Dishing up biodiversity: how does out-of-home catering affect biodiversity?

Assessment methodology and implementation in commercial kitchens

Julia Heinz, Anita Menzel, Lynn Wagner, Nina Langen, Melanie Speck

Abstract

Biodiversity is under threat all over the planet. Implementing sustainable out-of-home catering (OHC) is a key way to reduce the environmental impact of the agri-food sector. Thus far, there have been no studies that show the impact of food on biodiversity at the menu level in Germany. This means that neither commercial kitchens nor their patrons can record the biodiversity impact of the menus or dishes served there. This article describes the development of an assessment framework and some initial findings. The framework was developed on the basis of a systematic literature review and expert interviews. Taking this as a starting point, an indicator-based approach was developed with a focus on land use. The approach was then validated by assessing recipes used at OHC facilities. The results show that using the BiTe[1] Biodiversity Index (BBI) that was developed, it is possible to assess the biodiversity impacts of meals and optimize them at the level of the dish. The article outlines the possible areas for improvement. Overall, it is clear that this approach can already be used in the OHC context today.

Keywords: biodiversity, biological diversity, agrobiodiversity, out-of-home catering, sustainable commercial catering

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Corresponding author

M. Sc. Julia Heinz
Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Döppersberg 19, 42103 Wuppertal
julia.heinz@wupperinst.org

Introduction and research question

A healthy ecosystem depends on biodiversity and the associated diversity of ecosystems, animal and plant species, biotic communities and living organisms, as well as the genetic diversity of these organisms [1]. However, despite the pivotal role of agricultural landscape biodiversity in supplying ecosystem services (bearing in mind that food security depends on these services), the association between individual diets and the associated loss of biodiversity has received little scientific attention. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the current food system is the main cause of global species loss. This can primarily be attributed to factors such as land use change, climate change, invasive species, pollution and contamination, and overexploitation of natural resources [2]. The Planetary Health Diet [3] is an example of what a diet that remains within planetary limits could look like. However, the menu plan for this diet can only be seen as a starting point for biodiversity conservation because it focuses on health-related aspects and only deals with food groups (such as fruit, vegetables or meat) rather than with meals as a whole.

There are both completed and ongoing scientific research projects and corporate research projects [4–6] that demonstrate the association between biodiversity and food production. The available data are often limited to snapshots of the status of individual species in specific production systems, habitats or geographical areas [7]. Various approaches [8–10] to assessing the effects of agricultural production on

[1] BiTe *(Biodiversität über den Tellerrand)* is a research project funded by the German Federal Ministry of Education and Research.

biodiversity and agrobiodiversity can be found in the literature, but methods for consistently measuring these effects along all stages of value chains and across all diets are lacking.

Furthermore, the preservation of biodiversity is still not given much space in public discourse. The Nature Awareness Study 2019 revealed that the majority of the German population does not know the meaning of the term "biodiversity" [11]. In order to help people make the connection between biodiversity and their everyday (food) choices at home and outside the home, a meaningful way of assessing the biodiversity impacts of meals is needed, as well as practical approaches to disseminating the results.[2]

Out-of-home catering (OHC) is the second largest sales channel in the food industry [12]. It is therefore a key lever that can be used to reduce the environmental impact of the food sector and simultaneously improve human health [13, 14]. Assuming that eating outside of the home influences eating behavior at home [15] and that changes made in a commercial kitchen have a direct impact on anything from several hundred to a thousand meals per day, OHC can be understood as an indirect driver of dietary change in society as a whole [16]. In addition, regular visits to OHC facilities such as company or school cafeterias, can cultivate a preference among patrons for sustainable and biodiversity-friendly menus [17]. Finally, Göbel et al. [18] identify the preservation of biodiversity as one of the eight guiding principles in their guidelines for sustainability in the OHC context. These characteristics make OHC an important field for living lab research [13, 14, 17]. Meaningful ways of assessing and optimizing existing meal options are needed to enable businesses to put together biodiversity-friendly meals. Therefore, the research questions under consideration here are as follows:

Q1: How can the biodiversity impacts of meals served in out-of-home catering contexts be meaningfully quantified?

In addition, such approaches must be designed to be not only meaningful, but also practical and accessible, so that they can be used by a large number of companies in the OHC context. The second research question follows from this:

Q2: What are the opportunities and barriers in terms of translating this scientific approach into practice?

Methodology

Developing the indicator-based assessment tool

A standardizable framework for assessing the biodiversity impacts of meals was to be developed based on an analysis of existing concepts, indicators and target values (◆ Figure 1).

This was developed based on secondary research and it draws on existing multi-criteria assessment methods. A systematic literature search was conducted using an iterative process with keyword searches: *biodiversity*, *LCA*, *biodiversity impact assessment* (n = 18,400). This search yielded 19 published impact assessment methodologies for assessing the impacts on biodiversity of land use on biodiversity. These were then reviewed. The results of the literature review were supplemented by guideline-based expert interviews[3] (n = 4) and were finally developed into an indicator-based approach for assessing the biodiversity impact of meals.

Approaches to biodiversity impact assessment

There is currently no standard scientific approach to assessing the impact of human activities on biodiversity. One way to measure direct impact on biodiversity is to measure taxonomic diversity, i.e., species richness or species loss. Another way is to measure the state of species assemblages (functional diversity) [19–21]. Indirect impacts can be assessed through climate impacts, invasive species, ecotoxicity, acidification and eutrophication, as well as land use/transformation [7, 8, 10, 22]. The primary driver of biodiversity loss is land use [23, 24]. For this reason, this study focused on assessment methods with an emphasis on land use. Unlike for other indicators, extensive datasets recommended by UNEP-SETAC[4] are available for modeling biodiversity loss [25]. The dataset used here is based on a method that uses species-area-relationship models (SAR models). This is a common method for capturing land-use effects [26-30]. The BiTe Biodiversity Index (BBI) methodology for assessing biodiversity loss is based on the studies by Chaudhary et al. [29] and Chaudhary and Kastner [31]. It provides a quantitative representation of terrestrial biodiversity impacts in terms of potential regional species losses per ton of crop grown.[5] Data refer to conventional cultivation.

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[2] The article is based on a research project funded by the German Federal Ministry of Education and Research called "BiTe – *Biodiversität über den Tellerrand*" (which ran from 9/2020 to 8/2021 and from 12/2021 to 11/2023). One aspect of BiTe was the development and practical testing of an assessment framework for meaningful assessment of the biodiversity impacts of dishes served in out-of-home catering (OHC) contexts. Another aspect was targeted communication with patrons in the OHC context, with the goal of increasing demand for optimized food options in OHC facilities through the use of various materials (e.g., biodiversity comics, tray mats).

[3] From the following fields: biodiversity in organic agriculture, modeling biodiversity impacts in LCA, sustainability/biodiversity in OHC contexts.

[4] International Life Cycle Partnership of the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC)

[5] Species loss data for four taxa (birds, mammals, reptiles, and amphibians) were combined with global yield maps to calculate species loss per ton for 170 crops across 184 countries. The selection of crops and countries is based on classifications in the United Nations FAOSTAT database of agricultural products [32].

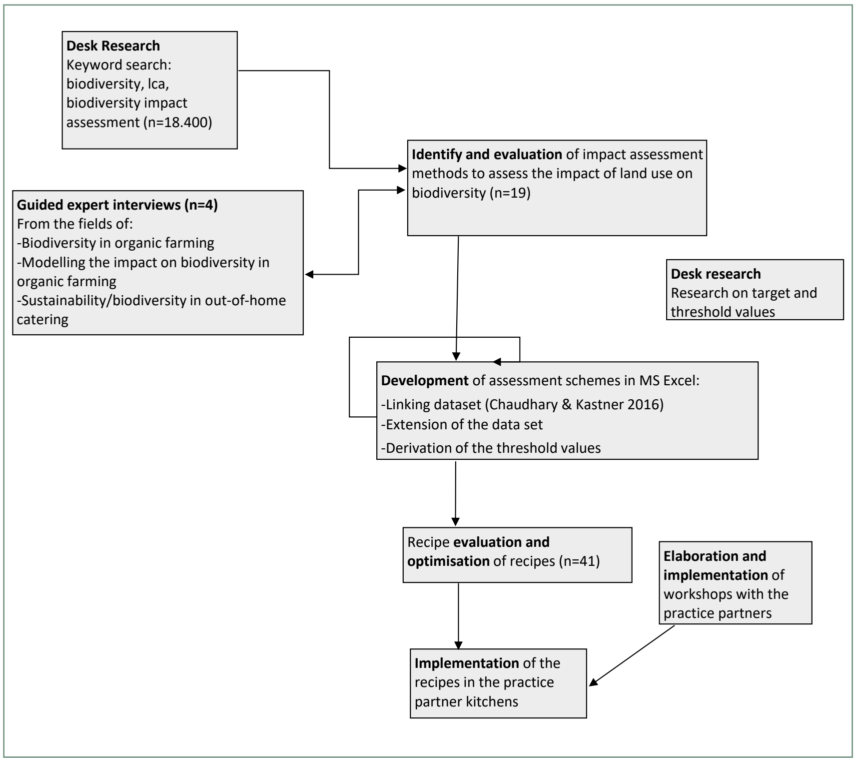

Fig. 1: **Development and review of an assessment framework for the biodiversity impacts of meals**

Expanding the dataset

The data derived from the work of Chaudhary and Kastner [31] are limited to the cultivation of crops. The dataset was therefore expanded to include the impact of animal-based products. For this purpose, the biodiversity impacts of animal-based products were derived from data on feed consumed in the form of concentrates [33]. The dataset was further expanded to include processed foods. In the case of foods with various stages of processing, the value of a basic ingredient from the dataset was multiplied by the appropriate multiple or percentage (7 L of milk equals 1 L of cream). In the case of combined foods, the percentages of the various basic ingredients were added together. Examples of this would be broths and pasta. The dataset was expanded from 65 to 220 ingredients in total.[6]

Determining threshold values

Assessing and ranking the biodiversity impacts of meals/dishes using the BBI requires a rating scale, a target value, and other threshold values. A total of 6 assessment categories were defined. The planetary boundary for biodiversity (biosphere integrity), defined as 10 extinctions per million species per year by Rockström et al. [34] was used as the basis for calculating the target value. If this value is multiplied by the estimated number of species on earth, which is 8 million [23], this means that no more than 80 species per year may become extinct. Based on this, the target daily food consumption of one person was calculated by dividing the 80 extinctions per year by 365 days and the number of the world population ($7.8*10^9$) [35], and then multiplying by agriculture's share of biodiversity loss, which is 0.7 [36] (◆ Figure 2). This results in a maximum target value of $1.96*10^{-11}$ extinctions/person/day.

$$\text{Target}_{\text{food}} = \frac{80 \text{ ext.}}{\text{year}} * \frac{1}{7.8 * 10^9 \text{ (global pop.)} * 365 \text{ days}} * 0.7 \text{ (agriculture)}$$

$$= 1.96 * 10^{-11} \frac{\text{ext.}}{\text{day}}$$

Fig. 2: **Formula for calculating the target value for the biodiversity impacts of a person's food consumption per day**
(ext./day = extinctions/day) [37]

Assuming a person eats three main meals per day, the midday meal accounts for about one third of a person's daily intake. Therefore, the target value for one day is divided into thirds, giving $6.53*10^{-12}$ extinctions/person/midday meal.
Threshold values for zones were determined based on the target value (◆ Figure 3).

Testing the BiTe Biodiversity Index

In addition to the conceptual development of the assessment framework, this study also tested the integration of the approach into the operational processes of commercial kitchens. As part of this, a test was conducted to determine whether OHC recipes could be assessed using the BBI and how the assessment results should be classified in relation to the threshold values. To evaluate this, 41 recipes from commercial kitchens were assessed. The recipes were assigned to four categories: meat, vegetarian, vegan and sweet dishes. In the sweet dishes category, only sweet dishes served as main courses were assessed. Fish dishes were not assessed because the dataset does not cover seafood. Recipes were selected based on which dishes were popular in the commercial kitchens. The ingredients in all of the 41 recipes that were assessed have a low degree of

[6] Other relevant indicators found for the OHC context were cultivation and husbandry methods as well as the diversity of the menus in terms of ingredient composition and variety/breed selection. These will be integrated into the ongoing research.

Rockström scale	Green	Yellow			Red	
Planetary boundary according to Rockström et al. 2009 [34]	< 80 E/Y (target value)	80–800 E/Y			> 800 E/Y	
BBI scale	Green	Light green	Yellow	Orange	Red	Dark red
Scaling of the target value (extinction rate in E/Y)	< target value	< 2.5 x target value	< 5 x target value	< 10 x target value	< 20 x target value	> 20 x target value
Limit value per person per day	< $1.96 * 10^{-11}$	< $4.9 * 10^{-11}$	$9.8 * 10^{-11}$	$2.18 * 10^{-11}$	$1.43 * 10^{-10}$	$1.96 * 10^{-10}$
Limit value per meal	< $6.53 * 10^{-12}$	< $1.63 * 10^{-11}$	< $3.27 * 10^{-11}$	< $6.53 * 10^{-11}$	< $1.31 * 10^{-10}$	> $1.31 * 10^{-10}$

Fig. 3: **Classifications on the rating scale with the associated threshold values**
This shows the underlying limits according to Rockström, how the threshold values relate to the target value, and the correspondingly calculated threshold values for the six assessment categories [37].
BBI: BiTe Biodiversity Index; E/Y: extinctions per year

convenience. In all cases, the assessment refers to the quantities specified for one serving. For standardization purposes, the recipes were adjusted to an average weight of 600 g. Species loss data only take the impact of agricultural production into account. Therefore, only information on ingredients, countries of origin and quantities used was requested.
In addition, a carbon footprint was calculated for all recipes. As a result, this study investigated whether the results of both indicators – the BBI and the carbon footprint – follow the same trend for the recipes under consideration, or whether there are conflicting objectives. According to the IPCC methodology 2007, when calculating the carbon footprint, the total amount of greenhouse gases released is expressed as units of kilograms of CO_2 equivalents (CO_2-eq) that are directly and indirectly released during the different life cycle stages of a product [38]. The environmental data are taken from the Ecoinvent database versions 3.1 and 3.6. In contrast to the BBI, the system boundaries here include agricultural production and further processing of ingredients, distribution processes as far as the commercial kitchen, and preparation in the commercial kitchen. To facilitate comparison of the carbon footprint assessment results with the BBI, the results are also classified using threshold values. According to Lukas et al. [39], a midday meal is considered recommended if it generates less than 800 g CO_2-eq[7]. Dishes with a carbon footprint of up to 1,200 g CO_2-eq are recommended to a limited extent. Dishes that exceed the limit value of 1,200 g CO_2-eq are not recommended [13, 14, 39–40].

Applying the BiTe Biodiversity Index in commercial kitchens

The application of the BBI was also tested in three OHC facilities that operate in the business and education sectors and together cater for up to 1,800 patrons per day. The testing phase involved training participants in workshops, optimizing selected recipes, and preparing and serving the optimized dishes. In this first testing phase, patrons were not told about any change in recipe composition.
To ensure that the method was applied properly, one workshop covering menu planning and the application of the BBI was held at each facility (5/2021–8/2021). Recipes were assessed and optimized at each facility. The optimized dishes were then prepared and served at the facilities. Experience gained during the testing phase was qualitatively recorded in a second workshop.

Results

Applying the BiTe Biodiversity Index – example

◆ Figure 4 shows a fictitious example of the assessment of chicken curry.
The results table shows the potential species loss for each ingredient as well as cumulatively for the entire dish. It also shows the percentage that each ingredient contributes to the total impact. Looking at the results for the individual ingredients, it is clear that within the menu, certain plant-based ingredients (coconut milk, pepper, rice) have the highest impact after the meat component. For the plant-based ingredients, this is due to the higher biodiversity density found within the tropical zone countries where they are grown [41]. For the meat component, it is due to the high use of high-protein fodder (soy).

Biodiversity impacts of selected recipe categories

The results for the recipes (n = 41) show that at least one recipe was represented at each level of the six-point rating scale. This suggests that the scale can be used to illustrate changes that can be made, for example, through substitution or reduction strategies.
In addition, the carbon footprint was calculated for the recipes and this was then graded on the scale using the threshold values for

[7] Taking recent study results into account, it can be assumed that the limit value of 800 g CO_2-eq [39] will have to be made stricter in the near future.

Selected foods	Country of origin	Amount per meal [g]]	Percentage of regional species loss per portion	Percentage of regional species loss out of total portion
			Conventional	
Onions, shallots, green	Netherlands	25	1,81E-13	0,0%
Garlic	Central China	2,5	3,80E-13	0,1%
Ginger	India	5	7,52E-12	1,2%
Paprika/chili powder	Spain	15	9,54E-13	0,1%
Spinach	Germany	25	1,87E-13	0,0%
Green peas	Germany	25	4,14E-13	0,1%
Poultry		112,5	4,77E-11	7,3%
Greeb peppers and chilis	Spain	12,5	7,95E-13	0,1%
Coconut oil	Indonesia	10	8,28E-11	12,7%
Spices	India	5	1,12E-11	1,7%
Coconut milk	Indonesia	200	3,55E-10	54,5%
Soy sauce		10	7,66E-13	0,1%
Pepper	India	2,5	1,03E-10	15,8%
Rice	Central China	150	4,02E-11	6,2%
	total	600	6,51E-10	100,0%

Fig. 4: **Example recipe: chicken curry**
Combined foods and animal-based products were not assigned any data for the country of origin.

the carbon footprint [13, 14].[8] ◆ Figure 5 shows the results of the recipe assessment for the BBI and for the carbon footprint, divided into the recipe categories (1) meat, (2) vegetarian, (3) vegan and (4) sweet dishes.
A comparison of the impacts shows that the dishes in the meat category are predominantly classified as not recommended in both assessments.

The results show that vegetarian meals have a similar distribution within the threshold ranges for both indicators. The main reason for this is the animal-based ingredients such as milk, cheese and egg. These ingredients cause both high emissions of CO_2 and a high impact on biodiversity. Vegan recipes vary widely. Most of the recipes in this category can be categorized as recommended in terms of carbon footprint. However, in terms of biodiversity impacts, none of the recipes can be categorized as recommended. The assessment of greenhouse gas emissions does not consider the impact on species density in the countries where the ingredients are grown.
Initial recommendations for the composition of biodiversity-friendly recipes can be derived from the recipe assessments:

- **Consider countries of origin:** Foods from growing regions with high species density should be avoided. In addition to tropical zones, such regions also include the Mediterranean, which is mainly used for vegetable cultivation.
- **Avoid animal-based ingredients**, especially meat: meat has a high impact due to the use of high-protein (soy) fodder.
- **Use plant-based ingredients** with a particularly high impact only sparingly. Examples include: olive oil, coconut oil, coconut milk and palm oil. In addition, spices such as real vanilla and, depending on the country of origin, pepper are also problematic ingredients.

Applicability of the BiTe Biodiversity Index in practice

Recipe assessment and optimization

The participating facilities were able to work through the Excel-based assessment framework independently with the help of specially prepared explanatory videos and workshops. It was possible to optimize some of the dishes to within the recommended range using substitution or reduction strategies at the recipe level [16]. Achievable optimizations were identified. For example, reducing animal-based products, substituting starch side dishes that have a high biodiversity impact, such as rice, or substituting the frying oil (consisting of palm oil and soybean oil). For example, in the recipe for creamy vegetable stew, cream was completely replaced with oat-based cream alternative, and the proportion of cow's milk was reduced by 50%. In the one-pot vegetable and rice recipe, rice was substituted with millet, and imported vegetables (peppers, out of season) were replaced with local, seasonal vegetables.

Procurement management

Some recipes required sourcing of new ingredients, such as oat-based milk alternative or soy-based cream alternative. Some of these products were not available in bulk from wholesalers. As an alternative, the facilities had to use smaller pack sizes. In addition, some ingredients had to be purchased from food retailers because they were not available from wholesalers at all. This required an additional investment of time. As outlined in the section "Applying the BiTe Biodiversity Index – example", the biodiversity impact assessment requires the country of origin to be specified for each ingredient. It was found that in practice, catering facilities rarely or never have access to this information. While they were always able to ascertain the registered office of the distributor (as required by the German Food Law), the country of origin of the individual products could usually only be ascertained by asking suppliers.[9] This problem was particularly evident in the case of combined products. With this in mind, these ingredients were assigned standard countries of origin for Ger-

[8] The recipes were categorized on the basis of the existing NAHGAST calculator threshold values for greenhouse gas emissions [13, 14].
[9] This will change in the future as a result of the new German Supply Chain Act.

man consumption within the assessment framework [32]. Furthermore, some catering facilities also mentioned higher procurement costs as an obstacle to modifying and optimizing recipes to be more biodiversity-friendly. Ingredients and brands that were not part of their standard product range, such as millet or soy-based cream alternative were more expensive to procure.

Food preparation
Preparing large quantities of food using small pack sizes was more time-consuming and resulted in increased packaging waste. It was also noted that some substitutes behaved differently during preparation (cooking times, textures) and in some cases contained more allergens. This required more fine-tuning of the recipes. It was also reported that testing the recipes sparked interest in exploring the subject of biodiversity and trying out new dishes among kitchen staff.

Serving food
At all of the catering facilities, patrons enjoyed the optimized dishes from a sensory perspective, and all of the new ingredients were accepted. However, differences were found between newly developed dishes and those whose existing recipe had been optimized. One catering facility reported that dishes that were already familiar to patrons, and were therefore associated with certain expectations, had a lower acceptance rate than before in some cases.

Discussion

This article explored the question of whether the biodiversity impacts of meals in the OHC context can be quantified and optimized using appropriate approaches. It can be concluded from the findings that the BBI is suitable for assessing meals in this regard in the OHC context. The assessment of the recipes (n = 41) showed that using the assessment framework and the extended dataset, it is possible to calculate and classify the biodiversity impacts of common recipes served in the OHC context. In the future, data on the assessment of seafood[10] and food from organic farming should also be integrated into the assessment concept to ensure a comprehensive approach.

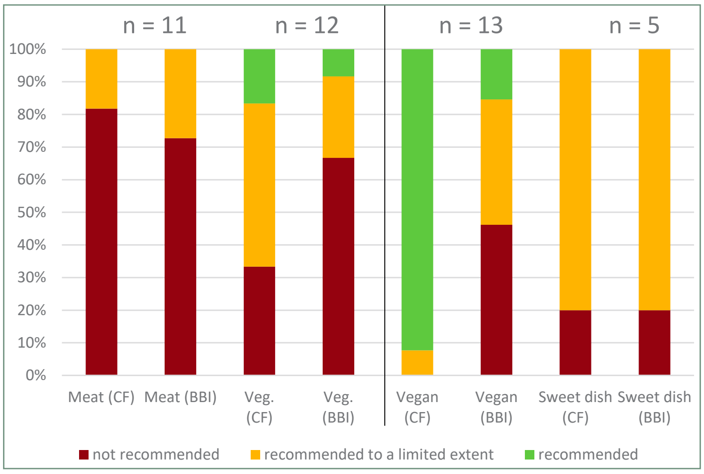

Fig. 5: **Impacts of the recipe categories (1) meat, (2) vegetarian, (3) vegan, (4) sweet dishes on biodiversity and the climate**
BBI: BiTe Biodiversity Index; CF: Carbon Footprint

In its current version, the BBI determines biodiversity impacts using species numbers. The field of biodiversity research emphasizes the importance of considering species assemblages and ecosystem assemblages (functional diversity) in addition to taxonomic diversity when assessing biodiversity. This is because if even there is constant immigration and extinction, the number of species can still remain unchanged, even though a fundamental change in composition has occurred [19, 20]. However, there are only sufficient data to assess taxonomic diversity [44]. Given this situation, it has not been possible to take species assemblage into account in the BBI to date. This highlights the need for more comprehensive data collection on functional diversity.
An analysis of recipe assessments at the ingredient level shows that, similar to other environmental indicators, animal-based products have a major impact on biodiversity, even though the effects associated with animal husbandry (land use due to barns and spaces for livestock, input of liquid manure) cannot yet be taken into account. A new finding is that assessing biodiversity impact highlights the special role played by the country of origin or country of cultivation of the ingredients. The results show that biodiversity is severely threatened by agricultural land use in many regions of the world, and not just in the tropics. Additionally, biodiversity assessment sheds new light on the use of certain plant-based foods and is therefore indispensable when designing sustainable plant-based meals. Oils, fats and legumes have a particularly strong impact. Since legumes are important sources of protein in a low-meat diet and cannot be excluded from out-of-home catering at this point in time, there is an urgent need for further research on biodiversity-friendly alternatives in this

[10] Nearly one-third of fish stocks are already overfished and one-third of freshwater fish species are under threat [42]. This makes fish a relevant area of concern in the context of biodiversity loss. The consumption of fish is also an important issue in the OHC context, especially from a nutritional perspective. For example, regular consumption of fish is recommended in the DGE (German Nutrition Society) Quality Standards [43].

area. The comparative assessment has shown that CO_2 assessment alone cannot cover these impacts, particularly in the case of vegetarian and vegan recipes.

During testing of the BBI in real kitchen operations (school catering, workplace catering), it became apparent that some of the described levers, such as the reduction or substitution of ingredients from regions with a particularly high biodiversity density, cannot be implemented. The real-world situation in catering kitchens is that they rarely know what country an ingredient comes from and can seldom influence this. The same applies to the choice of (heritage) species/varieties and breeds.[11] The lack of transparency in the food value chain emerged here as a major obstacle to the implementation of biodiversity-friendly menu planning. Moreover, the majority of the recipes assessed did not reach the target value despite optimizations. In the context of food consumption in Germany, this observation is not surprising. Current German consumption alone would account for half of the maximum permissible species extinction worldwide.[12] In the future, when designing biodiversity-friendly menus, the biodiversity aspect must be taken into account from the outset when developing dishes for the out-of-home catering context. The recommendations derived from this study could serve as an initial approach to this. Furthermore, there is a need for a change in production methods and a reduction in food waste throughout the food sector [3].

The price pressures that kitchens face also play a significant role. Biodiversity-friendly alternative products can be more expensive to procure than the "standard" ones. For alternative products to be usable in the OHC context, they must first be supplied by wholesalers in suitable bulk containers. That said, biodiversity-friendly cuisine does not always have to be more costly. For example, reducing the use of animal-based products can make it cheaper. However, the cost issue is not unique to biodiversity-friendly menu planning: it is a general problem in the discourse on sustainable out-of-home catering.

Conclusion

The BBI is a first step toward putting biodiversity conservation into practice in the OHC context. The results are consistent with studies related to nutrition [8, 45]. However, the results also show that there is room for improvement and that there are further areas to be addressed. It is also clear that commercial kitchens currently have only limited room for maneuver. If OHC is to become more biodiversity-friendly, greater transparency is needed in terms of origin labels and species/variety identifiers, and a wide range of options will also be required in terms of procurement. That being the case, it is essential to focus on the entire value chain. Furthermore, in addition to the initial recommendations, much more knowledge is required about the impacts of farming methods and heritage varieties and species, as well as about the use of fish, other marine animals and game meat. In principle, however, the BBI can already be implemented in commercial kitchens by identifying recipe optimizations that kitchens can feasibly implement, that align with their budgets, and that maintain acceptance among patrons. In addition, this approach has the potential to be integrated into the assessment framework of the NAHGAST calculator, making it readily accessible and free for OHC facilities to use. In the OHC context in particular, this could be leveraged to drive sustainable change in the food system.

Conflict of Interest
The authors declare no conflicts of interest.

M. Sc. Julia Heinz[1, 2, 3]
M. Sc. Anita Menzel[4]
M. Sc. Lynn Wagner[1]
Prof. Dr. Nina Langen[3]
Prof. Dr. Melanie Speck[1,2]
[1] Hochschule Osnabrück, Fakultät Agrarwissenschaften und Landschaftsarchitektur
Am Krümpel 31, 49090 Osnabrück, Germany
[2] Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Döppersberg 19, 42103 Wuppertal, Germany
[3] Technische Universität Berlin, Institut für berufliche Bildung und Arbeitslehre, Fachgebiet Bildung für Nachhaltige Ernährung und Lebensmittelwissenschaft
Marchstraße 23, 10587 Berlin, Germany
[4] iSuN – Institut für Nachhaltige Ernährung, FH Münster
Corrensstraße 25, 48149 Münster, Germany

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[11] This is to be integrated into the assessment and is therefore already being queried now.

[12] Derived from potential species losses in Germany (46) [31] and a defined target value of max. 80 species losses per year.

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