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Analysis

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Nature-positive goals for an organization's food consumption

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Organizations are increasingly committing to biodiversity protection targets with focus on 'nature-positive' outcomes, yet examples of how to feasibly achieve these targets are needed. Here we propose an approach to achieve nature-positive targets with respect to the embodied biodiversity impacts of an organization's food consumption. We quantify these impacts using a comprehensive database of life-cycle environmental impacts from food, and map exploratory strategies to meet defined targets structured according to a mitigation and conservation hierarchy. By considering the varying needs and values across the organization's internal community, we identify a range of targeted approaches towards mitigating impacts, which balance top-down and bottom-up actions to different degrees. Delivering ambitious nature-positive targets within current constraints will be challenging, particularly given the need to mitigate cumulative impacts. Our results evidence that however committed an organization is to being nature positive in its food provision, this is unachievable in the absence of systems change.

Transformative actions are needed to address the triple challenge of global biodiversity loss, climate change and improving human wellbeing[1–3]. Bold targets are being proposed internationally (for example, 'nature-positive' targets that aim to achieve net-positive impacts on biodiversity by 2030 relative to 2020 (refs. [4–6])) and nationally (for example, UK Environment Act[7] and Biodiversity Net Gain policies[8]). These targets are being translated to subnational levels (for example, circular cities[9]). Organizations are committing[10,11] to strategic biodiversity targets[12] aimed at mitigating negative biodiversity impacts, and increasingly to nature-positive outcomes in line with global policy directions[4,6,13].

The first step towards achieving these targets is to measure biodiversity impacts. This enables organizations to design effective impact-reduction strategies, assess progress towards targets and make explicit contributions to wider environmental goals[10,14–16]. Targets and strategies must also be designed in consultation with affected groups, to ensure equitable and sustainable outcomes[17].

One approach is to use the mitigation hierarchy framework, a structured approach for impact mitigation towards a specified target (for example, net gain in biodiversity). It prioritizes prevention before compensation, beginning with avoiding and reducing impacts before restoration or offsetting of any unavoidable impacts[18]. In the past, this framework has been primarily applied to impacts from the infrastructure and extractive sectors, although it has been expanded to agriculture and fisheries[19–23] and could be extended to all impacts from human activities[24,25].

However, reactive compensation is not enough to achieve transformative change. Recently, the 'mitigation and conservation hierarchy' (MCH) has been proposed[26], which integrates the reactive mitigation hierarchy with a 'conservation hierarchy' for actions that proactively address historical, systemic and non-attributable impacts[26]. It provides a framework to support individuals, communities, businesses and governments to meet ambitious biodiversity targets. However, this framework has yet to be applied to the full range

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of direct and indirect impacts that organizations need to tackle to meet nature-positive targets.

For many organizations, a key consideration is the embodied impacts from food consumption by its members[27] (individuals over whom organizations can exert influence, for example, through food options or information in canteens). Food systems are a major driver of global biodiversity loss, with over one-third of land currently used for agricultural purposes[28] and ~88% of terrestrial birds, mammals and amphibians predicted to lose habitat to further agricultural expansion by 2050 (ref. [29]). Changes to food systems (for example, sustainable production and trade, reduced food waste and shifting to healthy, sustainable diets) will be essential for halting global biodiversity loss[30] while simultaneously addressing issues of climate, food security and health[31–36].

Recently, life cycle analysis (LCA) has enabled development of large-scale databases on the environmental impacts of foods[34]. In this Analysis, we use these datasets to quantify impacts from food consumption of a case study organization, applying the MCH to explore feasible routes towards achieving biodiversity targets, considering differences in risk and preference across various consumer groups. We consider how bold but necessary nature-positive targets (for example, cumulative biodiversity net gain) could be achieved in this context. While others have measured biodiversity impacts associated with food consumption[27,37], we provide a robust, quantitative application of the MCH to this crucial element of environmental impacts, generating evidence on how organisations can contribute towards a science-based global goal for nature[4,12].

Approach overview

We focus on a higher education college (Lady Margaret Hall, Oxford University, UK; herein, 'the college') and the community of individuals that work, study and visit as part of its operations. The college canteen provides food and beverages (herein, 'food') regularly for ~500 university students, ~130 support and facilities staff, and ~75 academic staff. The college also prepares food for commercial conference and event attendees, and for external students attending summer school programmes. All food is ordered and prepared through the college's central kitchen.

The college provides a useful case study owing to its detailed records of food consumption for multiple groups, its keenness to reduce its environmental impact and its controllable food system. However, our approach is generalizable to any food-providing organization, particularly as we make use of consumption datasets that are often readily available (sales and purchase data). Furthermore, the MCH framework[26] is generalizable to other scales (for example, individuals tracking their food consumption), other forms of environmental pressure (for example, greenhouse gas emissions) and other types of activity beyond food consumption[38].

The approach comprises four stages (Table 1): (1) estimating current biodiversity impacts from food; (2) defining biodiversity targets; (3) assessing possible interventions; and (4) exploring different intervention combinations that achieve these targets. Each stage involved consultation with end users (Methods). For stages 3 and 4, we predominantly focus on reactive impact mitigation, although we do discuss possible proactive actions.

Table 1 | Approach Overview

Stage	Description	Method
1: Baseline	Estimate biodiversity impacts from food currently served, identifying focal areas of high impact (in terms of both products and consumer groups).	Combine consumption data with LCA data and a biodiversity metric[40] to estimate impacts per product type and consumer group.
2: Targets	Establish a set of possible Specific, Measurable, Achievable, Realistic and Time-bound (SMART) targets for future levels of biodiversity impact from food consumption.	Identify target options based on stakeholder consultations and science-based best practice (such as aligning with a nature-positive target[4]) Model annual and cumulative impacts under each target scenario over the target period to gauge the level of effort required.
3: Actions	Identify possible interventions that would reduce impacts under each of the 'four steps': Refrain, Reduce, Restore, Renew.	Scan of relevant academic and grey literature. Consult with stakeholders to identify existing interventions in place at the college.
	Assess each intervention in terms of potential effectiveness ('technical potential').	Approximate changes to baseline biodiversity impacts expected under each intervention.
	Assess each intervention in terms of socio-economic feasibility.	Conduct stakeholder interviews with key individuals at the college.
4: Strategy	Explore strategies (combinations of interventions) for reaching chosen targets using different combinations of interventions that balance different risks to varying degrees.	Model combinations of interventions and assess predicted progress towards targets.

A summary of the approach used, applying the MCH framework proposed by Milner-Gulland et al.[26].

Stage 1: estimating biodiversity impacts

Biodiversity impacts from food served at the college were estimated by pairing 2018/2019 kitchen purchasing data (by mass or volume per product) with environmental LCA databases[34,39]. We applied a United Nations Environment Programme-recommended biodiversity metric[40], which estimates the number of species destined for extinction on the basis of land transformation and occupation in food production locations. LCA approaches to biodiversity accounting have several limitations[41] (Methods). They ideally require information on food sourcing, which is often not available (including here), and their units (for example, 'species extinctions equivalents') can be complex to communicate. However, they do provide a data-driven approach for estimating relative biodiversity impacts, which can be compared across a broad scope of activities.

We estimate the college purchased ~156 tonnes of food over the 2018/2019 academic year, which required ~541,904 m^2 of land, resulting in a negative biodiversity impact of ~7.9×10^{-7} potential global species extinctions equivalents (interpretable as a relative measure of species extinction risk;[40] Fig. 1a). In line with prior research[27,34,37], the highest biodiversity impacts were driven by foods with disproportionately large land footprints, including red meat, poultry and fish (linked to 16.5%, 15.7% and 12.6% of total impacts, compared with 3.7%, 3.9% and 1.7% of consumption by mass, respectively; Fig. 1a). Considerable impacts were also derived from products containing ingredients sourced from highly biodiverse regions, including desserts, chocolate and confectionary (15.1% of impacts, compared with 5.8% by mass), as well as coffee and tea (9.3% of impacts, compared with 0.3% by mass) as has also been highlighted elsewhere[42,43]. Students consumed the greatest quantity of food and had the highest overall impact (36.8%), although the lowest impact intensity (4.6×10^{-12} species eq. per kilogram food; Fig. 1b). Conference attendees contributed a large proportion of overall impacts (33.0%) and had the highest impact intensity (5.4×10^{-12} species eq. per kilogram food). Support

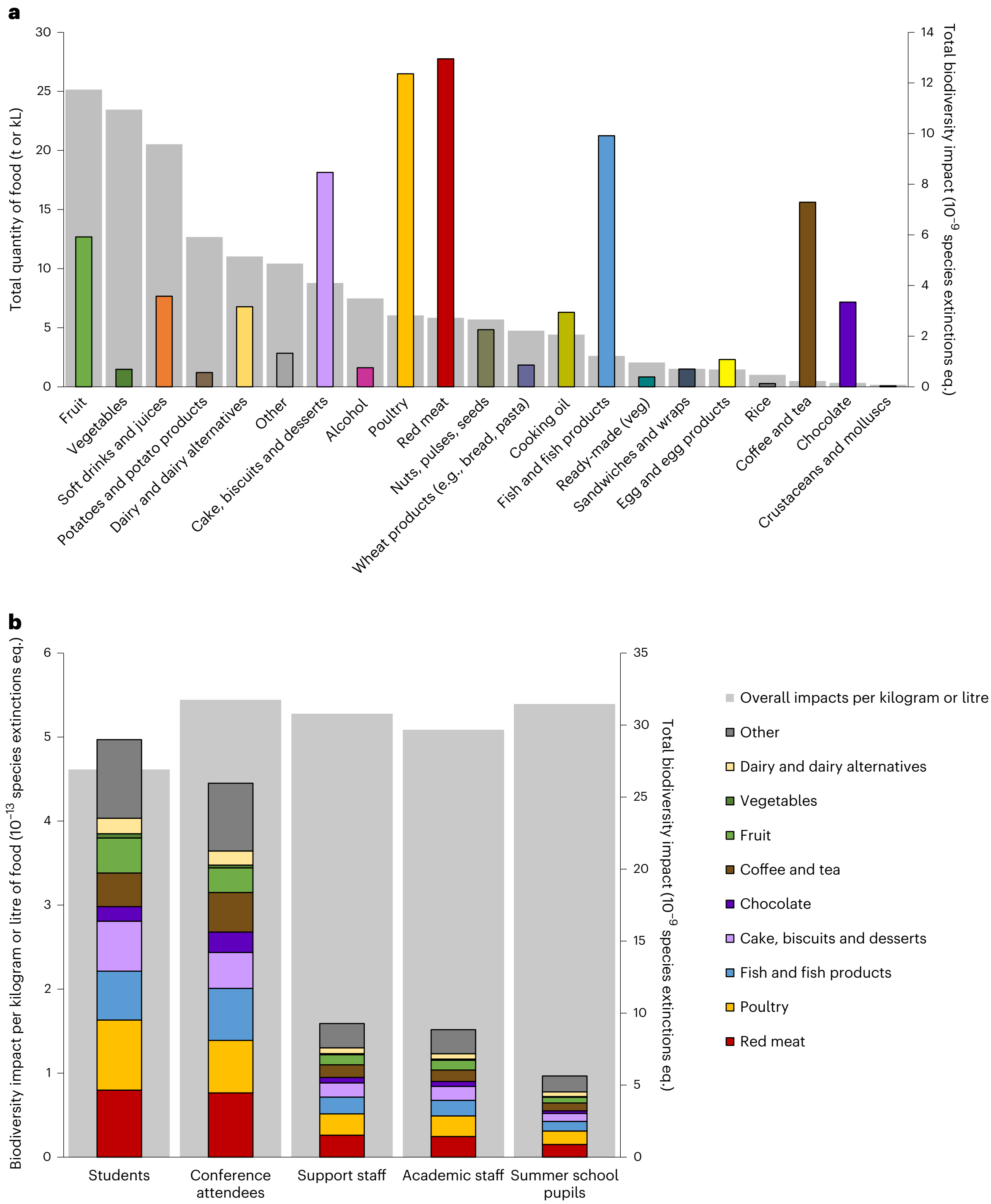

Fig. 1 | Food consumption and biodiversity impacts at the college. a, Total food quantities (in terms of mass or volume) consumed at the college by food product category (shaded bars) and estimated total biodiversity impacts (in terms of the additional impacts caused by agricultural land occupation and transformation) by food product group (coloured bars). **b**, Biodiversity impacts per consumer group: shaded bars show impacts per kilogram or litre of total food consumption (a measure of biodiversity impact intensity) and coloured bars show the total biodiversity impact per consumer group, separated by food product. Further details, including impacts in terms of greenhouse gas emissions, are provided in Supplementary Information.

staff, academic staff and summer school pupils accounted for 11.8%, 11.2% and 7.2% of total impacts, respectively. Further details, including estimates for greenhouse gas emissions, are provided in Supplementary Information.

Stage 2: defining targets for impact reduction

We considered five 'Specific, Measurable, Achievable, Realistic and Timebound' (SMART) targets to reduce biodiversity impacts from food. Possible targets were explored with key stakeholders at the college (Methods), including an ambitious target broadly aligned with nature-positive (cumulative biodiversity net gain) and intermediate steps towards this goal. We modelled annual changes to the college's impacts that would be required under each target over a 15 year period to 2035, given the pragmatic assumption of a slow start to allow for initial capacity building. A 'business as usual' (BAU) scenario was also modelled, assuming that annual consumption remained broadly similar,

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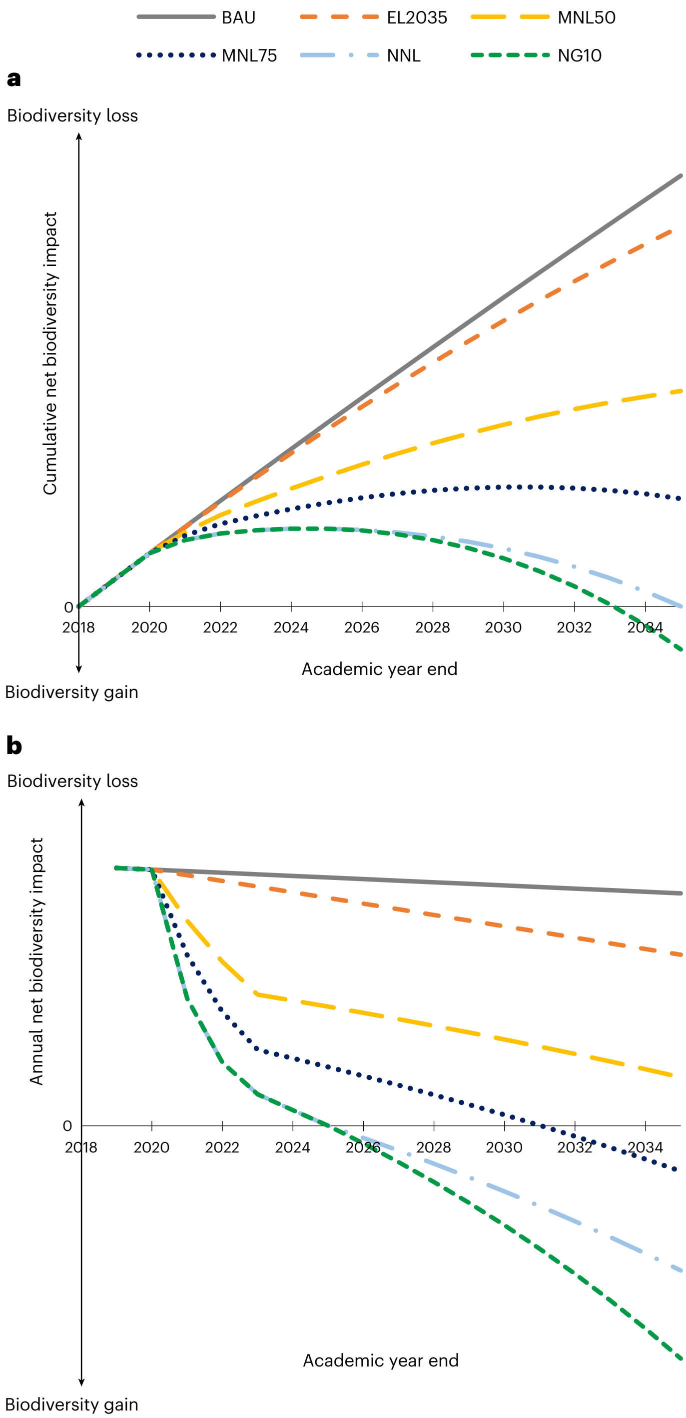

Fig. 2 | Net changes in cumulative and annual biodiversity impacts from food, modelled for five illustrative target scenarios and a BAU scenario. a,b, Values below '0' represent a cumulative (**a**) or annual (**b**) net positive impact on biodiversity (that is, biodiversity net gain). The BAU scenario assumes similar impact each year with a slight declining trend based on data from the UK National Diet and Nutrition Survey[44]. EL2035 represents a process-based target for the college to switch to serving healthy and sustainable diets by 2035, based on EAT-Lancet recommendations[33]. MNL targets aim to reduce cumulative impacts relative to BAU by 50% (MNL50) or 75% (MNL75). NNL and NG10 aim to mitigate 100% of absolute cumulative impacts, with additional compensation to achieve 10% biodiversity net gain under NG10. For more detail, see Supplementary Table 1.

with a slight overall decline in impacts (approximately −10% relative to annual impacts in the baseline year) driven by national dietary trends[44,45] (Fig. 2 and Supplementary Table 1).

First, a process-based target was defined for switching to healthy and sustainable diets in line with science-based best practice, as set out by the EAT-Lancet Commission[33] ('EL2035', Fig. 2). It involves linear change towards 100% adoption of a flexitarian planetary health diet by 2035. Achieving this target would reduce annual impacts by ~33.6% by 2035 against the 2018/2019 baseline. However, this would still result in substantial cumulative biodiversity loss over the 15 year period, only ~12% less impact than under BAU. This demonstrates the importance of understanding cumulative outcomes when target setting, and indicates that gradual dietary shift alone is inadequate to tackle the full extent of impacts.

The four remaining outcome-based targets ('managed net loss (MNL) (50%)', 'MNL (75%)', 'no net loss' (NNL) and 'net gain (10%)' (NG10)) aim to reduce this 15 year cumulative biodiversity impact by a set amount (respectively, by 50%, 75%, 100% or 110%) by 2035. Therefore, if the target percentage reduction is missed in any year, it must be compensated for in subsequent years. For example, under MNL (75%) we assume the college begins working towards this target in 2021/2022, initially reducing annual impacts by one-third each year until 2024. Annual biodiversity impacts are then reduced to net zero by 2031, after which an annual net gain in biodiversity is needed until 2035 to compensate for impacts incurred during initial years, thereby achieving an overall cumulative impact reduction of 75% relative to BAU (Supplementary Table 1).

This demonstrates the ambitious nature even of relative targets such as MNL75, which would still result in a cumulative net loss of biodiversity. Additional uncertainty is introduced by MNL targets being calculated relative to a dynamic counterfactual (BAU), which may change depending on factors that have not been modelled here (for example, changes in student numbers, unanticipated effects of coronavirus disease 2019, or changes in food production practices or efficiency). Achieving more stringent nature-positive targets for cumulative biodiversity net gain (for example, NG10) would thus require urgent and substantial action[38].

Stage 3: assessment of interventions

We collated a set of 44 interventions (actions that mitigate biodiversity impacts from food; Supplementary Table 2) from the academic and grey literature, categorized according to the four steps of the MCH[26] (Refrain, Reduce, Restore, Renew). Interventions included top-down and bottom-up approaches, as well as environmentally sustainable sourcing and options for compensation. We considered each intervention's technical potential (effectiveness for reducing biodiversity impacts) and socio-economic feasibility (or 'initiative feasibility'[46]), following previous research[21,22,46,47]; Table 2).

Technical potential was quantified on the basis of biodiversity impacts estimated in stage 1, further informed by relevant academic literature. Socio-economic feasibility was qualitatively assessed for each consumer group through semi-structured interviews with key stakeholders (the head chef, catering manager and domestic bursar; Supplementary Table 2). It was not within scope to conduct an in-depth review of behaviour-change interventions, and we acknowledge the limitations of our assessments (for example, limited accounting for behavioural plasticity[46]; Methods). A more comprehensive analysis of behaviour-change interventions—utilizing specific behaviour-change frameworks (for example, refs. [48–50])—may have led to different conclusions. However, the expertize of our stakeholders provides a useful basis for decision making and strategy prioritization.

Stakeholder consultations revealed key considerations and constraints at the college, including: (1) ensuring consumers' wellbeing by providing healthy and nutritionally balanced food, (2) ensuring freedom of choice and a variety of meal options, (3) ensuring ethical and sustainable sourcing, and (4) budgetary constraints.

Interventions covered a broad spectrum of socio-economic feasibility and biodiversity risks (Table 2 and Supplementary Table 2). Top-down interventions to restrict the highest-impact foods ('Refrain') had higher technical potential, but lower levels of feasibility due to the social risk of restricting consumer choice and the potential for leakage (consumers deciding to eat high-impact food products elsewhere). The reverse was true for bottom-up interventions aimed at shifting consumer choice (that is, behaviour-change interventions; 'Reduce'). Environmentally sustainable sourcing ('Reduce') had strong but highly uncertain technical potential, with effectiveness contingent on supply chain transparency[10,51–53], product affordability and extent of leakage (displacement of sourcing impacts to other organizations given supply of sustainable products may be limited). Furthermore, the low biodiversity impact of these products may trade off with other aspects of sustainability important to the college (for example, greenhouse gas emissions or animal welfare[34]).

Compensatory actions under the mitigation hierarchy could include restoring biodiversity directly affected by the college's food consumption ('Restore', for example, on or near farms where ingredients are sourced) and restoring equivalent biodiversity (offsetting) elsewhere ('Renew')[18]. Our chosen biodiversity metric has many assumptions (Methods), and there is limited information on food origin or production practices, limiting the accurate calculation of ecologically equivalent[54] areas for restoration that would compensate for negative impacts. Other uncertainties include ensuring additionality, long-term monitoring, compliance and cost[55].

Once all impacts have been mitigated, an aspirational biodiversity net gain target can be achieved through proactive biodiversity-enhancing actions[26]. Examples include contributing to research, education and innovation in sustainable food systems (Refrain/Reduce), supporting local restoration/re-wilding projects (Restore) or creating community food gardens (Renew). Although these actions are challenging to quantify and cannot be counted towards a biodiversity net gain target until direct impacts have been mitigated, they may help avert future biodiversity losses from food systems and can build wider support for biodiversity and its social benefits.

Stage 4: exploring strategies for impact mitigation

Our final step was to investigate the feasibility of achieving each of the outcome-based targets described in stage 2 by combining interventions. A set of five exploratory strategies was constructed, balancing risks and uncertainties identified at stage 3 to varying degrees (Fig. 3 and Supplementary Table 3). The biodiversity impact mitigation potential of each strategy was quantified on the basis of stage 1 and 3 results, and provides an approximation intended to inform organizational decision making.

Strategy A aims to prevent ('Refrain' and 'Reduce') as much biodiversity impact as possible while providing a healthy diet. It involves the college switching to nutritionally balanced vegan food, with all ingredients sourced from best-practice suppliers for biodiversity (assuming the same overall mass of food is served). Given the technical and feasibility assessments, this strategy is unlikely to be socially, financially or logistically achievable in the near future. Risk of leakage (Table 2) means the potential benefits of this strategy are unlikely to be realized until system-wide changes beyond the college's direct control are implemented. If such changes were to occur, the scenario indicates that ~83% of annual biodiversity impacts calculated in stage 1 could theoretically be preventable; ~42% from serving vegan food and ~41% from biodiversity-friendly sourcing (Fig. 3). If the college also halved its consumption of coffee, chocolate and palm oil, preventable impacts could be up to ~88%. However, a 'flexitarian' diet (allowing for small amounts of meat, fish, dairy and eggs)[33] combined with best-practice sourcing could still prevent ~79% of impacts, indicating that considerable progress could be made without requiring controversial measures such as banning animal products.

Strategies B–E show various combinations of interventions considered potentially feasible for the college, based on stage 3 results. They range from a top-down 'avoidance-focused' approach (lower risk for biodiversity, but high choice infringement) to a bottom-up strategy focusing on behavioural interventions and best-practice sourcing (high biodiversity uncertainty, but less risk for consumers). 'Refrain/Reduce' actions could enable the college to make good progress towards each target (~37–42% impact mitigation for strategies B–E). However, achieving more ambitious targets would require a considerable level of restoration/offsetting (68–73% of impacts for NG10), particularly when compared with strategy A. Given the need for a slow start to build capacity, this issue would be exacerbated by the need to over compensate in later years to reach the specified cumulative target (see stage 2).

Furthermore, while targets could in theory be achievable through a more bottom-up strategy (for example, strategy E), large uncertainties for behavioural and sourcing interventions make mitigation difficult to predict, achieve or measure. While such interventions are valuable, enacting top-down measures will be key to ensuring that biodiversity outcomes are achieved. Assessments of financial feasibility for each strategy would also need to be carried out, accounting for product purchase and offset costs, commercial viability, fair pricing for consumers, and potential funding streams.

These results highlight the challenge for organizations in achieving nature-positive targets (for example, NG10), since even avoidance-weighted strategies (for example, strategy B) would incur substantial residual impacts, requiring considerable levels of offsetting to meet targets within current socio-economic constraints. The challenge is enhanced by the difficulties of calculating, delivering and monitoring offsets[11,23,54]. particularly when limited sourcing information is available. Crucially, issues around leakage suggest that achieving true nature-positive outcomes would require urgent systemic action beyond the direct influence of the college[56].

Recovering biodiversity one organization at a time

Here we have applied the MCH to address the globalized impacts of an organization's food consumption, quantifying biodiversity impacts and framing potential targets and strategies within context-specific constraints. By considering varying levels of impact and feasibility for different consumer groups, we highlighted variation in opportunities and constraints, and suggested targeted group-specific strategies. Accounting for behavioural plasticity (through trialling and monitoring interventions) and gathering further data on food sourcing would inform better-targeted approaches for impact mitigation and compensation in future.

Our approach is generalizable across scales, environmental pressures and sectors[26,38]. Our case study organization is both an educational institution and an events catering business, so results may be applicable across a broad range of food-providing organizations. However, it is hard to know how scalable our results are until similar analyses are carried out, and we recognize that consumers at the college may not be representative of the wider population.

Transparency regarding the scale of the challenge is essential to achieving ethical and sustainable paths towards nature-positive goals[17,57]. Here we show for one organization that mitigating the embodied biodiversity impacts of their food may not currently be feasible. A recent example applying this framework to the operational biodiversity impacts of Oxford University[38] similarly found that strategies considered feasible by the focal organization left substantial residual impacts needing to be offset to achieve a net gain target.

However, reversing global biodiversity loss remains urgent and necessary[1,4], and will require organizations to take rapid and ambitious action on food and other elements of their operations. Actions will in some cases need to be top down, may result in socio-economic risk and will require engagement with affected communities. Delaying action will lead to extensive negative impacts requiring compensation later. However, if more organizations commit to ambitious nature-positive pathways, issues of leakage are likely to reduce

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Table 2 | Technical and feasibility assessments

Intervention category: REFRAIN, REDUCE, RESTORE or RENEW	Technical mitigation potential (average % impact reduction)	Biodiversity risks and benefits	Socio-economic feasibility: financial and logistical risks and benefits	Socio-economic feasibility: consumer risks and benefits	Recommendations
REFRAIN from serving the most impactful foods (for example, 'top-down' restrictions on meat, fish, coffee, chocolate and so on)	6.2% (2.5–14.8%) (*N*=11)	Generally lower risk due to focus on prevention (not compensation). Risk of leakage if consumers seek restricted foods elsewhere (particularly if highly valued/available).	May be time- and resource-consuming for kitchens to produce a good variety of low-impact choices. Ingredient costs may increase or decrease, depending on the product/replacement.	High choice infringement risk for those who eat regularly at the college. Some (for example, academic staff) have previously opposed restrictions on meat. Others (for example, student groups) have advocated for restrictions.	(1) Apply to conference/ summer school attendees who eat infrequently at the college; (2) avoid refraining from serving highly valued/easily accessible foods (for example, coffee and chocolate) to minimize leakage; (3) for students/ staff, focus on sustainable sourcing, bottom-up interventions and reducing use where possible.
REDUCE consumption of impactful foods through 'bottom-up' interventions (for example, behaviour change interventions)	4.0% (1.0–9.4%) (*N*=4)	Uncertain effectiveness as this would be context dependent (for example, owing to behavioural plasticity); reliant on long-term, bottom-up changes in dietary choices, rather than instant changes to organizational food purchasing.	Most interventions would be low cost and simple to carry out (for example, rearranging menus), others may require more resources and collaboration (for example, eco-labelling).	No restriction on consumer choice, although could be perceived as choice manipulation. Awareness raising interventions could provide educational benefits.	(1) Implement simple interventions soon (for example, increasing ratio of low-impact options on conference menus); (2) collaborate to implement more complex interventions (for example, eco-labelling); (3) monitor implemented behavioural interventions to improve estimates of effectiveness and behavioural plasticity.
REDUCE impacts through sustainable sourcing of ingredients (for example, buying certified biodiversity-friendly products and using local suppliers)	8.8% (2.4–18.8%) (*N*=7)	High uncertainty due to lack of supply chain transparency; biodiversity-friendly food production may trade off against other aspects of sustainability; impacts may be displaced to other organizations (leakage).	More environmentally sustainable produce may have more limited availability and higher cost.	Avoids risk of choice infringement. May result in pricing changes at the college for consumers.	(1) Source environmentally sustainable foods where budget allows (for example, in more commercial aspects of food provision), particularly for impactful foods that are unable to be avoided entirely; (2) identify opportunities for low-cost, seasonal and local sustainable sourcing (for example, allotment produce, repurposing excess food and so on).
REDUCE impacts by reducing food waste (for example, efficient use of ingredients and repurposing leftovers)	Not possible to calculate here owing to data limitations.	Reducing the amount of food wastage would help to reduce biodiversity impacts. There is uncertainty in how much 'repurposed' wasted food would be replacing rather than adding to consumption.	The college already implements several measures to minimize food waste; resources would be needed for monitoring and communication with food redistribution networks.	No identified negative impact on consumers. Consumers may benefit from discounted leftovers.	(1) Participate in existing flexible food redistribution schemes as and when required; (2) increase rates of onsite composting; (3) improve monitoring of waste streams.
RESTORE impacted biodiversity and RENEW through biodiversity restoration offsets to compensate for residual impacts in ecosystems affected by college food consumption.	Dependent on the nature and extent of residual impacts and the chosen biodiversity target.	High risk unless carried out according to best practice[54], complicated by a lack of supply chain transparency and assumptions made in the biodiversity metric calculation.	Likely to be expensive, requiring novel funding streams, availability of expertize, and adequate like-for-like offsets on the market (for example, biodiversity credits).	May result in pricing changes at the college for consumers.	(1) Seek greater transparency in all college food supply chains to enable appropriate targeting of offsets to the site of biodiversity impact.
Proactively REFRAIN, REDUCE, RESTORE and RENEW biodiversity (for example, research, innovation, and local or global conservation initiatives).	Not normally quantifiable.	Must not be used as a substitute for offsetting of specific, quantifiable biodiversity impacts (to prevent greenwashing).	Resource or funding required but potential for cost-effective initiatives that produce socio-economic value.	May deliver added social benefits (for example, opportunities for college members, or empowering local communities in areas of impact).	(1) Pursue proactive actions that will help reduce future impacts (for example, supporting research, innovation and education on sustainable food systems); (2) maximize the social benefits of proactive actions; (3) do not replace quantifiable impact mitigation with proactive actions.

Results of the technical and feasibility assessments for different categories of interventions, under the four steps of the MCH—Refrain, Reduce, Restore and Renew. Ranges provided for the 'Technical mitigation potential' column show the range of average biodiversity impact reduction across the number of interventions that were assessed ('*N*') and are not an indication of statistical uncertainty (which cannot be estimated). Additional detail on specific interventions, consumer group-specific assessments and sources is provided in Supplementary Table 2.

(for example, through shifting dietary norms and creating greater demand for biodiversity-friendly produce), and strategies that appear highly ambitious for a single organization today may become feasible.

We have evidenced the urgent need for wider transformative change to minimize the impacts of food systems[30,33,56], which will allow consumers and food providers to make more sustainable choices

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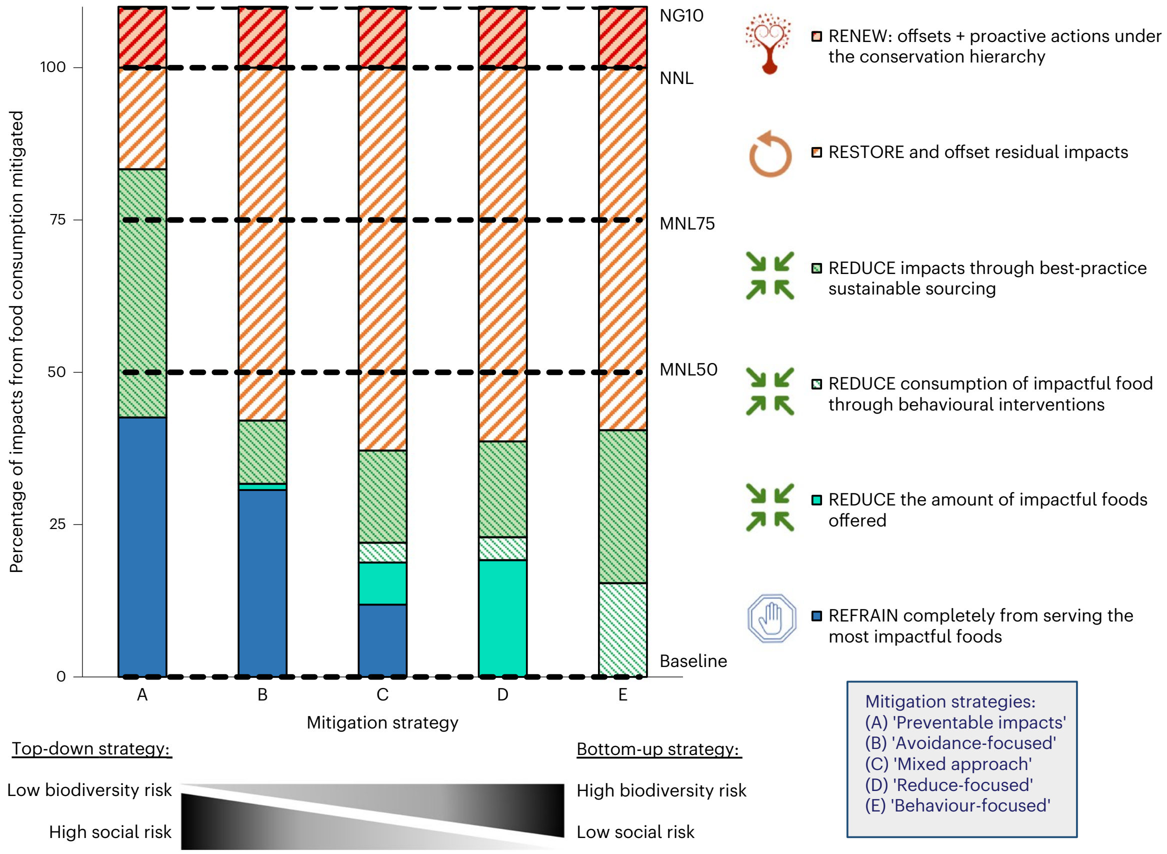

Fig. 3 | Comparison of five strategies for mitigating the biodiversity impacts of food served at the college. A breakdown of individual interventions per strategy can be found in Supplementary Table 3. Each strategy is represented by a bar covering 1 year's worth of biodiversity impacts. The *y* axis shows the approximated mitigation potential, such that 0% represents no action taken (stage 1 baseline impacts) and 100% represents NNL of biodiversity resulting from college food consumption. Dotted lines represent average annual impacts required under the different cumulative targets described in Fig. 2 (recognizing that in some years these targets may be missed, whereas in other years targets will need to be surpassed to compensate for missed years). Interventions that refrain from or reduce impacts (shown in blue and green) should be given precedence over compensatory actions such as biodiversity offsets (orange and red). Here, compensatory actions are considered only in terms of the extent of residual impacts needing to be restored or offset, rather than the areas or types of species or ecosystems to be targeted. Note that the values provided here are indicative for use in informing pragmatic policy decisions and are based on numerous assumptions, which are described in Methods and Supplementary Information.

at lower socio-economic cost[57]. Measures will be required across all scales (for example, government incentives, improved production and procurement practices, improved market standards, increased monitoring and transparency, improved biodiversity metrics, systematic approaches to offsetting and shifts in consumer behaviour) and will need to be integrated with other societal goals[34,51,58,59]. Organizations can make genuine, positive contributions to catalysing these changes through mitigation of impacts and proactive conservation efforts[23]. As new global biodiversity targets are being set, organizations have a critical opportunity to change their food systems, bringing themselves closer to a nature-positive future. If enough of them do this, societal transformation can be provoked.

Methods

Context and participatory approach

This research was based at a University of Oxford college (Lady Margaret Hall, Oxford, UK) and was carried out during July to December 2020. The college community consists of ~500 university undergraduate and postgraduate students, ~130 members of support staff and ~75 members of academic staff. The college has a central canteen, providing daily food and beverages (herein, 'food') at subsidized rates for students and free of charge for staff. The college also runs a commercial food service, frequently preparing food for conference, event and annual summer school attendees. All food is ordered and prepared through a central kitchen coordinated by a head chef and catering manager. Along with the college's domestic bursar, these individuals were considered the primary end users of this applied research and were involved throughout its inception and delivery in a participatory and iterative manner.

Stage 1: estimating baseline quantities and biodiversity impacts of food served at the college

Sources of food purchasing data. Our analysis was based on food purchased by the college during the financial (academic) year of 2018/2019, chosen as the most recent year for which a complete dataset was available and before the impacts of the coronavirus disease 2019 pandemic. For feasibility, analyses were based on 3 months of invoice data from September 2018, February 2019, and July 2019. These months captured different aspects of the college's food service: the main conference season, standard term time and summer schools, respectively. Data were primarily obtained from the college's online procurement system, supplemented with data from eight additional suppliers. All aspects of food under the control of the college's catering department were captured; this did not include food prepared by students. The final dataset consisted of 4,651 individual purchase records, 1,612 unique food products and included information on date, supplier, product code and description, number of units purchased, and cost per unit. Information on product mass or volume per unit was included for 37%

of products. Records were sorted into 63 product categories for further analysis, based on food type and price of product.

Estimating quantities of food served. Owing to limited available information on product mass or volume, these values were directly estimated for the 200 most frequently purchased products (which accounted for 70% of all purchased units). Estimates were based on information within supplier catalogues, other college purchasing reports or supermarket websites. All food categories included a minimum of 50% of items with direct mass or volume estimates (average per category: 89%). For the remaining 41% of unique products with no mass or volume estimate, this was approximated on the basis of an average cost-to-mass (or volume) ratio for each food category. For records with an unknown product description (9% of records), mass or volume of the product was approximated based on the known breakdown of food categories and average gram or millilitre per £1 for the product supplier. This approach was deemed reasonable, as most 'unknown' products came from specialized suppliers (for example, butchers). However, most records had detailed estimates and final values were sense checked by college stakeholders.

Estimating biodiversity impacts from food. The 1,589 unique products were matched to a corresponding item in one of the following environmental datasets to obtain its biodiversity impact value:

(1) A dataset derived from Poore and Nemecek[34,60], of 55 raw ingredients with their associated environmental impacts, including land occupation and transformation values, based on a meta-analysis of global LCA studies. The LCA system boundary ranged from agricultural inputs at farm stage to retail stage (for details, see ref. [34]). Environmental values were provided for each ingredient at three levels of impact based on the range of producers assessed: low (5th percentile), average (50th percentile) and high (95th percentile). Biodiversity impacts were quantified using a United Nations Environment Programme-recommended metric developed by Chaudhary et al.[40]. This models the number of expected global species extinctions ('species extinctions equivalent') for a given area of land occupation (extent × time occupied) and transformation (land use change) per food item and country, based on the countryside species–area relationship model and species vulnerability scores (including levels of threat and endemism). Further details on underlying models are provided in Chaudhary et al.[40].

(2) An extensive database of products from six major UK online supermarkets ('foodDB', developed by Harrington et al.[39] and used under license). An extract containing back-of-packet ingredients for 2,138 unique supermarket products was obtained. Products consisted of composite food items in categories such as ready meals, sandwiches, desserts and sweet treats, pies and quiches, as well as specific vegan and vegetarian products. Raw ingredients for each product were paired with corresponding ingredients in dataset 1 and weighted according to quantity to derive overall biodiversity impacts per 100 g of supermarket product. Full details on the dataset and methodology are described in Clark et al.[61,62].

(3) A dataset derived from foodDB, with biodiversity impact values aggregated at the supermarket 'shelf' level, as opposed to specific products. This dataset captured a broader range of food items than dataset 2 (including 3,687 shelf categories) and was used for more generic categories of composite food items (such as 'red wine', 'chocolate bars', 'dairy-free cheese' and so on). It was applied when an appropriate match could not be identified in dataset 1 or 2, and where a specific product was not required (that is, owing to low intra-category variation in environmental impacts).

Biodiversity impacts could then be derived by multiplying the mass or volume of each product by the impact values in the corresponding databases. Generally, the median (50th percentile) impact values were used (but see below).

Accounting for existing sustainable sourcing efforts. Consultations with college stakeholders identified that certain products were routinely sourced with sustainable certifications (for example, all purchased tea, coffee and sugar was either Rainforest Alliance or Fairtrade certified). To broadly account for this, a weighted combination of 50th (64%) and 5th (36%) percentile impacts was used for these certified products. This was based on the assumption that certified products were likely to have some positive impact on biodiversity relative to average (50th percentile) products, but these positive effects could be weak or uncertain. Percentage weightings were based on DeFries et al.[53]. While this was a broad approximation, it was an evidence-based way to account for actions already undertaken in the absence of more detailed data on product-specific impacts.

Scaling up and allocating impacts. To calculate biodiversity impacts for the full baseline year (2018/2019) and allocate portions of impacts to each of the college's main consumer groups outlined above, estimates for the three focal months were factored up on the basis of a breakdown of annual food costs provided by college stakeholders. This was done by calculating the average quantity (mass or volume) or impact (species extinctions equivalents) per £1 spent for each consumer group across the three focal months, and then multiplying this value by the overall amount spent per consumer group for the full year.

Key uncertainties and assumptions for stage 1. The methods used here were the best available at the time and provided a set of estimates from which decisions could justifiably be made by college stakeholders. However, they are necessarily broad and based on several assumptions:

i. When factoring up estimates based on food costs, we assumed that food consumed during the three focal months was representative of the food consumed during the rest of the baseline year (2018/2019). Thus, there may be some unaccounted-for seasonal variation (although college stakeholders stated this was minimal). Furthermore, this analysis focuses on a single year.

ii. The chosen biodiversity metric only measures impact on the basis of one component of biodiversity (species) ignoring other components, such as habitats, ecosystems and genetic or functional diversity. Its development was based on datasets biased towards certain taxa (terrestrial vertebrates and vascular plants) and geographic regions (often high income or high biodiversity), not accounting for the impact of agriculture on taxa important to continued ecosystem functioning (for example, soil microbes, plants and arthropods) or freshwater and marine taxa. The metric is intended for calculating relative levels of impact on biodiversity, and cannot be interpreted in terms of absolute impact owing to assumptions made in its calculation[40].

iii. The biodiversity metric focuses only on the effects of land use on biodiversity, not directly including other important pressures on biodiversity, such as over-extraction of water, pollution, climate change, direct exploitation of wild populations or invasive species. The relative biodiversity impact for food products may therefore be under- or overestimated. For example, relative biodiversity impacts of red meat might be higher if the indirect impacts on biodiversity from climate change were considered (Supplementary Information).

iv. In the absence of information on the region from which food products were sourced, datasets were based on global average LCA data per product. Any region-specific differences in food product impacts were unable to be accounted for. While assuming global average sourcing introduces uncertainty, high-level sensitivity analyses indicated this assumption is unlikely to change the main conclusions. Ingredients with the highest environmental impacts in the baseline scenario tended to also have the highest impact whether sourcing from best-case (5th percentile impacts) or worst-case (95th percentile impacts) producers (Supplementary Information). However, when product-specific information on food sourcing becomes available, future analyses could incorporate biodiversity impacts that reflect an organization's actual food supply chains. This would have additional benefits, for instance providing insight into how an organization's negative impact on biodiversity might be compensated by actions with a 'like-for-like' biodiversity benefit (for example, in the same country and ecosystem type).

v. Certain food categories are likely to be less accurate than others. All fish was assumed to be produced through aquaculture rather than wild caught (college stakeholders said this was representative of their fish sourcing). Additionally, impacts for lamb and mutton products were based on a single set of LCA values, meaning that 5th and 95th percentile impacts could not be estimated. Given that lamb was purchased in quantities an order of magnitude lower than other meats, it is unlikely that this had a substantial effect on the overall results.

vi. With regard to datasets 2 and 3, limited data were available for ingredient composition of certain products, so estimated environmental impacts have limited reliability. However, these products tended to be 'low-impact' foods, so this lack of data is unlikely to have substantial effects on overall results.

Stage 2: constructing target scenarios

Modelling the BAU scenario. The BAU scenario was calculated on the assumption that the quantity and type of food served at the college would remain similar each year until 2035. Slight changes were predicted to occur in certain food groups, based on trends in the UK government's National Diet and Nutrition Survey[44], including average annual increases of 2.7 g of vegetables and 1.1 g of poultry, and average declines of 2.1 g of red meat and 4.1 ml of fruit juice per person per day. These trends were converted to percentage changes, based on known total average daily intakes per person per ingredient in the National Diet and Nutrition Survey data, and yearly percentage changes were applied to baseline impacts described in stage 1. This BAU scenario does not consider possible changes to community numbers and associated consumption patterns in future years, as this information was unknown.

Process-based target: modelling the 'Healthy and Sustainable Diets' target ('EL2035'). The 'EL2035' target was calculated on the basis of best practice in healthy, sustainable diets, as set out by the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems[33]. Food products purchased by the college were disaggregated into their constituent ingredients, using datasets 2 and 3 where necessary (that is, for composite food products). This provided a proportional breakdown of the total mass or volume of raw ingredients served at the college during the baseline year. To predict impacts under an EL2035 target in 2035, these proportions were altered to match the proportions of an EAT-Lancet 'flexitarian' diet (assuming 100% uptake, specific dietary values taken from Supplementary Table 7 in Springmann et al.[31]), with the assumption that overall mass or volume of food served would remain constant. These new proportions were combined with biodiversity impacts per food product (as described above) to estimate overall impacts. Consumption of ingredients that were not captured within the EAT-Lancet dietary recommendations (for example, tea and coffee) was assumed to remain the same.

Outcome-based targets: modelling cumulative targets. The four remaining outcome-based targets ('MNL50', 'MNL75', 'NNL' and 'NG10') aim to reduce cumulative biodiversity impacts by a set amount by 2035 (respectively by 50%, 75%, 100% or 110%). Targets were modelled on the basis of their overall cumulative outcome, with a period of capacity building in the initial years of the scenario (Supplementary Table 1). These scenarios were chosen to represent increasing ambition towards achieving a nature-positive target.

Stage 3: assessment of interventions

Collation of interventions. Possible interventions to reduce biodiversity impacts from food at the college were identified from a high-level review of the academic literature (a full systematic review was out of scope). The search strategy involved identifying existing systematic academic reviews of behaviour-change interventions[63–66], along with key sources of grey literature[67], and expanding the search following a snowball sampling strategy (following references and citations) until no additional intervention categories were highlighted. A category could include several similar interventions, such as promoting pro-environmental social norms through various forms of advertising. These were further refined on the basis of consultations with stakeholders to identify and exclude any interventions already in place at the college (and therefore captured under baseline impact calculations). The final list of interventions along with relevant sources is provided in Supplementary Table 2.

Technical assessment. Percentage reductions in biodiversity impact (technical potential values) were calculated for each intervention using one of three approaches, depending on intervention type:

1. For top-down interventions that restricted quantity of certain foods served at the college, the change in impacts was estimated by substituting highly impactful foods with the same mass or volume of their lower-impact equivalents (for example, by replacing 100 kg of red meat with 100 kg of plant-based meat alternative products). Replacements were made on the basis of ingredient mass or volume, not on the basis of calories or nutrition. This was considered practical, as it reflects the functional replacement of an ingredient in a recipe, which is more easily communicated to catering staff.
2. For interventions focused on sourcing ingredients from producers with the lowest impacts on biodiversity, we used the range of impact levels provided by dataset 1. Average (50th percentile) impact values used in calculating the baseline were replaced with low (5th percentile) impacts (for example, replacing 100 kg of average red meat with 100 kg of red meat sourced from the top 5% of producers in terms of reducing biodiversity impacts).
3. 'Bottom-up' interventions (for example, behaviour-change interventions) were challenging to predict since these are highly dependent on context and consumer responses. We used indicative estimates of impact based on previous examples in the literature (Supplementary Table 2), broadly assuming that the proportional change estimated in these studies would apply to ingredients and meals at the college. Literature sources were identified from our review of behavioural interventions and selected on the basis of similarities in context (that is, food in a higher education setting)[68–72]. These estimates are therefore only rough, order-of-magnitude indications used to inform policy recommendations; trials and monitoring at the college would be needed to assess the actual changes that these types of intervention might achieve.

Feasibility assessment—stakeholder consultations. The feasibility assessment for interventions was completed using information from interviews and follow-up discussions with three key food and operations staff members at the college (head chef, catering manager and domestic bursar). Semi-structured interviews were carried out in early 2020 as part of the Wellcome Trust -funded 'Our Planet Our Health' (Livestock, Environment and People—LEAP) project. Interviews were carried out with informed consent of participants and approval from the University of Oxford's Central University Research Ethics Committee (reference number R68035/RE002).

The interviews followed a set of questions that aimed to (1) understand how the college's food service operations work, (2) identify facilitators and barriers to implementing environmental initiatives to promote sustainable meals and (3) understand lessons learned from environmental initiatives that have been tried previously in the college. Interviewees were questioned on whether sustainability measures had been discussed and implemented at the college, both generally as well as measures relating specifically to food. They were also asked whether responses to measures had been positive or negative for different stakeholders, and the perceived reasons for those responses. Some questions were specifically focused on approaches to meat consumption at the college. Additional information on specific aspects of the college's operation, core values and food provision was gained through further ad-hoc discussions.

Interventions were assessed against qualitative information in notes from these interviews, to identify key relevant points relating to social, logistical and financial risks or opportunities (as captured in Table 2). Information regarding specific consumer groups was used to categorize the level of social risk (in terms of poor, moderate or adequate perceptions of an intervention; Supplementary Table 2), with additional reference to responses when similar interventions have been trialled in the past, or predictions based on stakeholder familiarity with consumer requirements and values. As such, the categorizations used here are based on well-informed assumptions about likely stakeholder responses. This was a pragmatic approach to prioritizing interventions to aid decision-making processes; the relevant expertize of stakeholders makes this a good basis on which to begin prioritizing strategies and interventions.

Stage 3 limitations. As it was not within scope to conduct an in-depth review and comprehensive analysis of interventions, it is important to acknowledge the limitations of our approach:

Technical assessments for 'top-down' interventions involved taking an average value for plant-based meat alternatives, rather than considering for example, direct vegetable substitutes. Further, the approach to modelling sustainable sourcing assumed a switch from 50th percentile producers to producers with the minimum level of impact (5th percentile). This therefore does not consider the actual availability of such low-impact products to the college.

For bottom-up interventions, limiting the assessment to behaviour-change studies in similar university settings meant that few studies were used to inform estimates of technical potential, therefore limiting consideration of behavioural plasticity (that is, the extent to which the interventions actually change consumer behaviour[46]), which may influence the effectiveness of interventions. Moreover, the risks and benefits to consumers assessed as part of our socio-economic feasibility assessment arose through interviews with college stakeholders, and while the importance of these expertise-driven insights should not be underestimated, some of the concerns raised were hypothetical, and may not reflect actual behaviour should the interventions be enacted.

The latter two limitations emphasise the importance of (1) running surveys or focus groups with affected consumers to more directly understand consumer perceptions, (2) trialling proposed initiatives and gathering data to estimate behavioural plasticity, (3) applying specific behaviour-change frameworks for a comprehensive analysis (for example, refs. [48–50]) and (4) monitoring changes in consumer behaviour or perceptions and adapting the approach accordingly. We recommend consideration of these points in future applications of our approach, although the methods used here provide a solid, pragmatic basis for prioritizing strategies for initial implementation.

Stage 4: modelling mitigation strategies

Strategy A. Strategy A assumes that the college serves no animal-derived food products and sources all ingredients from producers with the lowest impacts on biodiversity. Percentage reductions in impact were calculated following a similar approach to the 'Healthy and Sustainable Diets' target (EL2035): baseline food quantities were disaggregated into individual ingredients and relative proportions were altered to nutritionally balanced vegan dietary proportions (obtained from Supplementary Table 7 in Springmann et al.[31]). Newly proportioned food impacts based on average (50th percentile) values were then replaced with low-impact (5th percentile) values to account for environmentally sustainable sourcing.

Combining interventions in strategies B–E. Supplementary Table 3 lists the specific interventions included in strategies B–E. Interventions were applied sequentially to avoid double counting of mitigation potential (for example, if a strategy contained more than one intervention pertaining to the same category of food). For strategy E, an assumption was made that the impacts of 'bottom-up' behavioural interventions would be additive, that is, we do not account for any interactions that might occur when co-implementing several behavioural interventions. As such, percentage reduction values for these behavioural interventions are indicative only, although this was considered adequate for the purposes of informing policy decisions at the college.

Ethics statement

Interviews were carried out with informed consent of participants and approval from the University of Oxford's Central University Research Ethics Committee (CUREC reference number R68035/RE002).

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Data on environmental impacts per food ingredient[34] (dataset 1 described in Methods) is publicly available via the Oxford University Research Archive depository[60]. Data providing environmental values per food product linked to foodDB[39] (see description of datasets 2 and 3 in Methods) is described by Clark et al. (2022)[61] with an anonymized version of this dataset freely available via the Oxford University Research Archive depository[62]. Owing to legal constraints, non-anonymized data from the foodDB database is available under license upon request (foodDBaccess@ndph.ox.ac.uk). Datasets on food product quantities and anonymized interview responses used in this study are available from the corresponding author on reasonable request. For legal confidentiality reasons, financial data from the college cannot be made publicly available. Source data are provided with this paper.

Code availability

Code relating to calculations of environmental values per food product (as per Clark et al.[61]) is available on the Oxford University Research Archive depository[62].

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Author contributions

All authors have provided content, reviewed, edited and approved this manuscript. I.T. coordinated the project, including conducting analyses and initial drafting of the manuscript. E.J.M.-G. supervised the project, with co-supervision provided by J.W.B. and additional project coordination provided by H.M.J.G. E.B. and N.G. provided support with data processing and impacts analysis. M.C. contributed and supported the use of datasets relating to the environmental impacts of food products. C.S. conducted and recorded participant interviews. B.A. represented and liaised with the focal college, providing underlying datasets as well as key contextual information.

Competing interests

The authors declare no competing interests, but we note for transparency that B.A. is an employee of Lady Margaret Hall (the focal organization of this study).

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s43016-022-00660-2.

Correspondence and requests for materials should be addressed to I. Taylor or E. J. Milner-Gulland.

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	No software used for data collection. Collection methods for data extracts used in this study are described in prior works (Poore & Nemecek, 2018, Science; Clark et al., 2022, PNAS).
Data analysis	All data handling was conducted in Microsoft Excel. Analysis for data extracts used in this study are described in prior works (Poore & Nemecek, 2018, Science; Clark et al., 2022, PNAS).

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Data on environmental impacts per food ingredient (dataset (1) described in Methods) is publicly available via the Oxford University Research Archive depository (DOI: 10.5287/bodleian:0z9MYbMyZ).
Data providing environmental values per food product linked to foodDB (see description of datasets (2) and (3) in Methods) is described, with an anonymised version of this dataset freely available, in Clark et al. (2022, PNAS). Due to legal constraints, non-anonymised data from the foodDB database is available under license upon reasonable request (foodDBaccess@ndph.ox.ac.uk).

Datasets on food product quantities and anonymised interview responses used in this study are available from the corresponding author on reasonable request. For legal confidentiality reasons, financial data from the College cannot be made publicly available.

Field-specific reporting

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Ecological, evolutionary & environmental sciences study design

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Study description	This study explored how Nature Positive targets can be achieved for organisations through a novel application of the Mitigation and Conservation Hierarchy Framework, focusing on the embedded biodiversity impacts associated with food consumption. The study is split into four stages Stage 1: Annual impacts from food consumed at a focal organisation were quantified by pairing consumption data with environmental databases containing life-cycle biodiversity impacts of specific food products. Stage 2: A series of biodiversity targets were defined, including ones aligned with a nature-positive target, and annual impacts under each target scenario were modeled in terms of changes to annual and cumulative biodiversity impacts. Stage 3: The feasibility and technical potential of interventions to mitigate impacts were assessed based on Stage 1 quantifications and on qualitative interview data gathered from key stakeholders at the focal organisation. Stage 4: Five mitigation strategies were explored by combining sets of interventions, outlining the risks/feasibility for each strategy, and quantifying potential progress towards different targets - highlighting the challenges around achieving Nature Positive targets (e.g., Biodiversity Net Gain) at an organisational level within the current food system.
Research sample	Stage 1 consumption data consisted of 4,651 purchase records for individual products, including 1,612 unique food products. Each product in the dataset included information on date, supplier, product code and description, number of units purchased, and cost per unit. Data was gathered from three months (September 2018, February 2019, and July 2019) Environmental datasets included biodiversity impact and carbon dioxide equivalent (CO_2e) values for 55 raw food ingredients provided by Poore & Nemecek (Science, 2018) and for extracts of 2,138 food products and 3,687 food 'shelves' listed in foodDB (data provided by and described in Clark et al., 2022, PNAS). The foodDB extracts consisted of a specific subset of product categories (including composite/'ready-made' meals as well as specific plant-based meat alternatives), aggregated at both product and supermarket 'shelf' level. FoodDB data was provided under license from the authors (Harrington et al., 2019). Stage 3 qualitative data (in the form of interview notes) were gathered from interviews from a sample of three targeted interviewees at the focal organisation.
Sampling strategy	Stage 1 consumption data was gathered for three representative months and then factored up to represent a year. Three months were selected on the basis of consultation with stakeholders to ensure adequate representation of the different aspects of the organisation's food operation while enabling a feasible level of manual data handling. These three months' of data were then factored up to represent a year using a financial breakdown of organisational spending per operational area for the purposes of establishing a single-year fixed baseline. Stage 3 interviewees were selected using targeted/purposive sampling. Interviewees were limited to those meeting the required criteria: Inclusion criteria: - Adults aged ≥18 years - Able to speak and read English - Having direct responsibility for management of the organisation's food operations - Knowledge of the organisation's finances - Having some interaction with the wider organisation's governance structures Exclusion criteria: Unable or unwilling to provide consent for interview Stage 3 interventions were collated from a non-systematic review of the literature. The search strategy involved identifying existing systematic academic reviews of food consumption-related behaviour-change interventions, along with key sources of grey literature, and expanding the search following a snowball sampling strategy (following references and citations) until no significantly new additional intervention categories were able to be identified.
Data collection	Stage 1 consumption data (food sales and purchase data) was provided directly by an authorised individual at the focal organisation Stage 1 Environmental data was obtained directly from the authors of the relevant studies (Poore & Nemecek, 2018, Science; Chaudhary et al., 2015, Environ. Sci. Technol; Clark et al., 2022, PNAS) Stage 3 data was collected by the authors (C. Stewart) by conducting, recording, and transcribing interview notes.
Timing and spatial scale	Consumption data covers three months over the 2018/19 academic year (September 2018, February 2019, and July 2019). Consumption data relates to food prepared and consumed within the focal organisation. Interviews were conducted in February 2020.
Data exclusions	No data were excluded.
Reproducibility	This study was exploratory, rather than experimental. Anonymised data/code for reproducibility of the impacts analysis can be

Reproducibility

provided (code is available from Clark et al., 2022, PNAS) however non-anonymised data extracted from foodDB cannot be provided without license due to legal requirements.

Randomization

Food consumption data was allocated to food products in environmental datasets based on the greatest degree of similarity between products. Products were then allocated to food categories based on food group/composition. Randomisation was not relevant to this study.

Blinding

Interviews were recorded anonymously. Interview notes were applied in this study by a different individual to the interviewer, with no way to link specific notes to the identity of single interviewees.

Did the study involve field work? ☐ Yes ☒ No

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Materials & experimental systems

n/a	Involved in the study	
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☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology and archaeology
☒	☐	Animals and other organisms
☐	☒	Human research participants
☒	☐	Clinical data
☒	☐	Dual use research of concern

Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging

Human research participants

Policy information about studies involving human research participants

Population characteristics

Three adult males (>18 years), able to speak and read English. All were employed by the focal organisation and had direct responsibility for management of the organisation's food operations, knowledge of the organisation's finances and were engaged with the wider organisation's governance structures.

Recruitment

Participants were targeted through purposive sampling via email from a small number of individuals within the organisation that fit the inclusion criteria (described in 'sampling strategy' above)

Ethics oversight

University of Oxford’s Central University Research Ethics Committee (CUREC Reference number: R68035/RE002)

Note that full information on the approval of the study protocol must also be provided in the manuscript.