makers to position and assess studies in this field.

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Chapter 8
Biodiversity in the Context of 'Biodiversity – Mental Health' Research

Sjerp de Vries and Robbert Snep

To measure is to know, but know what you measure.
(anonymous)

Abstract In this chapter the concept of biodiversity and its measurement and use in 'biodiversity – mental health' research is discussed, as well as access to and contact with biodiverse nature. It is pointed out that biodiversity is an ecological concept that originated in the context of nature conservation. It has evolved without consideration of its potential role in mental health promotion. In studying the latter, the concept of biodiversity is frequently adapted. Such adaptations are likely to occur at the expense of its relevance for nature conservation. Using the concept of biodiversity as originally intended may be fruitful for a different type of research question, focusing more on multi-functionality issues: can the same nature constitute a healthy, biodiverse ecosystem and enhance mental health simultaneously? By pointing out this and related issues, this chapter aims to support researchers and students in future research, and help both scientists and policy-makers to position and assess studies in this field.

Keywords Health promotion · Nature conservation · Functional biodiversity · Ecosystem health · Measurement · Multi-functionality

Highlights
- The concept 'biodiversity' is frequently adapted in studies on its health effects.
- Such adaptations tend to make these studies less relevant for nature conservation.
- Health promotion and nature conservation may have different requirements.

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8.1 Key Concepts

In this chapter we take a closer look at one of the central concepts of this book, biodiversity, and especially at the way it is defined. We do so because the definition of this concept has a bearing on what to measure, how best to measure it, and how to study its relationship to other concepts, such as mental health and well-being. The latter concepts are also discussed, but only briefly.

8.1.1 Biodiversity

These days, the term 'biodiversity' is often interpreted and used by conservationists, policy-makers and the general public as an alternative for the broader term 'nature', more or less suggesting that they are interchangeable (Kaphengst et al. 2014; for examples, see Wossink et al. 1997; Wall et al. 2016, Chap. 4). 'Biodiversity', however, originates from the scientific fields of ecology and nature conservation, and there it has a much stricter meaning. Here we start from this original meaning in which biodiversity – as defined by the Convention on Biological Diversity (CBD 1992) – is the variability among living organisms and the ecological complexes of which they are part. Sources of this variability include intra-species diversity (e.g. genetic variability), interspecies diversity (species diversity) and diversity in ecosystems (from biomes to biotopes). Although biodiversity encompasses these three levels of variability, in relationship to human health the species diversity level seems to be the most studied level thus far (Lovell et al. 2014; see also Marselle et al. Chap. 9, this volume). To confine the discussion, in this chapter we therefore focus on this level.

An initial question is whether species are required to be part of an ecological complex, and if so, what counts as such a complex. We equate the term 'ecological complex' with 'ecosystem', for which the CBD (1992) also has provided a definition: a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Some authors include humans as a possible species within an ecosystem. In this chapter, we do not. Given the requirement of interacting as a functional unit and the exclusion of humans, although a zoo contains many animal species, it can hardly be considered an ecosystem. The same holds true for a *hortus botanicus* or arboretum. With regard to species, Angermeier (1994) already made a distinction between biodiversity and artificial diversity.

To a lesser extent, urban parks and private gardens may also contain combinations of plants and animals that do not occur in that composition in a (natural) ecosystem, many of which may not be indigenous to the area. Non-indigenous plants include (wild) ornamental trees, shrubs, perennials and garden pond plants. Non-indigenous animals include (feral) cats, dogs, aviary birds and other pet species. The living nature that parks and gardens contain usually is not intended or allowed to

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interact as a functional unit. Therefore, most parks and gardens require constant human interference (maintenance and wild management) to remain in existence in their present (desired) state. Actually, human influence is virtually omnipresent, but the level of this influence differs. Consequently, it is a matter of choice how much human interference is deemed acceptable to still consider a collection of plants, animals, insects and micro-organisms a natural ecosystem, or an ecosystem at all.

Biodiversity – here limited to species diversity – has its primary focus on *variability* in the biotic part of nature, the living nature. But even the concept of variability may be interpreted differently. One interpretation is in terms of species richness, usually defined as the number of species in a certain area. This implies the notion that more (richer) is better. From an ecological perspective this interpretation has little value. Ecologists study communities that are linked to the ecosystem type present in the study area. Diversity here is seen more from a functional perspective. The question is to what extent the species diversity of an area contributes to the health of the ecosystem, with ecosystem health being defined in terms of sustainability and resilience (Costanza 2012). This leads to the following more specific questions: Is the species community complete, or are (key) species missing? Are population levels of the species above the viability level, so the species may expect to survive in the defined area in the long run? Are there sufficient species – and sufficient individuals per species – within a functional group (e.g. pollinators) to ensure functional traits (e.g. pollination) continue to be present, even under changing conditions (e.g. climate change)? Thus, desired diversity here is seen as a combination of species diversity (number of species, within each functional group) and species abundance (number of individuals per species). If key species are missing and population levels of existing species are below the viability level, one may define the ecosystem as degraded. If the diversity within a functional group is small, the ecosystem may be considered vulnerable. It is important to note that some ecosystems require a higher number of species to be present in order to be considered healthier than others. Adhering to a strict, functional definition of biodiversity would require that first the applicable ecosystem is determined, and only subsequently the level of biodiversity at the species diversity level of those ecosystems is assessed.

We already mentioned that the concept 'biodiversity' has its origin in ecology. *A priori*, there is no reason why it should be as relevant from a human health perspective as it is from a nature conservation perspective. It may be too specifically geared towards its ecological purpose, as well as too crude from a public health perspective. With regard to the latter, the composition of species that hides behind a certain level of biodiversity may be relevant with regard to its influence on mental health. This latter argument is similar to one made in a more advanced field of environmental epidemiology, that on air pollution. It is not only the level of air pollution that matters, but also the precise pollutants that make up the air pollution, with some being more harmful than others for human physical health. Also from an ecological perspective all animals are equal but some more than others: rare species tend to be more valued than very common species. But this does not necessarily mean that the presence of rare species will coincide with higher mental health benefits.

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Thus, one may question whether the level of biodiversity, especially that in terms of functional species diversity, is a relevant factor with regard to the mental health benefits that a certain amount of nature or a natural area may generate. Given that nature conservation and mental health promotion are two separate goals, an appropriate first question might be whether successful nature conservation and efficient application of nature to promote mental health can go hand in hand. Are the requirements that nature conservation imposes compatible with those that the promotion of mental health imposes? Such a question fits in the context of multi-functional use of space, something that is particularly relevant in the urban domain. And yes, perhaps there are synergy benefits to be had by using the same area to accomplish both goals. But it is also possible that trade-offs have to be made. Some ecologically desirable species of animals or plants may be either considered too dangerous to expose people to, or too vulnerable to human presence or certain types of human activity in their habitat to allow people to access the area.

8.1.2 Mental Health and Well-Being

Although the focus of this chapter is on biodiversity, this is in the context of biodiversity – mental health research. Therefore, we discuss the concepts of mental health and mental well-being as well, although less extensively. Mental health is defined by the WHO as a state of well-being in which an individual realises his or her own abilities, can cope with the normal stresses of life, can work productively, and is able to make a contribution to his or her community (World Health Organization 2016). Although the WHO does not provide a definition of well-being, mental health is clearly not merely about the absence of mental disorders. For a definition of mental well-being, in this book the description proposed by Linton et al. (2016) is suggested: dimensions linked to the theme of mental well-being assess the psychological, cognitive and emotional quality of a person's life. This includes the thoughts and feelings that individuals have about the state of their life, and a person's experience of happiness.

A first comment regarding these definitions of mental health and mental well-being is that it is difficult to say where the one ends and the other begins. Furthermore, although the WHO definition of mental health talks about a state, this is not a very transient or momentary state. Mental health usually is not thought of as fluctuating over the course of a day. The time dimension of mental well-being is less clear. Happiness can be used to describe a very momentary state of affairs or be interpreted more in terms of life satisfaction: satisfaction with one's life when looking back over a longer period of time (Eid and Diener 2004). Linton et al. (2016) seem to focus on the latter, given their use of the term 'state of their life'. Furthermore, both life satisfaction and happiness may be thought of as having both a hedonistic (pleasurable) and a eudaimonic (meaningful/fulfilling) component (Ryan and Deci 2001). In the remainder of this chapter, when we use the term 'mental health', mental well-being is implied.

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Yet another definitional issue is where to draw the line between a risk factor and mental health itself. Risk factors may act as mediators, with a high risk of increasing the likelihood of poor mental health or a specific mental disorder. However, if something is not to be considered a risk factor, but a specific form of poor mental health, then it becomes questionable to use it as a mediator at the same time.[1] A case in point is chronic stress. Whereas some authors suggest that chronic stress may cause poor mental (and physical) health (e.g. Marin et al. 2011), others see it as an expression of poor mental health in itself (e.g. Aszatalos et al. 2009).[2]

8.1.3 Linking Biodiversity to Mental Health: Research Questions and Conceptual Model

Methodological choices in doing research depend not only on the definition of the key concepts, but also on the question that the research is intended to answer. In the section on biodiversity, it was stated that biodiversity is predominantly an ecological concept, not evolved from theoretical notions on how contact with nature is thought to positively impact mental health. The section ended suggesting that a relevant first research question might be whether or not nature with a high level of biodiversity can go together with high mental health benefits resulting from contact with that same nature. This issue of compatibility does not yet look into possible causal relationships, whether the one leads to the other or not. However, the question, under which conditions a high level of biodiversity may go together with high mental health benefits, already necessitates insight into which characteristics of nature are important with regard to mental health. Of course, the level of biodiversity present within a certain amount of nature might still be one of those characteristics.

With regard to the level of biodiversity of a natural area actually being an instrumental factor in mental health promotion, it may be that the sheer (sustained) existence of a certain (highly biodiverse) natural area engenders mental health benefits, even though one never visits or otherwise comes in direct contact with it (van den Born et al. 2018). However, most theories focus on pathways requiring some sort of sensory contact with that nature for it to exert its positive influence on mental health (Markevych et al. 2017). Furthermore, more contact is usually assumed to lead to greater benefits, at least up to a certain point (Shanahan et al. 2016). This is likely to have consequences for what one may want to measure. In the remainder of this chapter, we limit ourselves to the latter type of pathways, requiring direct contact.

[1] It still can be used as a predictor of overall mental health, but such an analysis may also be interpreted as showing how important a component it is of overall mental health, more than as a causal factor.

[2] A similar argument can be made with regard to being seriously overweight and having bad physical health.

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8.2 Measurement of Biodiversity

The choice of definition, in this case of biodiversity, has implications for (a) how to (objectively) measure the level of biodiversity and, as a consequence, (b) which environments will be considered high, and which ones will be considered low in biodiversity. For example, an arboretum may be considered an area with an extremely high biodiversity per acre, or it may be discarded completely, as not constituting an ecosystem.

8.2.1 Characteristics of Nature in General

It seems fair to say that most of the epidemiological research on nature and human health until now has focussed on access to or availability of nature, and has not paid much attention to its characteristics, including the level of biodiversity (Hartig et al. 2014). Moreover, in such studies nature usually translates to green space, greenery or vegetation, without much consideration for whether or not it may be considered a part of an ecosystem. For example, studies have been conducted looking at the amount of green space, including everything from urban parks to agricultural areas to forests (de Vries et al. 2003), the amount of greenery (Cohen-Cline et al. 2015), that of streetscape greenery (van Dillen et al. 2012) and even the number of street trees per kilometre of road (Taylor et al. 2015). Characterising the nature included in these amounts in meaningful ways with regard to its mental health impact may be considered an important next step in the research agenda (Hartig et al. 2014; Shanahan et al. 2015).

8.2.2 The Object to Be Assessed: The Biodiversity of What?

Another issue is the definition of the area or object of which the biodiversity is to be assessed. In experimental research on nature and human health, this area or object is usually well-defined, for example the biodiversity present in the landscape that is depicted on a screen (Wolf et al. 2017) or that is present in a large aquarium (Cracknell et al. 2016). In intervention studies, the focus is usually on a single green area, such as an urban park. For example, such a study may be about evaluating the impact of the redevelopment of a park or woodland (see e.g. Ward Thompson et al. 2013). In large-scale epidemiological studies, the area of choice is often the residential environment. Note that from an ecological perspective, the area that is assessed may not constitute an ecosystem in itself, but be a part of a larger ecosystem.[3] If so,

[3] This could be linked to the discussion on what constitutes the unit that provides a certain ecosystem service (see Andersson et al. 2015).

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it is relevant to take the functional role of the area within that ecosystem into account. For example, the redevelopment of a park may either be beneficial or detrimental to this function.

We will focus on the residential environment for a moment. This environment is defined in very different ways. In some studies it is defined as an administrative unit, such as a census tract or postcode area. In other studies, the residential area is defined as a buffer around the resident's home. In the latter case, the buffer sizes that are used vary considerably, from 100 metres up to 3 km (Egorov et al. 2017; van den Berg et al. 2010). There are no clear rules for the most appropriate definition to use. However, using the boundaries of administrative units may be considered rather arbitrary from the perspective of a citizen's lived experience. A very nearby green area that is located just on the other side of an administrative boundary may be as relevant as a green area within one's own administrative area (which might even be located further away). Furthermore, administrative units may not all have the same size, which may introduce confounds.

As for using buffer sizes, it may be argued that the optimal size depends on the mobility of the population, or the population segment, at hand. For example, when focusing on physical activity during outdoor play without adult supervision by children below the age of 10 years, then in many contexts using a buffer size of 1 km or more does not seem very sensible; parents usually do not allow their young children to play that far away from home on their own. Using a 'wrong' buffer size is likely to lower the strength of associations. If too large, irrelevant natural areas or natural elements are included; if too small, relevant natural areas/elements are ignored.

8.2.3 How to Measure Distance?

With regard to the use of distance in buffer approaches, there is also the issue of whether this should be Euclidean distance or network distance. Accessibility depends more on network distance than on Euclidean distance, since in the latter case barriers may prevent people from travelling in a straight line. However, network distances depend on the mode of transport. The network for travelling by foot may be quite different from that for travelling by car. Stairs, lawns and small alleys may be accessible or crossed by foot, but not by car. Incomplete networks can easily lead to an overestimation of network distance for some people, and in this way introduce a source of error. Nowadays, some researchers also take vertical distance into account (Jim and Chen 2010). A person living on the 20th floor of a high-rise residential building first has to get to the ground level, before getting out of doors (except for balconies and roof gardens, of course). When small buffer sizes are considered appropriate, taking vertical distance into account may make a substantial difference.

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8.2.4 Aggregating Biodiversity Across Different Areas

With regard to the level of biodiversity, an additional issue is how to arrive at an aggregated measure for the residential environment as a whole. One way might be to look at the biodiversity of each green area separately, and to calculate an average biodiversity level. This would allow for conclusions such as 'the green areas in this environment are highly biodiverse on average'. Another approach is to assess biodiversity at the level of the residential environment as a whole. That is, to pool all the species from the different green areas in the residential environment (and perhaps include isolated natural elements as well), and base the biodiversity score on the variety in this total pool. This would allow for conclusions such as 'there is a lot of biodiversity in this residential environment'.

Note that in extreme cases the two approaches may lead to quite different rankings of residential environments. A residential area with few urban parks, each with a rather high level of biodiversity in itself, but very similar to each other in species composition, may score high in the first approach. However, in the second approach it may be outscored by a residential environment with a larger number of smaller urban parks that each in themselves are not very biodiverse, but are complementary to each other in species composition. In the latter case there is more variety in the residential environment as a whole, but less variety in each individual park. Note that from an ecological perspective, one might also want to look at the functional links between the different green areas and natural elements that the inventoried area contains or their contribution to the larger ecosystem of which they are a part. In ecological studies, the Shannon Diversity index, which combines number of species and abundance of each species, is sometimes used to indicate functional diversity within a taxonomic group (Krebs 1989).[4]

8.2.5 Type of Access Metric

In the above, we focused on access to nature in terms of the availability or presence of nature within a certain area. Ekkel and de Vries (2017) have termed this a cumulative opportunity access metric, given that it takes all nature within that area into account. They distinguish the cumulative opportunity metric from another type of access metric, based on the distance to the nearest qualifying natural area. 'Qualifying' here refers to the area having at least a certain size and usually being open to the public as well. A minimum level of biodiversity could be added as another criterion in such an approach. A second option is not to use it as an additional criterion, but to look at it as a quality aspect of the otherwise qualifying natural area. The latter is more similar to the way access is handled in the cumulative

[4] Required abundance across taxonomic groups may differ by group, e.g. lower numbers for top predators than for prey animals.

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opportunity approach. As for the merits and (implicit) assumptions behind the two types of access metrics, the reader is referred to Ekkel and de Vries (2017).

8.2.6 Actual Versus Perceived Biodiversity

Information on the level of biodiversity, in terms of species diversity, is not always readily available. Sometimes data are gathered on perceived biodiversity, as for example in terms of how survey respondents rate the species richness of a specific site, or the number of species present in their residential environment. It is not clear to what extent perceived biodiversity coincides with actual biodiversity, not even if the latter is defined in terms of species richness (see e.g. Fuller et al. 2007 and Dallimer et al. 2012 for contradictory findings).[5] Perceived biodiversity is likely to depend strongly on the visibility of the different species, and on the extent to which they are perceived as being different. For example, biodiversity in the aquatic domain may go largely unnoticed (with the exception of aquaria). The same may be the case for the variety in the insect world, and even more so for that of micro-organisms. On the other hand, the biodiversity as perceived may be more likely to influence mental health than the objectively defined actual biodiversity (Dallimer et al. 2012). To the extent that the two do not coincide, different things are measured.

Furthermore, there is the methodological issue of a potential single-source bias when both biodiversity and mental health information are provided by the same source. Actually, when people rate the level of biodiversity of the same area, and subsequently how this is associated with their mental health is analysed, it is solely the co-variation of individual differences in perception and those in mental health that is studied, and not that of the actual level of biodiversity, which in that case is the same for everyone. A potential solution for the single-source problem is not using perceptions at the individual level, but aggregating the ratings regarding the same object to an average score for that object. A more sophisticated method of aggregating individual level data to characterise an environment is the ecometric approach introduced by Raudenbush and Sampson (1999). In this approach, the number of informants sampled, as well as the intersubjective agreement among informants, is statistically taken into account. This ecometric approach does not seem to have been applied for perceived biodiversity specifically thus far (but see de Jong et al. 2011).

[5] Fuller et al. (2007) provide an example of a study in which objectively assessed and perceived species richness for three categories of species/taxonomic groups are compared. It may be pointed out that they selected rather easy to perceive species: plants, birds and butterflies. Moreover, they aggregated individual perceptions per site. This may have helped them to arrive at the conclusion that greenspace users can more or less accurately perceive species richness. Even so, Dallimer et al. (2012), using the same approach, did not observe a positive association between perceived and actual species richness for any of the three taxonomic groups. See Marselle et al. Chap. 9, this volume.

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8.2.7 Access Versus Exposure, and Type of Contact

Earlier in this chapter, it was stated that most theories regarding pathways by which nature affects mental health assume that contact with that nature is required (see e.g. Hartig et al. 2014, on stress and social contact as mediators). Therefore, it is important to make a clear distinction between access to nature and actual contact with nature. According to these theories, only if access to nature leads to exposure to nature, will it be accompanied by mental health benefits. Although in some studies access is equated to exposure, the first is a proxy for the latter at best. Given the focus on biodiversity, exposure should be about the biodiversity with which an individual comes into contact. The level of biodiversity of a natural area might be hypothesised to increase the mental health effect of a visit to that area. It might also be hypothesised to make the area more attractive to visit (initially and subsequently), and thereby increase the frequency and/or duration of visits to that area.

It may be noted that a visit is a specific form of contact. People may also encounter nature, especially small natural elements such as street trees and those present in front gardens, while they are travelling to and from all kinds of destinations. Moreover, they may also have a window view of nature, allowing visual contact with outdoor nature while indoors. And even the latter has been shown to be related to mental health (Honold et al. 2016). It depends on the definition of biodiversity that is used whether or not such contacts should be included in the measure of the amount of biodiversity that a person comes into contact with over a certain period of time.

A focus on exposure implies that not only the residential environment is of interest, but also natural areas and elements that are encountered elsewhere, as in the work or school environment, as well as between such settings of ordinary activity. Nowadays, exposure measurement seems to head in the direction of the exposome: a comprehensive description of lifelong exposure history (Wild 2012; Kondo et al. 2018). The concept of 'exposome' is introduced as the environmental counterpart of the genome. Measuring actual total exposure is not easily achieved. For example, even when looking only at the number of visits to a specific type of nature, such as forests, retrospective self-reports tend to be rather inaccurate (Jensen 1999), though this presumably depends on the time frame for recall. To complicate matters further, the type of contact itself, ranging from indirect contact (e.g. looking at a nature documentary or looking at actual nature through a window), to being in a natural environment and actually interacting with nature (e.g. gardening or picking berries), may also have consequences for its mental health effects (Keniger et al. 2013).

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8.2.8 Mediators, Confounders and Covariates

The level of biodiversity, in terms of species diversity, may go hand in hand with that of other characteristics of a natural area, such as its perceived naturalness. From studies on landscape appreciation it is well known that the perceived naturalness of an area tends to have a positive impact on its scenic beauty (Gobster et al. 2007), and therefore may be a relevant concept in itself. Although perceived naturalness is not a very well-defined concept, it is almost by definition negatively affected by the presence of buildings and other human artefacts, while this presence does not necessarily lower the level of biodiversity of an area. Also, a park may seem highly natural to a lay person, while it is completely artificial from an ecological perspective. Thus, although the two concepts are likely to be correlated, they are definitely not the same. This brings up the following question: if, whether by observation or experimentation, the level of biodiversity has been shown to be associated with mental health, is it really the level of biodiversity that is instrumental in these associations, either directly or indirectly, by way of its effect on perceived naturalness? Or does the level of biodiversity tend to co-vary with perceived naturalness, without actually influencing it? In other words, is perceived naturalness to be considered a mediator, or a confounder, when researching the effect of the level of biodiversity on mental health?

Besides perceived naturalness, there are other characteristics that might be considered, for example visual complexity in terms of the richness and diversity of elements in the landscape, including their shapes, and how these are arranged in space (Ode et al. 2010; see also Marselle, Chap. 7, this volume). This is also not the same as, but likely to co-vary with, the level of biodiversity, while at the same time it may be relevant for mental health in itself. Similar conceptual questions can be asked as those for perceived naturalness. Moreover, a specific causal path may involve more than one mediator, complicating matters further (Dzhambov et al. 2018).

Especially in epidemiological research, there are also confounders that are less directly linked to the level of biodiversity, but are likely to co-vary with it in real-life situations, even more so when it comes to availability and access. These are to a large extent the same variables that are also important covariates in research on the amount of nature, rather than on its variety in terms of the number of species. For example, one could think of noise level, air quality, socio-economic position and population density. In research focusing on biodiversity, it should be noted that an additional covariate is the amount of nature: one would like to make sure that the variety makes an independent contribution, and it is not solely the amount of nature that is present, or the size of the nature area, that drives the association or the effect.

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8.3 Concluding Remarks

In this chapter, we focused on definitional and measurement issues with regard to access to and contact with nature, more specifically the biodiversity of that nature. We stated that biodiversity is originally an ecological concept, developed in the context of nature conservation. As we have illustrated, the concept has been adapted ('tweaked') to make it more relevant in the context of mental health. To begin with, frequently its functional aspect with regard to the sustainability and resilience of ecosystems is ignored. In addition to this, in several studies the measurement of biodiversity is limited to the parts that are perceivable and/or appreciated by lay persons. At the same time, such adaptations are likely to make the concept less relevant from a nature conservation perspective. So, much depends on the research question at hand.

We envision two lines of research. The first line has its focus on mental health promotion. In this line of research it makes perfect sense to look for qualities of nature that are likely to be conducive to produce (more or greater) mental health benefits. The concept of biodiversity may be adapted at will (preferably though based on theoretical arguments), but confusion may be reduced by (a) making clear that the concept has been adapted and (b) consistently labelling it differently (e.g. perceived species richness rather than biodiversity, without equating the both). The second line of research is about whether or which ecologically sound systems, requiring a certain amount of functional biodiversity, may go together with mental health promotion. Within this second line of research, focusing on multi-functional land use, adapting the concept of biodiversity seems less fruitful. To evaluate whether nature conservation and mental health promotion by contact with nature go well together, the success of each function, ecological and human health, needs to be assessed according to its own criteria.

Up till now, the first line of research seems to be more popular. That is, while there is a broad array of studies that refer to biodiversity and (mental) health, few of these studies address biodiversity in its ecological sense of functional species diversity. In fact, Dean et al. (2011) identified only one study, that of Fuller et al. (2007). We agree that the latter study provides one of the best examples of a rigorous measurement of species richness in the context of 'biodiversity – mental health' research. At the same time, even this study does not seem to put species richness in the context of the functional species diversity that is needed for a healthy ecosystem. The same argument can be made for the additional studies addressing species richness in the context of biodiversity and health that have been identified in more recent reviews (Lovell et al. 2014; Korpela et al. 2018; Marselle et al. Chap. 9, this volume). Also, in ecological science, where it is more likely that a stricter definition of biodiversity is adhered to, the compatibility of ecosystem health and human health also does not seem to be high on the agenda. Von Döhren and Haase (2015) conclude that in ecosystem services research possible negative

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effects, or ecosystem disservices, are an understudied subject.[6] Despite it not being a popular line of research, we strongly feel that research focusing on the combination of healthy ecosystems that help people keep mentally healthy is also worthwhile pursuing, not only from a nature conservation perspective (Bugter et al. 2018), but also from a long-term mental health, as well as an urban planning, perspective (Tzoulas et al. 2007).

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[6] This in contrast to the traditional focus of the environmental epidemiological branch of public health research, which focuses on the hazards that the environment may contain (Frumkin 2001).

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