Impact Of Replacing Animal Products: Methodology

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This document sets out Faunalytics' methodology for estimating the number of animal lives that would be saved and the days of suffering that would be avoided if various animal food products were replaced. This was estimated for three different use cases:

1. If an institution purchases fewer pounds or kilograms of animal product for retail sale,
2. If individual animal food products were replaced in the U.S. for one day, and
3. If an individual replaced a single serving of various animal food products in their diet with non-animal alternatives.

Calculations estimating the impact of each aspect of animal farming on animal lives and suffering can be found in an Excel workbook entitled 'Animal Product Impacts - Calculations Workbook,' also on the OSF. This is all that is needed for the first use case.

For the second and third use case, data from the National Health and Nutrition Examination Survey (NHANES) were combined with the previous estimates using R. All of these files can be found on the Open Science Framework.

Our estimates of the most impactful products in terms of lives saved and days of suffering avoided are described in a series of infographics that can be found on Faunalytics' website, and the full set of results for all animal products is also available as a downloadable spreadsheet on the Open Science Framework.

Impact Equations

We estimated the impacts using the following equations. Equations 1a and 1b were used to estimate the impact per kilogram of animal product purchased for retail sale; Equations 2a and 2b were used to convert those estimates to impact per pound; Equations 3a and 3b estimate the U.S. total impacts of replacing the animal food products; and Equations 4a and 4b were used to estimate the individual impacts. Each component of these equations is described in the sections below.

$$\text{Animal lives per kilogram of product purchased} = \text{Product per life} \times \text{Loss proportions (primary to retail)} \times \text{Elasticity factor} \times \text{Indirect impact factor} \quad (1a)$$

$$\text{Animal days of suffering per kilogram of product purchased} = \text{Animal lives per kilogram of product purchased} \times \text{Lifespan} \quad (1b)$$

$$\text{Animal lives per pound of product purchased} = \frac{\text{Animal lives per kilogram of product purchased}}{2.205} \quad (2a)$$

$$\text{Animal days of suffering per pound of product purchased} = \frac{\text{Animal days of suffering per kilogram of product purchased}}{2.205} \quad (2b)$$

$$\text{Animal lives saved (U.S. total)} = \frac{\text{Total weight of product consumed per day}}{\text{Product per life} \times \text{Loss proportions (primary to consumption)}} \times \text{Elasticity factor} \times \text{Indirect impact factor} \times \text{USDA weighting factor} \quad (3a)$$

$$\text{Animal days of suffering avoided (U.S. total)} = \text{Animal lives saved (U.S. total)} \times \text{Lifespan} \quad (3b)$$

$$\text{Animal lives saved (individual)} = \frac{\text{Weight per individual serving}}{\text{Product per life} \times \text{Loss proportions (primary to consumption)}} \times \text{Elasticity factor} \times \text{Indirect impact factor} \times \text{USDA weighting factor} \quad (4a)$$

$$\text{Animal days of suffering avoided (individual)} = \text{Animal lives saved (individual)} \times \text{Lifespan} \quad (4b)$$

Equation Components

Total Weight Of Product Consumed Per Day

Used in Equations 3a and 3b for U.S. totals

To estimate the total weight of different animal products consumed per day, we used the 2015-16 National Health and Nutrition Examination Survey (NHANES), a nationally representative, in-person survey of over 8,000 people in the U.S. [1]. The survey includes a dietary recall interview, which asks respondents to report their food consumption over a 24-hour period [2]. Though the survey includes two days of data collection, we used the data from Day 1 only, because Day 2 has incomplete participation that could introduce selection bias. This survey also estimates the weight of the animal product component of each food item consumed. For simplicity, we included only one animal product per food code in our estimates (e.g., the beef patty from a cheeseburger but not the cheese slice or mayonnaise). This means that our estimates from the NHANES data, if used alone, would probably slightly underestimate total consumption. However, as described in the 'USDA Weighting Factor' section below, we applied a correction to our overall estimates.

The NHANES data allows for very specific categorization of animal products consumed in the U.S.. We categorized respondents' reported consumption based on the type of animal products consumed (e.g. beef, pork, dairy) and the product formats (e.g. steak, bacon, cheese). We then applied sample weights included in NHANES to ensure the estimates are representative of the U.S. population on an average day.

Product Per Life

Used in all equations

The product per life refers to the initial weight of product per animal life that we use in our analysis. For livestock meat products (beef, pork, chicken, turkey), eggs, and dairy, we used data from the Food and Agriculture Organisation of the United Nations (FAO) for the U.S. in 2020 [3]. For livestock meat products the data are carcass weights -- the weight after slaughter with some parts, such as the head and inedible organs, removed. For eggs and dairy, the data are the yield per animal in the year. To estimate the weights of eggs and dairy produced over the animals' whole lives, we multiplied these yields by how long (in years) cows and hens typically produce these products [4] [5].

For fish and shellfish we estimated the weighted average weights of the species most commonly consumed in the U.S. using two key sources of data: (1) The per-person edible weights of the most commonly consumed seafood in the U.S. estimated by the National Fisheries Institute [6]; and (2) harvest weights of each of these most commonly consumed fish and shellfish from Fishcount [7]. We applied the proportion of each product consumed to the harvest weights to estimate weighted average weights for fish and shellfish. Fishcount does not estimate weights of wild-caught fish, so we estimated a weighted average for crabs using several alternative sources, as most crabs in the U.S. are wild-caught [8] [9] [10] [11] [12].

Loss Proportions

Used in all equations

There are several forms of loss in the weight of an animal from the farm to the point of consumption. The United States Department of Agriculture (USDA) estimates losses between the farm and retail sale (e.g., due to errors during storage, processing, or transport), and between retail sale and consumption (e.g., due to removal of inedible parts of the animal, waste or damaged products, and shrinkage during cooking) [13] [14]. These stages of loss are clearly differentiated in the USDA's 'Food Availability (Per Capita) Data System' [13] and are replicated in our Excel workbook.

For livestock, the USDA estimates the proportions of carcass weights lost, so we used these estimates directly in our analysis. We also used the USDA estimates for eggs and dairy directly in our analysis. For eggs this should be accurate, as the USDA proportion is an estimate of the farm weight. For dairy, the estimate is a proportion of the retail weight, so our estimate for dairy products will likely be a slight underestimate.

For fish and shellfish, the USDA estimates are proportions of the edible weight of the products. Because our estimates for fish and shellfish start at harvest weights, we applied an additional adjustment for the edible proportions of fish and shellfish using FAO data [15], in addition to the loss adjusted proportions estimated by USDA. The FAO data does not include crab species, so several alternative sources were used to estimate an average edible proportion instead [16] [17] [18] [19] [20] [21] [22].

Milk Loss Proportion

In addition to the sources of food loss tracked by the USDA, we also accounted for loss during production of processed dairy products. The weight of ice cream, cheese, yogurt, and butter is smaller compared to the weight of milk used to produce them as a result of physical and chemical reactions during their manufacturing process. This source of loss occurs between primary and retail weight.

To take into account the milk weight loss in consumed ice cream, cheese, yogurt, and butter, we obtained sources for the ratios of milk to produce these dairy products and averaged them. Principally, the sources are from dairy companies, regulatory authorities, farm organizations, and universities [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34].

To ensure that the proportion of milk loss calculated was consistent with the unit of weight used in the analysis, we converted the units from the sourced ratios into kilograms before averaging, taking into account the density and composition of the products when necessary to convert from volume to weight. For this, we consulted a textbook and the standards of compositions that the United States Department of Agriculture (USDA) provides in its Grades and Standards [35] [36].

Elasticity Factor

Used in all equations

If an individual (or group of individuals) reduces their consumption of an animal product by a certain amount, this will likely result in a less than proportional reduction in society-wide consumption of that product. This is because the lower demand for the animal product will likely reduce the market price of the product, which will, in turn, slightly increase the quantity demanded by consumers. The size of this effect depends on the price elasticity of demand and supply for the product; that is, how responsive demand and supply are to changes in the price of the product.

We made adjustments to our estimates to account for this effect. We followed the approach of Norwood and Lusk (2011), which uses the following equation to estimate the net impact on quantity consumed of a unit change in consumption [37]:

$$Impact\ of\ a\ unit\ change\ in\ consumption\ = \frac{Price\ elasticity\ of\ supply}{Price\ elasticity\ of\ supply - Price\ elasticity\ of\ demand} \quad (5)$$

Full details of how this equation is derived can be found in the appendix of chapter 8 of Norwood and Lusk (2011), and also in chapter 3 of ‘Agricultural Marketing and Price Analysis’ [38].

We used estimates directly from Norwood and Lusk (2011) for impacts of reducing consumption of beef, pork, chicken, dairy, and eggs. The book does not contain estimates for turkey, finfish, and shellfish. We therefore estimated these as consistently as possible with the method of Norwood and Lusk. We used demand elasticities for turkey from Huang (1986) and fish from Huang and Lin (2000); the same papers used for the demand elasticities in Norwood and Lusk [39] [40]. For turkey, we estimated the same supply elasticity as used in Norwood and Lusk for chicken. For fish, data on long run supply elasticities are quite scarce. We used estimates of the long run supply elasticity for wild caught fish from Pascoe and Mardle (1999) and aquaculture from Andersen, Roll and Tveteras (2008) [41] [42]. Due to a lack of data about price elasticities for shellfish, we applied the overall elasticity estimate from finfish.

Indirect Impact Factor

Used in all equations

We applied adjustments to account for the fact that consuming the various animal products also has indirect effects on animal lives. We aimed to account for the largest impacts: pre-production mortality of farmed animals, male chicks in the egg industry, male calves in the dairy industry and feed fish used in the diets of farmed animals[1].

To account for the additional number of lives lost due to pre-production mortality of farmed animals, we used estimates of mortality rates largely from USDA sources [46] [47] [48] [49] [50]. For fish, we estimated the weighted average mortality rate of the most frequently consumed species in the U.S. from data provided by the Welfare Footprint Project [51]. For shellfish, we use the average of the mortality rates in the six largest producing countries in the world [52].

Our favored approach to estimate the number of additional days of suffering due to pre-production mortality was to use data on mortality at different phases of the animals' life cycles. For example, for pigs, the data suggests a 10% mortality rate at the preweaning stage, 4% at the nursery stage, and 4% at the grower to finisher stage [48]. Based on an average lifespan of 168 days [53], we estimated the average age of pre-production mortality to be 33 days. We used the same general approach for other livestock, though in some cases we relied on weaker mortality data. For fish and shellfish, data on the average age of mortality are particularly weak, so to estimate the additional days of suffering we assumed the point at which fish and shellfish die prematurely in proportion to their expected lifespan is the same as the average across the livestock species in our analysis.

To account for the indirect impact on male chicks, we assumed one male chick life is lost for each layer hen. This is in line with estimates of the number of layer hens and male chicks killed in the egg industry every year, at around 7 billion each [3] [54]. We assumed one additional day of suffering is caused per layer hen, as the male chicks are typically one day old when they are killed [55].

To account for the additional number of lives lost due to non-replacement male dairy calves used in the veal industry, we estimated the number of male calves a cow gives birth during its productive lifespan on a dairy farm [56]. For the calculation, we used the overall calving interval estimated by USDA in its Dairy 2014 study [57] and assumed a sex ratio of 50:50.

Furthermore, to obtain the number of additional days of suffering, we used the factsheet Veal from Farm to Table published by USDA [58]. This publication reports that 15% of veal caves are bob calves and provides the age range of bob calves and veal calves at slaughter. Based on

[1] We did not include bycatch of wild caught fish, as some bycatch is used for feed fish [35], which could lead to double-counting in our estimates, and while a large proportion of bycatch is discarded back to sea, some of these discards survive [36]. Reliable estimates of the breakdown were unavailable. We also did not account for breeder animals to avoid double-counting, as the meat of these animals are sometimes used for human consumption (e.g. [37]) and reliable estimates were not available. With these exclusions, our indirect impact estimates are likely to be somewhat conservative.

that, we calculated the number of bob calves a dairy cow has by applying 15% and assumed that other veal calves represent 85%. Additionally, we converted the age range into days and averaged them for these two groups, bob calves and other veal calves.

To account for feed fish used in the diets of aquacultured fish and shellfish, pigs, and chickens, we first applied global estimates of the proportion of feed fish per species to Fishcount data on the total number of feed fish caught globally [59] [60]. We then converted these estimates to the number of feed fish per individual animal based on estimates of the number of farmed fish, shellfish, pigs, and chickens consumed globally every year [3] [61] [62]. For farmed fish and shellfish we applied an additional weight to account for the difference between the average weight of fish and shellfish in the global Fishcount data and the average weight of those consumed in the U.S.

Since feed fish are generally wild caught [59], we assumed that each fish used causes the equivalent of one life lost and one additional day of suffering (see 'Lifespan' section for more details on this assumption).

In the final infographics we present the impacts of the various animal food products including the indirect impacts. However, the totals with indirect impacts excluded are available in the full data spreadsheet.

USDA Weighting Factor

Used in Equations 3a, 3b, 4a, and 4b to adjust consumption estimates

We also estimated the overall number of lives and the days of suffering for each animal based on the USDA data on food availability, which is often taken as a proxy for total consumption in the U.S. [13]. Summing the number of lives and days of suffering avoided for each of our animal product categories showed that our total estimates based on the NHANES data were, in most cases, slightly below our estimates based on the USDA data. This was as we had expected, given that our procedure with the NHANES data excluded some animal products.

We consider the USDA estimates to be the most reliable source of information on the total amount of consumption in the U.S. Therefore, we applied multiplicative factors to our NHANES estimates using the ratio of our estimates and the numbers expected from the USDA data.

This adjustment has the impact of increasing the number of lives saved or days of suffering avoided (where we underestimated compared to what we expected from the USDA data) by replacing a certain food product, but retaining the relative impacts of the different food products reported in NHANES.

Lifespan

Used in Equations 1b, 2b, 3b, and 4b for days of suffering avoided

To estimate the days of suffering avoided for each animal food product, we multiplied the number of lives saved for each product by the average lifespan of each animal. For livestock, we used estimates of typical lifespans directly in our analysis from several sources [4] [5] [53] [63] [64] [65].

For fish and shellfish, we estimated weighted average lifespans based on the proportion of consumption that is wild caught versus farm raised. These proportions were largely taken from Seafood Health Facts, a joint project of several U.S. universities [66]. We used lifespans for farm raised finfish from Welfare Footprint Project, and used an FAO estimate for farmed shellfish [51] [67]. For wild caught fish and shellfish, we assumed a “lifespan” of one day, since consumers are only responsible for the period of capture and slaughter in the animals’ lives.

Weight Per Individual Serving

Used in Equations 4a and 4b for individual impacts

The weight per individual serving refers to the weight of the animal product in an average serving of a particular food product (e.g. the weight of the meat patty in a burger). The NHANES dietary recall interview includes this data for each of the food products consumed. We estimated the average of all the servings in the dietary recall data for each of our product categories (e.g. beef steak, pork bacon, etc.) to give us an average weight per individual serving for each category. This allows individuals to directly compare products that they may eat more or less often than the general population.

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