Re-Consider the Lobster:
Animal Lives in Protein Supply Chains

Karl T. Ulrich
University of Pennsylvania
The Wharton School – Operations, Information, and Decisions Department
500 Huntsman Hall, 3730 Walnut Street, Philadelphia, PA 19104 US
ulrich@upenn.edu ׀ ktulrich.com

Original Version: February 2, 2025
This Version: July 31, 2025

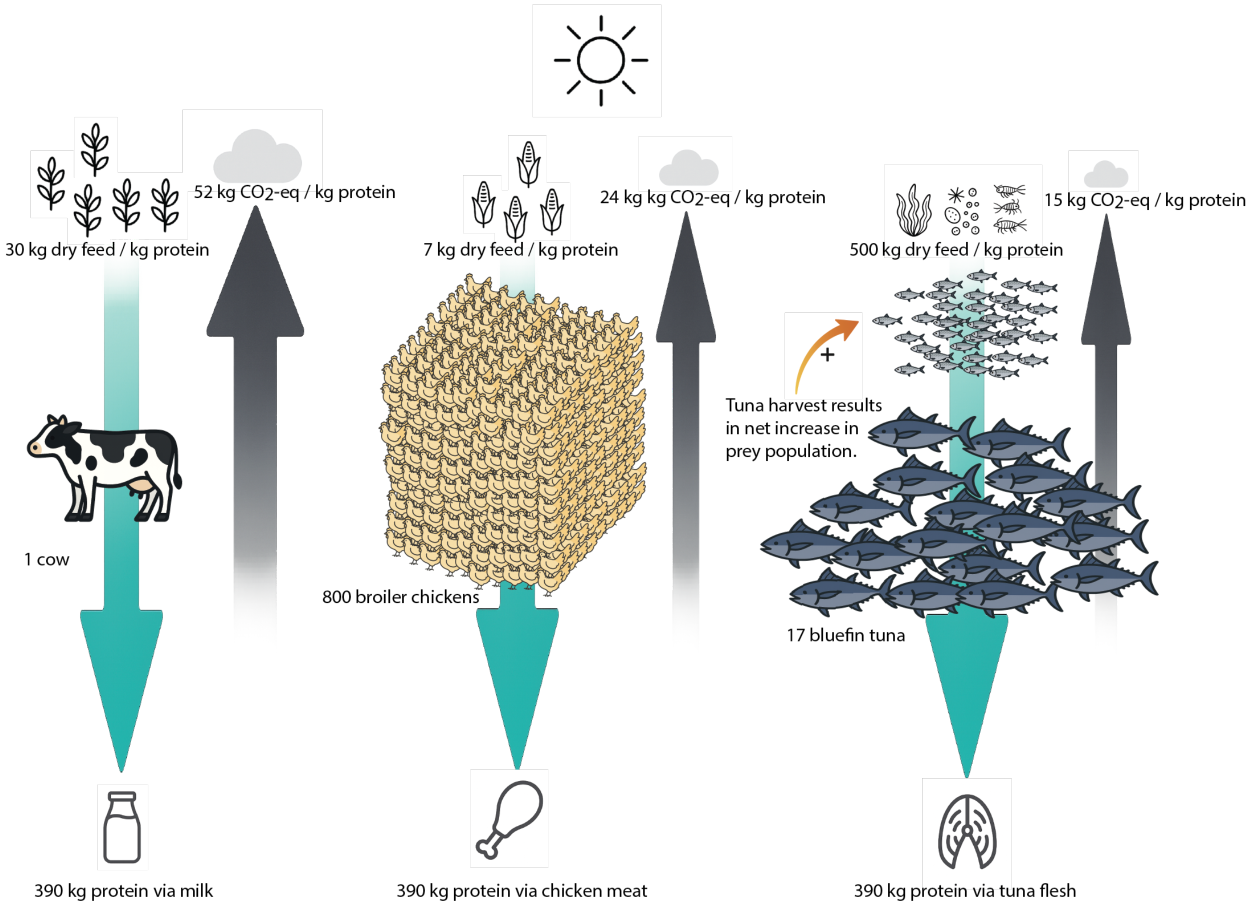
Abstract

Animal protein production represents a complex system of lives transformed into nutrition, with profound ethical and environmental implications. This study provides a quantitative analysis of animal lives required to produce human-consumable protein across major food production systems. Categorizing animal lives based on cognitive complexity and accounting for all lives involved in production, including direct harvests, reproductive animals, and feed species, reveals dramatic variations in protein efficiency. The analysis considers two categories of animal life: complex-cognitive lives (e.g., mammals, birds, cephalopods) and pain-capable lives (e.g., fish, crustaceans). Calculating protein yield per life demonstrates efficiency differences spanning more than five orders of magnitude, from 2 grams per complex-cognitive life for baby octopus to 390,000 grams per life for bovine dairy systems. Key findings expose disparities between terrestrial and marine protein production. Terrestrial systems involving mammals and birds show higher protein yields and exclusively involve complex-cognitive lives, while marine systems rely predominantly on pain-capable lives across complex food chains. Dairy production emerges as the most efficient system. Aquaculture systems reveal complex dynamics, with farmed carnivorous fish requiring hundreds of feed fish lives to produce protein, compared to omnivorous species that demonstrate improved efficiency. Beyond quantitative analysis, this research provides a framework for understanding the ethical and ecological dimensions of protein production, offering insights for potential systemic innovations.

Keywords: animal lives; protein production; protein yield; cognitive complexity; food systems; food supply chain; aquaculture; livestock efficiency; meat production; ethical food production; trophic levels; animal welfare

Acknowledgments: I acknowledge the helpful comments on a previous version of the manuscript by Christian Terwiesch, Karan Girotra, and Senthil Veeraraghavan.

A version of this paper will appear as:
Karl T. Ulrich, "Re-Consider the Lobster: Animal Lives in Protein Supply Chains," *Sustainability*. Volume 17. 2025.



Graphical Abstract

1. Introduction

In his 2004 essay "Consider the Lobster," David Foster Wallace confronted readers with an uncomfortable question: Does the lobster suffer when boiled alive for our culinary pleasure? [1]. Wallace's essay used a Maine lobster festival as a lens to examine broader questions about consciousness, suffering, and the ethical implications of food choices. Two decades later, this paper brings an analytical perspective to a related fundamental question about animal protein supply chains: How many animal lives are required to produce a given quantity of human-consumable protein? This analysis moves beyond the philosophical question of suffering to provide a quantitative foundation for ethical decision-making about food systems, while acknowledging that different forms of animal life may have different capacities for suffering and consciousness [2].

Protein is a critical macronutrient in the human diet. Current dietary guidelines recommend 0.8 grams of protein per kilogram of body weight daily for adults, with higher requirements for athletes and active individuals, who may need 1.2 to 2.0 g/kg [3]. For a 70kg adult, this translates to 54-140g of protein daily. While adequate calories can be readily obtained from plant sources in developed societies, high-quality protein remains a key bottleneck in food production and nutrition. Animal sources are particularly important as complete proteins containing all essential amino acids in proportions that match human needs. Animal proteins typically show higher digestibility and bioavailability compared to plant sources, making them an effective way to meet essential amino acid requirements [4].

The relationship between animal lives and protein production is complex and often counterintuitive. A dairy cow produces milk protein for years before being processed for meat, but this production requires the birth of calves, about half of which are male and destined for early slaughter. This same cow may experience welfare challenges from intensive production methods [5]. A tuna consumes thousands of smaller fish during its life before being harvested, yet its removal from the ecosystem may increase the total number of fish lives through trophic cascade effects [6]. A laying hen requires the parallel production of male chicks that are usually culled shortly after hatching [7].

This complexity is compounded by philosophical questions about the relative value of different forms of animal life. Recent research has revealed sophisticated cognitive abilities in species previously considered simple. Chickens demonstrate numerical abilities and self-control comparable to primates [8]. Pigs show cognitive abilities similar to dogs and young children [9]. Octopi exhibit remarkable problem-solving capabilities and emotional states [10]. Even fish, long considered purely reflexive creatures, show evidence of pain perception and basic learning [11].

Drawing on the work of Martha Nussbaum in animal justice, I establish a framework for considering different categories of animal life while acknowledging the profound philosophical questions raised by this logic [12]. My analysis focuses on two broad categories: cognitively complex lives (including mammals, birds, and cephalopods) and pain-capable lives (including fish and crustaceans). While simpler organisms like zooplankton and bivalves technically constitute lives ended in food production, I exclude them from my quantitative analysis while acknowledging that some ethical frameworks might accord them moral weight.

To my knowledge, this is the first systematic analysis of protein yield per animal life across major food production systems. While the primary focus is on animal lives, I also include approximate estimates of greenhouse gas emissions to allow comparison of both ethical and environmental efficiency. These impacts, though not explored in depth here, are an essential component of broader food system sustainability.

The analysis accounts for total lives involved in production including feed species and offspring, calculates protein yield per life across production methods, and examines key sensitivities and assumptions. I find that protein yields per complex-cognitive life vary by more than five orders of magnitude across production systems, from as little as 2 grams of protein per cognitively complex life for wild-caught baby octopi to 390,000 grams for dairy production. These dramatic differences emerge from biological factors like trophic level, production characteristics like lifespan, and system design choices in agriculture and aquaculture.

The analysis provides practical guidance for both individual dietary choices and food system policy. Though philosophical debates about consciousness and suffering continue, I demonstrate that measurable improvements in protein yield per life are possible through targeted changes in production methods and consumption patterns. Most participants in these debates would agree that, all else equal, fewer lives taken is better than more lives taken. This common ground provides a basis for practical progress even as deeper ethical questions remain unresolved.

The remainder of this paper is organized as follows: Section 2 presents my analytical framework for categorizing animal life and measuring protein yield. Section 3 applies this framework to analyze major protein production systems including dairy, land animals, aquaculture, and wild-caught species. Section 4 presents my results comparing protein yield per life across systems. Section 5 discusses implications for policy and practice while examining key philosophical considerations and limitations.

2. Approach and Analytical Framework

This section defines the analytical framework used in the paper, including how animal lives are categorized, how system boundaries are drawn, and how protein yield per life is calculated. These definitions structure the ethical and ecological comparisons throughout the analysis.

2.1. Categorizing Animal Life

To analyze protein production per animal life, we must first establish a framework for what constitutes a “life.” This question presents fundamental challenges because individuals assign different values to different forms of animal life. Many humans exhibit strong empathy for animals that share human-like characteristics, leading to greater concern for mammals than for crustaceans [13]. Some argue that such anthropomorphic valuation lacks ethical justification, while others, like Nussbaum, argue that cognitive and social capabilities create morally relevant differences between species. Nussbaum's capabilities approach suggests that what matters is not just the capacity to experience pain, but the broader ability to form intentions, maintain social connections, and experience complex emotions.

Rather than asserting a specific position on relative value, I provide a categorization based on scientific evidence of cognitive and sensory capabilities. Recent advances in animal cognition research have revealed increasingly sophisticated capabilities across many species, suggesting three distinct categories of animal life with different ethical implications for food production.

The first category, which I term “cognitively complex lives,” encompasses animals demonstrating sophisticated cognitive abilities, emotional responses, and social behaviors. Large, domesticated mammals exhibit remarkable capabilities: cattle show social learning and emotional bonds [14]; pigs demonstrate cognitive abilities comparable to dogs and young children, including mirror self-recognition and tool use [9]; and sheep display facial recognition and complex emotional responses [15]. Their wild relatives, such as bison, show similar capabilities.

Domesticated birds, particularly chickens, turkeys, and ducks, also demonstrate cognitive sophistication that places them firmly in this category. Chickens exhibit numerical abilities and basic arithmetic from just days after hatching [16], while showing self-control and planning capabilities comparable to primates [8]. They engage in complex social learning and cultural transmission [17], display emotional contagion and empathetic responses [18], and show evidence of self-awareness and anticipatory behavior [7]. Turkeys and ducks similarly demonstrate advanced cognitive capabilities, including sophisticated social recognition, tool manipulation, and complex problem-solving behaviors [19].

Cephalopods represent a unique case within this category as the only invertebrates showing cognitive complexity comparable to vertebrates. Octopi demonstrate striking problem-solving abilities, tool use, and spatial learning [10]. Both octopi and squid show evidence of play behavior, distinct personality traits, and emotional states [20]. Their sophisticated nervous systems and demonstrated cognitive abilities place them firmly alongside mammals and birds in terms of cognitive complexity.

The second category, "pain-capable stimulus-response lives," includes animals with clear evidence of pain perception and basic learning but without strong evidence of higher cognitive functions. Fish fall into this category, showing clear nociception and pain avoidance [11], along with basic learning and memory capabilities. While some fish species demonstrate more sophisticated behaviors, the evidence for complex cognitive abilities like self-awareness or emotional states remains limited compared to mammals, birds, and cephalopods.

Crustaceans, including lobsters, crab, and shrimp, also belong in this category. Research demonstrates that crustaceans show pain avoidance [21], exhibit basic learning from negative stimuli [22], and display stress responses and simple memory formation. However, they lack strong evidence of the more sophisticated cognitive abilities seen in the first category. Their nervous systems, while capable of processing pain and basic learning, appear primarily oriented toward stimulus-response behaviors rather than complex cognition.

The third category, "non-suffering lives," encompasses organisms with minimal neural structure that exhibit primarily reflexive behaviors. This includes bivalve mollusks, most insects, and simple marine organisms like zooplankton. While these organisms can respond to environmental stimuli, there is limited evidence for pain perception or learning capabilities. Their simple nervous systems suggest minimal capacity for suffering in any meaningful sense comparable to more complex animals.

This categorization framework reflects current scientific understanding while acknowledging that our knowledge of animal consciousness and suffering continues to evolve. Notably, recent research has consistently expanded our recognition of cognitive capabilities in species previously considered simpler, suggesting we should err on the side of caution when considering capacity for suffering. This framework allows individuals to apply their own ethical weights to different categories while maintaining analytical clarity about the number and types of lives involved in protein production.

2.2. Production System Analysis

For each production system, I analyze:

Direct Production Lives: Animals directly harvested for protein

Supporting Lives: Animals consumed as feed or lost in production

Reproductive Lives: Breeding stock and offspring

System Boundaries: Which lives to include or exclude

I adopt these measurement principles: count all lives ended in service of production; include feed species lives for farmed carnivores; account for breeding/replacement animals; establish clear system boundaries; and document key assumptions.

For wild-caught species, we face additional complexity in establishing system boundaries, as harvesting one predator species prevents that predator from consuming prey species. I address this through sensitivity analysis examining different boundary assumptions [23].

2.3. Protein Yield Model

For each production system, I calculate:

Total Protein Yield per Life = Total Protein Produced / Total Lives Required

Where:

Total Protein Produced includes all consumable protein (meat, milk, eggs)

Total Lives Required includes all categories of lives within system boundaries

Key conversion factors include live weight to edible weight ratios [24], protein content of edible portion [25], feed conversion ratios for farmed species [26], reproductive rates and offspring survival [27], and production lifespan [28].

For systems with multiple protein outputs (e.g., dairy producing both milk and meat), I allocate lives based on protein mass contribution. I report point estimates while acknowledging both natural variation in parameters and uncertainty in their values. The variance in results across systems of protein production is dramatically larger than the variance in the estimate for a particular system of production, which I demonstrate through calculation of confidence intervals for beef production.

This framework provides a systematic basis for comparing protein yield per life across diverse production systems while acknowledging fundamental differences in the nature of animal lives involved. The results enable evidence-based discussion of system efficiency while leaving deeper philosophical questions about relative value of different lives to the reader.

While edible protein mass serves as a practical functional unit for comparison, it is important to recognize that not all protein sources are nutritionally equivalent [29]. Animal proteins generally exhibit high digestibility and contain all essential amino acids in proportions well-matched to human needs, making them complete proteins. Among them, milk and eggs are often considered nutritional benchmarks due to their high bioavailability and amino acid scores. Fish proteins also score highly, with excellent digestibility and favorable lipid profiles. By contrast, protein from terrestrial meat sources can vary depending on muscle type, processing, and fat content. These differences do not significantly affect the ethical life-count analysis presented here, but they are relevant for future multi-criteria assessments that weigh both nutritional density and moral cost per unit of benefit.

2.4. Ethical Scope and Inclusion Criteria

My analysis focuses on cognitively complex and pain-capable lives, excluding the category of non-suffering lives (e.g., zooplankton, bivalve mollusks) from our quantitative assessment. While I acknowledge that some ethical frameworks, particularly those rooted in religious traditions like Jainism or certain Buddhist perspectives, accord moral weight to all living beings, my analysis reflects the scientific consensus on capacity for suffering. However, readers may choose to incorporate these additional lives into their ethical calculations.

2.5. Climate Impact Metric

While this analysis centers on ethical efficiency, measured in terms of animal lives affected per unit of edible protein, greenhouse gas (GHG) emissions remain a critical component of food system sustainability. To support side-by-side comparisons, I incorporate cradle-to-farm-gate GHG intensities (expressed in kg CO_2-equivalents per kg of edible protein) for all production systems examined.

For terrestrial systems, I draw primarily on the harmonized global meta-analysis conducted by Poore and Nemecek [30], which provides median emissions data by product category. Aquatic values are taken from the Blue Food Assessment LCA synthesis [31], which covers farmed species, and from Cashion and Tyedmers [32], who estimate GHG emissions from wild-capture fisheries based on fuel intensity per metric ton landed. Where multiple production methods exist within a system (e.g., rainfed vs. irrigated beef, cage vs. net-pen aquaculture), I use production-weighted medians to represent typical conditions.

All estimates are converted to a per-gram protein basis using species-specific edible yield and protein content [24, 25]. Protein yield per life and GHG intensity are reported together in Figure 1 to visualize trade-offs between ethical and environmental performance. While this GHG metric is not integrated directly into the ethical efficiency ranking, it supports a broader sustainability perspective and helps identify production systems with unusually favorable or unfavorable performance on both axes.

2.6. Data Sources and Assumptions

All quantitative estimates in this analysis are based on published data describing production yields, biological characteristics, and input-output relationships across food systems. These include:

Live-to-edible weight conversion factors for livestock, seafood, and eggs [24, 25]

Protein content of edible tissues, milk, and eggs, expressed as a percentage of wet weight [25]

Reproductive rates and lifespans for dairy cows, broilers, pigs, salmon, and other species [27, 33]

Feed conversion ratios for aquaculture and terrestrial systems [26, 34]

Fishmeal and fish oil yield assumptions for carnivorous aquaculture [35, 36]

Trophic cascade estimates and predator-prey dynamics for wild-capture fisheries [6, 37]

Where systems have multiple protein outputs (e.g., dairy producing both milk and meat), lives are allocated proportionally based on protein mass contribution. In systems where inputs such as feed are derived from other sentient species (e.g., small pelagic fish used in salmon feed), those lives are counted in full.

All parameter values are documented in Appendix A, and uncertainty is addressed through sensitivity analysis and reporting of confidence intervals where applicable.

2.7 Terrestrial Systems

While numerous life-cycle assessments have quantified feed-conversion ratios and greenhouse-gas footprints of terrestrial livestock, these metrics alone do not capture the ethical dimension of how many animal lives are taken per unit of protein. Prior studies show that ruminant systems typically require on the order of 133 kg of dry feed to produce 1 kg of protein [34] and emit a median of ≈52 kg CO_2-eq per kg protein, whereas monogastric systems require ≈30 kg of feed and emit ≈24 kg CO_2-eq per kg protein [30]. Building on this foundation, this section contains the core innovation of this paper: calculating protein yield per animal life. In the subsections that follow, I briefly summarize these established efficiency and emissions benchmarks for herbivorous and omnivorous species and then present the life-based efficiency metrics for dairy, beef, pork, and poultry.

2.7.1 Herbivorous Species

Dairy systems achieve the highest efficiency through continuous production over multiple years combined with meat protein from culled animals and excess offspring [33]. A dairy cow produces milk protein throughout her productive life while generating calves that enter either dairy or meat production streams. This continuous production model, coupled with large animal size, allows dairy to deliver approximately 390 kg of protein per life. (In all cases, I report two significant figures in the estimates.)

Among meat-focused terrestrial systems, beef cattle offer the next highest yield at 73 kg per life, benefiting from large animal size and efficient conversion of plant matter to protein. Pork production achieves moderate efficiency at 19 kg per life through omnivorous feeding and relatively fast growth cycles [38].

2.7.2 Omnivorous Species

Chicken meat provides 0.49 kg per life, while egg production yields 1.3 kg per life but introduces the complication of culled male chicks in breeding systems [39]. These systems involve only cognitively complex lives but achieve lower total protein yields due to smaller animal sizes.

2.8 Marine Systems and Trophic Cascades

2.8.1 Theoretical Framework

The analysis of carnivorous marine species requires consideration of complex trophic cascade effects. When humans apply fishing pressure to apex predators, we initiate a cascade of ecological changes that fundamentally alter population dynamics across multiple trophic levels. Traditional analyses that simply count direct harvest deaths and prey consumption fail to capture these systemic effects.

Recent research in marine ecology demonstrates that reducing apex predator populations through sustainable harvest leads to several key effects [6, 37]:

Reduction in apex predator population size and average age

Increase in immediate prey species populations

Subsequent cascade effects through lower trophic levels

Overall increase in total animal lives in the system

This counterintuitive result, that harvesting apex predators can increase total animal lives, emerges from fundamental principles of energy transfer through trophic levels. When apex predator populations are reduced, the energy they would have consumed becomes available to support larger populations of smaller species with faster reproductive rates.

2.8.2 Farmed Carnivorous Fish

Aquaculture of carnivorous species like salmon presents a special case in my analysis. While the feed fish primarily consume zooplankton and other non-suffering lives, industrial-scale harvest of these species for aquaculture feed has led to documented population depletions. Studies indicate that industrial fishing for feed has contributed to significant declines in small pelagic fish populations, particularly in regions where fish meal production is concentrated [39, 40].

These population reductions ripple through marine ecosystems. Species at higher trophic levels that depend on these fish populations likely experience reduced abundance due to food limitations [42]. While my analysis could theoretically account for these additional population reductions, I justify their exclusion based on trophic efficiency: each higher trophic level supports roughly one-tenth the biomass of the level below it [43]. Therefore, the number of affected lives at higher trophic levels is relatively small compared to the direct feed fish lives counted in my analysis.

Using the example of farmed salmon:

One 4.5 kg salmon requires approximately 468 feed fish lives

Yields 0.64 kg of protein

Results in 1.4 g protein per life
(in this case all are *pain-capable* lives as opposed to *cognitively complex* lives)

This accounting, while not capturing all ecosystem effects, provides a reasonable approximation given the order-of-magnitude differences between trophic levels. Unlike wild harvest of apex predators, aquaculture creates a fixed demand for feed fish that depletes rather than releases predation pressure, preventing the compensatory population increases seen in wild systems.

2.8.3. Wild Apex Predators

For wild-caught apex predators, my analysis suggests that sustainable harvest may result in a net *increase* in total animal lives through trophic cascade effects. Consider a bluefin tuna:

Individual harvest weight: 180 kg

Protein yield: 23 kg

Traditional prey consumption calculation: ~37,800 fish lives over lifetime

However, this simple calculation misses the key ecological dynamics. When tuna populations are reduced through sustainable harvest:

Tuna population typically decreases by 40-50%

Prey fish populations increase by 20-30%

Net result is an increase in total lives in the system

This suggests that the ethical calculation for wild-caught apex predators should consider: the suffering of the harvested individual, concerns about species preservation, the net increase in prey species lives, the relative capacity for suffering between apex predators and prey species.

2.8.4. Cephalopods and the Complexity of Life-Stage Effects

Cephalopods, particularly octopi, present a fascinating case study that illustrates the multifaceted nature of the protein-per-life calculus. As cognitively complex predators that consume pain-capable prey, they share characteristics with apex predators like tuna. However, their relatively short lifespans and different ecological role result in more localized trophic effects.

The case of juvenile octopi (yielding just 0.011 g protein per pain-capable life, and 2 g per complex cognitive life) is particularly instructive. Like juvenile harvest of any species, removing young octopi before reproduction creates stronger population pressures than harvesting adults. However, several factors make this case distinctive.

First, these are cognitively complex creatures capable of sophisticated problem-solving and emotional states [10], placing them in my highest category of cognitive capability. Second, even as juveniles, they consume pain-capable prey, primarily small crustaceans. This means that reduced juvenile octopus populations could, like other predator reductions, lead to increased prey populations. However, unlike apex predators where this effect might be seen as positive from a lives-per-protein perspective, the removal of juvenile octopi raises additional ethical concerns because it ends cognitively complex lives before they've had any chance to fulfill their biological potential.

This example illustrates how the quantitative framework of lives-per-protein interacts with other ethical considerations including cognitive complexity, life-stage effects, and ecosystem dynamics. While mature octopi provide 0.33 g per pain-capable life and squid yield 0.046 g per pain-capable life, these simple ratios capture only part of a complex ethical calculation.

3. Results

Table 1 and Figure 1 reveal two interacting gradients in animal-protein production: an ethical axis (protein yield per life) that spans five orders of magnitude, and a climate axis (median kilograms of CO_2-equivalent per kilogram of protein) that spans roughly two. These results synthesize data across 14 production systems and incorporate parameter uncertainty from multiple sources, as documented in the appendices. Detailed 10th–90th percentile bounds for GHG appear in Appendix B, but are reflected in the vertical error bars in Figure 1.

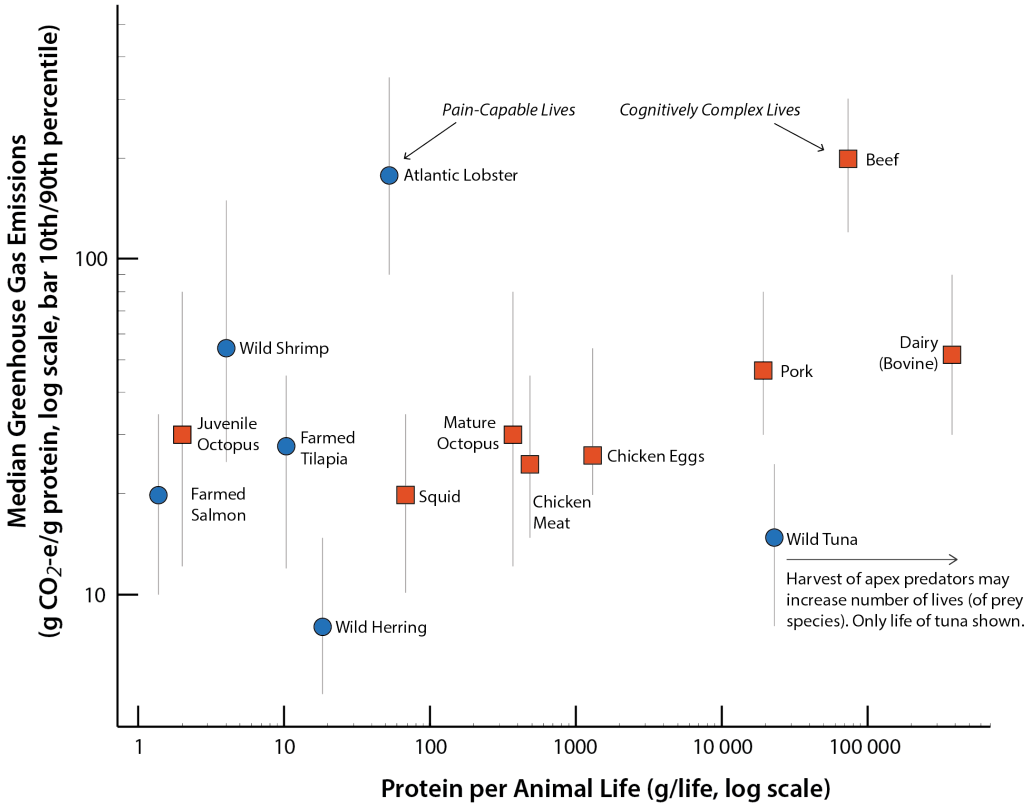


Figure 1. Ethical versus climate efficiency of protein production systems. (Squid and octopus harvests cost both complex-cognitive lives and pain-capable lives. In the graphic, only the cost of cognitively complex lives is shown.)

3.1. System Efficiency and Climate Trade-Offs

To reveal the interdependence of ethical and environmental performance, I overlay protein-per-life values onto established greenhouse-gas (GHG) intensity metrics. Previous meta-analyses report that dairy systems emit a median of 52 kg CO_2-eq per kg protein and beef systems emit about 200 kg CO_2-eq per kg protein [30]. My contribution is to combine these emission footprints with the life-based protein yields calculated in Section 3.3. This comparison shows that dairy delivers 390 kg of protein per cognitively complex life while maintaining a moderate climate burden (52 kg CO_2-eq/kg protein). Beef (73 kg per life) and pork (19 kg per life) follow, although beef incurs a markedly higher GHG penalty.

Among aquatic animals, wild tuna is a standout. The tuna itself provides 23 kg of protein, but recall that sustainable harvest of apex wild predators tends to increase net lives, so can be considered ethically quite efficient. At just 15 kg CO_2-eq per kg of protein, wild tuna is also relatively climate-efficient.

Feed-intensive systems such as farmed salmon (1.4 g per life, 20 kg CO_2-eq per kg protein) and crustacean trawls (4 g per life, 55 kg CO_2-eq per kg protein) sit at the opposite extreme, costing both a lot of lives and not being particularly efficient in terms of GHG emissions.

Lobster harvesting yields just 1.1 g protein per pain-capable life with a climate impact of approximately 45 kg CO_2-eq per kg protein, making it one of the least efficient systems both ethically and environmentally.

Cephalopods fall in between: mature octopi yield 360 g per complex-cognitive life at 30 kg CO_2-eq per kg protein, whereas squid yield 68 g at 20 kg CO_2-eq per kg protein. Juvenile-octopus fisheries remain ethical outliers at 2 g per complex-cognitive life.

3.2. Cognitive Complexity Patterns

Terrestrial systems involve only cognitively complex lives yet achieve kilogram-scale yields because animals convert feed over multiple years. Marine systems mainly affect pain-capable lives and require many more individuals per kilogram of protein, as energy passes through longer food chains. Cephalopods add complex lives to this marine chain, leading to some of the lowest protein efficiencies observed.

3.3. Production System Design Impacts

Two design levers dominate the pattern.

Production continuity. Continuous-yield systems such as dairy spread one life over hundreds of kilograms of protein. Single-harvest systems such as beef, pork and broiler chickens cannot do so.

Feed-chain architecture. Direct plant feeders (pigs and cattle) do not add extra lives to the chain, whereas fish-meal-dependent aquaculture multiplies pain-capable deaths and raises emissions through reduction of fisheries. Omnivorous tilapia, at 11 g per life and 28 kg CO_2-eq per kg protein, shows what is possible when fish-meal inclusion is minimised.

Ethical and climate efficiencies are not directly correlated. For terrestrial systems, fewer lives lost trades off against greater GHG emissions. Beef herds occupy the upper-right quadrant, combining strong ethical efficiency with a severe climate penalty. For aquatic systems, in general, ethical and climate performance are positively correlated, with fewer lives lost also associated with lower GHG emissions. The lower-right quadrant, where both metrics would be favourable, remains empty and marks a frontier for innovation in husbandry practices and alternative proteins.

Table 1. Protein produced and lives affected by animal protein production system.

Production System	Environment	Life Class	Protein / Total Lives (g)	Protein / Complex-Cognitive Lives (g)	GHG (kg CO_2e / kg protein)
Dairy (bovine)	Terrestrial	Complex cognitive	390 000	390 000	52
Beef	Terrestrial	Complex cognitive	73 000	73 000	200
Pork	Terrestrial	Complex cognitive	19 000	19 000	46
Chicken eggs	Terrestrial	Complex cognitive	1 300	1 300	26
Chicken meat	Terrestrial	Complex cognitive	490	490	24
Mature octopus	Aquatic	Hybrid	0.33	360	30
Squid	Aquatic	Hybrid	0.046	68	20
Juvenile octopus	Aquatic	Hybrid	0.011	2	30
Wild tuna (bluefin)	Aquatic	Pain-capable	Net increase in prey lives. Tuna life delivers 23 kg protein.		15
Wild herring	Aquatic	Pain-capable	18		8
Farmed tilapia	Aquatic	Pain-capable	11		28
Wild shrimp	Aquatic	Pain-capable	4		55
Farmed salmon	Aquatic	Pain-capable	1.4		20
Lobster	Aquatic	Pain-capable	1.1		180

Notes: Two significant figures shown. Median value shown for GHG. Detailed 10th–90th percentile GHG bounds are in Appendix B.

4. Discussion

4.1. Philosophical Foundations

My analysis reveals patterns in protein production efficiency that have significant implications for both food system policy and individual dietary choices. However, these quantitative results intersect with deeper questions about consciousness, suffering, and moral value. Philosophers have long debated whether animal lives should be counted equally, weighted by sentience, or evaluated by more complex considerations such as telos or narrative completeness.

The quantitative approach used here, measuring protein yield per life and categorizing animals by cognitive capability, may seem mechanistic when applied to ethical concerns. Yet structured analysis can help expose trade-offs that are obscured by intuition or tradition. When one production system ends a single cow life and another ends hundreds of chicken lives for the same nutritional output, we are forced to reckon with the scale and structure of harm in a way that vague ethical discomfort often avoids.

Some philosophers, particularly utilitarians, argue that bringing a sentient creature into existence with a life worth living constitutes a moral good. From this perspective, meat production systems that create billions of animals who experience net well-being before being painlessly killed may be ethically justifiable. This line of reasoning, sometimes called the *total view* in population ethics, shifts the moral focus from minimizing harm to maximizing welfare across all sentient lives, including those that would not otherwise have existed. While controversial, this view highlights the importance of clarifying one’s ethical framework when evaluating food systems.

4.2. Relative Moral Value of Individual Lives

Most readers instinctively feel that ending the life of a cow is “worse” than ending the life of a chicken, even though one cow yields roughly 73 kilograms of protein (via meat) while a single broiler yields less than 0.5 kilograms (Table 1). Three overlapping factors explain this reaction.

4.2.1. Cognitive complexity and welfare range

Empirical work on mind perception suggests that mammals score higher than birds on dimensions of self-awareness and emotional richness [44]. Experimental studies confirm that cattle demonstrate long-term social memories, object permanence, and emotional contagion [28]. Chickens also show sophisticated capacities, such as numerical competence, perspective taking and basic self-control [7], but the breadth of their welfare range (the set of states they can positively or negatively experience) may still be narrower than that of cattle [45]. Cross-species scoring systems [46] and precautionary policies such as the UK’s Animal Welfare (Sentience) Act provide frameworks for such adjustments.

4.2.2. Anthropomorphic bias

Psychological work on speciesism shows that humans assign moral standing in proportion to perceived similarity to themselves [47]. Large mammals elicit stronger empathic concern than birds, amplifying the intuitive moral gap even when cognitive evidence is comparable. Readers of popular culture will recognise an absurd illustration of anthropomorphic bias in Douglas Adams's novel *The Restaurant at the End of the Universe* [48], where a genetically engineered cow enthusiastically introduces itself at the table and recommends which of its own cuts the diners should order. Adams's scene lampoons the discomfort humans feel about killing animals once those animals can express preferences in near-human language. The humour underscores our tendency to grant moral standing in proportion to perceived similarity: a cow that talks like a waiter instantly outranks a silent chicken, regardless of their underlying cognitive capacities.

4.2.3. Scope neglect

People reliably undervalue harms distributed across many small victims compared with those concentrated in a single large victim, a phenomenon known as scope neglect [49]. Yet from an ethical standpoint, ending 150 conscious lives, though smaller, may carry more moral weight than ending one.

4.3. Quality of Life Considerations

The quality of life experienced by animals in different production systems adds another crucial dimension to this ethical calculus. Wild animals, particularly large herbivores like bison, may experience the highest quality of life, with natural social structures, freedom of movement, and species-typical behaviors fully expressed [50]. Some pasture-raised beef cattle may approach similar quality of life metrics, with research on extensive grazing systems showing more natural behavioral patterns, lower stress hormones, and better overall health outcomes compared to confined feeding operations [51].

The dairy industry presents a particularly complex case where efficiency and welfare often conflict. While dairy systems achieve the highest protein yield per life in my analysis, conventional dairy practices often compromise animal welfare. Studies document significant challenges including early separation of calves from mothers, high rates of lameness, metabolic stress from high milk production, and limited opportunity for natural behaviors in confined housing systems [5]. However, emerging research demonstrates that more ethical dairy production is possible, though often with reduced yields. Alternative approaches including cow-calf contact systems and pasture-based production typically show yield reductions of 15-30% compared to conventional systems, but with significant improvements in animal welfare metrics [52].

The relationship between cognitive complexity and quality of life raises additional ethical considerations. More cognitively sophisticated animals may have greater capacity for both positive and negative experiences, suggesting their welfare should be weighted more heavily. This becomes particularly relevant when considering species like pigs, which show cognitive abilities comparable to dogs and young children, or cephalopods, whose remarkable intelligence exists within fundamentally alien forms of consciousness.

4.4. Speculative Implications

These observations lead to provocative questions about the future of animal agriculture and bioengineering. Given that larger animals generally yield more protein per life, should we be engineering ever-larger domestic animals? We have already selectively bred cattle to be much larger than their wild ancestors. Following this logic to its extreme, perhaps we should develop elephant-sized cattle or whale-sized aquaculture species. More provocatively, if we accept that cognitive sophistication affects the ethical weight of ending a life, should we engineer food animals with minimal cognitive function? A hypothetical "zombie chicken" engineered to maintain basic biological functions but lacking higher consciousness would still convert feed to protein but might pose fewer ethical concerns [53].

This prospect becomes especially relevant as we develop lab-grown meat technology. Rather than growing meat from cell cultures, we might engineer minimally conscious bioreactors; organisms that are technically alive but lack meaningful consciousness. This could potentially offer better production efficiency than cell culture while minimizing ethical concerns about consciousness and suffering [54].

4.5. Limitations

My analysis faces several important limitations that deserve careful consideration. As elaborated in Section 4.3, my focus on lives ended provides an incomplete picture of animal welfare. My treatment of system boundaries presents another significant limitation. For wild-caught species in particular, the interconnected nature of marine ecosystems makes it challenging to definitively account for all affected lives. Similarly, in agricultural systems, my analysis does not fully capture lives affected by feed production, such as rodents killed during grain harvesting.

The categorization of lives into "cognitively complex" and "pain-capable" groups, while useful analytically, may oversimplify the rich continuum of animal consciousness and capabilities. Recent research suggests that many species we categorize as merely pain-capable may have more sophisticated cognitive and emotional lives than previously understood. My analysis also faces temporal limitations. I treat all deaths as equivalent, regardless of when in an animal's natural lifespan they occur. This may be philosophically problematic; ending the life of a juvenile animal might deserve different ethical weighting than ending the life of one that has lived most of its natural lifespan.

4.6. Common Ground and Future Directions

While deep philosophical questions about the relative value of different animal lives remain unresolved, my analysis suggests areas of common ground. Most ethical frameworks would agree that, all else equal, taking fewer lives is better than taking more. The dramatic differences in efficiency I document suggest significant opportunities for improvement through both system redesign and individual choice. Rather than waiting for resolution of philosophical debates about consciousness and suffering, we can make progress by applying evidence-based approaches to minimize lives taken while improving protein production efficiency.

The integration of quantitative analysis with ethical reasoning allows us to move beyond intuition to make more informed choices about food systems. Whether at the individual, institutional, or policy level, better understanding of the relationship between protein production and animal lives can help guide decisions toward more efficient and potentially more ethical outcomes. Future research priorities should include development of integrated welfare metrics, investigation of optimal production scales balancing yield and welfare, and innovation in housing and management systems that support natural behaviors while maintaining efficiency.

The tension between efficiency and welfare, between quantitative analysis and ethical reasoning, may never be fully resolved. However, by carefully examining these relationships and making them explicit, we can work toward food systems that better serve both human nutrition and animal welfare.

While this paper focuses primarily on expenditure of animal lives, these concerns are integral to a broader understanding of sustainability. A narrow conception of sustainability that focuses solely on greenhouse gas emissions or land use can obscure deeper systemic trade-offs. Ethical dimensions, such as how many sentient lives are lost, and under what conditions, must be considered alongside resource efficiency [55]. Food systems that minimize unnecessary suffering, distribute harms transparently, and recognize the moral status of sentient beings contribute not just to environmental goals but to a more just and humane planetary future. Viewed through this lens, sustainability is not only about emissions and land use but also about what kinds of lives, and whose lives, we value. Frameworks like the UN Sustainable Development Goals (e.g., SDG 12: Responsible Consumption and Production) [56] reflect this broader vision. The analysis in this paper offers one way to quantify and compare ethical efficiency alongside environmental impact. The framework developed here could inform institutional decisions ranging from food labeling and procurement standards to ethical sourcing policies and sustainability ratings.

5. Re-considering the Lobster

When David Foster Wallace asked readers to “consider the lobster,” he directed attention to a single animal in a boiling pot and invited reflection on consciousness, suffering, and appetite. Two decades later, the quantitative evidence presented here shows that the lobster dinner remains an ethically expensive choice. At 1.1 g of protein per pain-capable life, Atlantic lobster occupies the lowest end of the efficiency spectrum in Table 1 and Figure 1 and carries one of the highest greenhouse-gas intensities among marine foods.

The disparity is striking. A dairy cow provides nearly 400 kg of protein per cognitively complex life; a beef animal yields 73 kg; even a broiler chicken, inefficient by terrestrial standards, produces almost five hundred grams. In contrast, a single lobster life contributes only about a gram per life required. The animal that prompted Wallace’s moral unease turns out to be a statistical outlier as well.

The data also complicate intuitive rankings of moral concern. Because cows are large mammals, many people regard eating beef as more ethically troubling than eating crustaceans, yet the protein-per-life calculation reverses that hierarchy unless a cow is assigned about 70,000 times greater moral weight than that of a lobster. Cephalopods push the point further. Juvenile octopi, which are cognitively sophisticated animals, yield only two grams of protein per cognitively complex life, a result that challenges both intuition and some existing regulatory exemptions that treat invertebrates as ethically negligible.

The empirical pattern that emerges is not a simple correlation between cognitive complexity and efficiency. Terrestrial herbivores achieve high protein yield per life because continuous production or large carcass size amortises a single death over many kilograms of output. Marine systems pass energy through multiple trophic levels, so even when target species are less cognitively complex their harvest often requires many more lives. Ethical concern, therefore, cannot rest solely on the mental capacities of individual animals; it must also account for system architecture and trophic position.

These findings have pragmatic implications. First, efforts to reduce animal deaths per unit of nutrition would focus on continuous-yield systems such as dairy, on large-bodied terrestrial herbivores and on omnivorous or herbivorous aquaculture species that minimise feed-fish demand. Second, culinary traditions that valorise low-yield species like baby octopi merit renewed scrutiny, especially where substitutes with lower ethical and climate costs are readily available. Third, refining welfare standards within efficient systems remains essential, because high protein yield per life does not guarantee acceptable living conditions.

Wallace concluded that intellectual honesty about animal suffering might oblige us to reconsider cherished foods. The numerical evidence provided here strengthens that conclusion by adding scale and proportion to the moral calculus. In quantifying how many lives, and what kinds of lives, are exchanged for each gram of protein, the analysis converts vague discomfort into a decision space that is explicit, measurable, and open to improvement. Clearer numbers do not resolve every philosophical dispute about consciousness, but they sharpen the question: how many and what type of lives are we prepared to consume for dinner, now that we can measure the exchange rate?

Appendix A - Detailed Protein Supply Chain Calculations

Appendix A.1. Terrestrial Systems

Appendix A.1.1. Dairy Systems

Production Parameters:
  Daily milk production: 32 kg [57].
  Production period: 305 days/year [33].
  Productive life: 3 lactations [58].
  Milk protein content: 3.4% [25].
Welfare indicators tracked in analysis:
  Lameness prevalence: 20-55% in intensive systems [5].
  Metabolic stress markers [33].
  Natural behavior expression [59].
Protein Yield Calculation
  Annual milk protein: 32 kg × 305 days × 0.034 = 331.8 kg
  Lifetime milk protein: 331.8 kg × 3 years = 995.5 kg

Additional protein sources:
    Culled dairy cow: 64 kg [60].
    Male calves as veal: 24 kg total
    Excess female calves: 4.8 kg
    Total protein: 1,088.3 kg
Lives Required
    Primary dairy cow: 1 (cognitively complex life)
    Male calves: 1.5 (cognitively complex lives)
    Excess female calves: 0.3 (cognitively complex lives)

Total: 2.8 cognitively complex lives
Protein yield per life = 1,088,300g / 2.8 = 388,679g per life

Appendix A.1.2. Beef Cattle
Production Parameters
    Harvest weight: 635 kg [57].
    Dressing percentage: 63% [61].
    Edible meat percentage: 70% [62].
    Protein content: 26% [25].

    Total protein = 635 × 0.63 × 0.70 × 0.26 = 72.8 kg
    Protein yield per life = 72,800g per cognitively complex life

Confidence Interval Analysis
    Harvest weight: Normal distribution around 635 kg (±20 kg SD)
    Dressing percentage: Normal distribution around 0.63 (±0.02 SD)
    Edible meat percentage: Normal distribution around 0.70 (±0.02 SD)
    Protein content: Normal distribution around 0.26 (±0.02 SD)
    Mean protein yield: 72,800g
    95% Confidence Interval: [65,000g, 80,600g]
    Standard deviation: ~4,500g

Appendix A.1.3. Pork
Production Parameters
    Market weight: 125 kg [57].
    Dressing percentage: 75% [63].
    Edible meat percentage: 75% [64].
    Protein content: 27% [25].
Welfare indicators monitored [38]:
    Environmental enrichment access
    Social grouping opportunities
    Behavioral expression
Calculation
    Total protein = 125 × 0.75 × 0.75 × 0.27 = 19.0 kg
    Feed is primarily plant-based with no pain-capable lives required.

    Protein yield per life = 19,000g per cognitively complex life.

Appendix A.1.4. Chickens (Broilers)

Production Parameters

- Market weight: 2.8 kg [57].
- Dressing percentage: 75% [65].
- Edible meat percentage: 75% [66].
- Protein content: 31% [25].

Welfare considerations [67]:

- Growth rate stress
- Leg health
- Environmental conditions

Calculation

- Total protein = 2.8 × 0.75 × 0.75 × 0.31 = 0.488 kg
- Feed is plant-based with no pain-capable lives required.
- Protein yield per life = 488g per cognitively complex life.

Appendix A.1.5. Egg Production

Production Parameters

- Annual egg production: 280 eggs [57].
- Productive life: 1.5 years [68].
- Total eggs: 420
- Protein per egg: 6.28g [69].

Welfare indicators [70]:

- Nesting behavior
- Perching access
- Dust bathing opportunities

Calculation

- Total protein = 420 × 6.28 = 2,638g
- Accounting for culled male chicks [41].
- Protein yield per life = 2,638g / 2 = 1,319g per cognitively complex life.

Appendix A.2. Aquaculture Systems

Appendix A.2.1. Farmed Salmon

Production Parameters

- Harvest weight: 4.5 kg
- Feed conversion ratio: 1.3 [35]

Feed composition:

- 20% fishmeal
- 12% fish oil [36]

Feed fish requirements:

- 4.5 kg small fish per kg fishmeal
- 20 kg small fish per kg fish oil

Average feed fish weight: 0.03 kg [32]

System effects [39]:

- Direct reduction in wild feed fish populations
- No compensatory ecosystem effects

Calculation

Feed fish lives: ~468 pain-capable lives
Protein yield:
Edible percentage: 65% [71]
Protein content: 22% [25]
Total protein = 4.5 × 0.65 × 0.22 = 0.644 kg
Protein yield per salmon = 644g / 469 = 1.37g per pain-capable life

Appendix A.2.2. Farmed Tilapia

Production Parameters
Harvest weight: 0.7 kg [72]
Feed conversion ratio: 1.6 [73]
Feed composition:
2% fishmeal
1% fish oil [35]
Edible percentage: 60% [74]
Protein content: 20% [25]

Calculation
Feed fish lives: ~7 pain-capable lives.
Total protein = 0.7 × 0.60 × 0.20 = 0.084 kg
Protein yield per life = 84g / 8 = 10.5g per pain-capable life.

Appendix A.3. Marine Systems and Trophic Cascades

Appendix A.3.1. Wild Apex Predators (e.g., Bluefin Tuna)

Analysis of wild-caught apex predators requires consideration of trophic cascade effects. Using bluefin tuna as an example:

Direct Production Parameters
Harvest weight: 180 kg [75]
Dressing percentage: 80% [76]
Edible percentage: 70% [32]
Protein content: 23% [25]
Total protein = 180 × 0.80 × 0.70 × 0.23 = 23.2 kg

Ecosystem Effects (Based on [6, 37])
5% sustainable harvest rate of adult population
40-50% reduction in apex predator population
20-30% increase in prey fish population
Net increase in total pain-capable lives

Rather than counting prey fish consumed (traditional approach), my analysis considers the net ecosystem effect of removing apex predators. Evidence suggests that sustainable harvest of apex predators like tuna results in increased abundance of prey species through reduced predation pressure, leading to a net increase in total pain-capable lives in the system.

Appendix A.3.2. Ocean Small Fish (e.g., Wild Herring)

Production Parameters
Harvest weight: 0.15 kg [75]
Primary food source: zooplankton [77]

Edible percentage: 65% [32]
Protein content: 18% [25]

Calculation

Total protein = 0.15 × 0.65 × 0.18 = 0.018 kg
No cognitive complex or pain-capable prey (zooplankton not counted).
Protein yield per life = 18g per pain-capable life.

Appendix A.3.3. Ocean Trawl (wild shrimp and prawns)

Production parameters

Target species: Northern white shrimp Litopenaeus setiferus (representative of Gulf of Mexico and North-Atlantic cold-water trawl fleets).
Mean landed weight 0.026 kg per individual [75]
Edible (tail-meat) fraction 0.60 [78]
Protein content of tail meat 26 % of wet weight [79]
By-catch ratio approximately 4:1 (non-target fish and invertebrates to shrimp by mass) for typical otter-trawl operations [80]

Calculation

Edible protein per shrimp
0.026 kg landed × 0.60 × 0.26 = 0.00406 kg
1 pain-capable life ended.

Appendix A.3.4. Lobster

Production Parameters

Harvest weight: 0.55 kg [81]
Years to harvest size: 7 [82]
Primary diet: mollusks, crustaceans, fish carrion; about 50% is pain-capable (mostly rock crab). [83]
Edible percentage: 30% [84]
Protein content: 21% [25]

Calculation

Total protein = 0.55 × 0.30 × 0.21 = 0.035 kg
Prey lives over 7 years:
Pain-capable lives: ~30 (rock crab) prey plus the lobster.
Protein yield per life = 35g / 31 = 1.129 g per pain-capable life.

Appendix A.3.5. Cephalopods (e.g., Octopi, Squid, Cuttlefish)

Mature Octopus Parameters

Harvest weight: 3.0 kg
Edible percentage: 80%
Protein content: 15%
Prey consumption (per [10]):
Daily: 3 crustaceans (pain capable), 2 bivalve mollusks (not pain capable)
Annual: ~1,095 pain-capable lives

Calculation

Total protein = 3.0 × 0.80 × 0.15 = 0.360 kg
Total lives: 1 cognitively complex life + 1,095 pain-capable lives.
Protein yield = 360g per cognitively complex life; 0.3285 g per total lives.

Juvenile Octopus Parameters

Harvest weight: 0.015 kg
Edible percentage: 90%
Protein content: 15%
Pre-harvest survival rate: 0.1% [85].
Prey consumption: ~180 small crustaceans

Calculation

Total protein = 0.015 × 0.90 × 0.15 = 0.002 kg
Total lives: 1 cognitively complex life + 180 pain-capable lives.
Protein yield = 2g per cognitively complex life; 0.011g per total lives.

Appendix A.3.6. Squid

Production Parameters

Harvest weight: 0.5 kg
Growth period: 0.5 years
Daily prey consumption: 8 small fish/crustaceans
Edible percentage: 75%
Protein content: 18%

Calculation

Total protein = 0.5 × 0.75 × 0.18 = 0.0675 kg
Lives involved:
1 cognitively complex life (squid)
1,460 pain-capable prey lives Total lives: 1,461
Protein yield = 67.5g per cognitively complex life; 0.046g per total lives.

Appendix B Greenhouse-Gas (GHG) Intensity Dataset and Methods

B.1 Data sources and functional unit

Terrestrial livestock medians and 10th–90th percentile bounds are taken from the harmonised meta-analysis of Poore and Nemecek [30].

Aquatic medians are from the Blue Food Assessment life-cycle synthesis [31].

Wild-capture fisheries percentiles are derived from fleet-level fuel-use intensities reported by [32].

All values include land-use-change where applicable and are normalised to a cradle-to-farm-gate functional unit of kg CO_2-eq per kg edible protein.

B.2 Assignment of System Medians

Where multiple production technologies exist within a species the production-weighted median is used (see Section 3.2 of the main text). Small pelagic fisheries use a median diesel intensity of 0.9 L kg^{-1} catch.

B.3 Propagation of Uncertainty

The 10th and 90th percentiles are carried through all graphical outputs as vertical error bars. These bounds represent producer heterogeneity rather than statistical sampling error.

Table B1. Median and percentile GHG intensities (kg CO_2-eq kg^{-1} protein).

Production system	Life class	10th	Median	90th
Dairy (milk)	complex	30	52	90
Beef (beef-herd)	complex	120	200	450
Pork	complex	30	46	80
Eggs	complex	20	26	55
Chicken meat	complex	15	24	45
Wild tuna	pain-capable	8	15	25
Mature octopus	complex	12	30	80
Squid	complex	10	20	35
Wild herring	pain-capable	5	8	15
Farmed tilapia	pain-capable	12	28	45
Crustacean trawl (shrimp)	pain-capable	25	55	150
Farmed salmon	pain-capable	10	20	35
Juvenile octopus	complex	12	30	80

Note. Protein-per-life values reproduced from Table 1 of the main text. Two significant figures throughout.

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