



THE ECONOMIC VALUE OF A

RESCUED FEMALE HUMPBACK WHALE

A Comprehensive Valuation Report by StrandedNoMore

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Based on peer-reviewed research by Roman et al. (2016), Smith et al. (2013),
Chami et al. (2022), Pershing et al. (2010), and Lavery et al. (2010, 2014)

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Executive Summary

This report estimates the total economic value of a single live-stranded female humpback whale (*Megaptera novaeangliae*) that is successfully rescued and lives to 70 years old. The valuation draws on peer-reviewed research to quantify four distinct categories of market-valued ecosystem services: carbon sequestration in whale biomass, phytoplankton carbon capture enhancement (the whale pump), fisheries enhancement, and ecotourism revenue generation.

The analysis is conducted at two carbon price points: the EU Emissions Trading System (ETS) market price of approximately \$25 per tonne of CO₂, and the social cost of carbon (SCC) of \$500 per tonne. The social cost of carbon represents the true economic damage caused by each additional tonne of CO₂ emitted into the atmosphere, including healthcare costs, crop losses, infrastructure damage, and ecosystem degradation.

At market carbon prices, the rescued female humpback is valued at approximately \$5.2 million over her lifetime, with the majority of this value attributable to her reproductive capacity. At the social cost of carbon, the same whale is worth in excess of \$100 million, reflecting the enormous climate services she and her descendants provide.

Service Category	Market Price (\$25/t)	Social Cost (\$500/t)
Carbon in whale body	\$497	\$10,055
Phytoplankton carbon capture (70 yr)	\$413,438	\$8,362,975
Fisheries enhancement (70 yr)	\$67,800	\$67,800
Ecotourism revenue (70 yr)	\$90,413	\$90,413
Direct services subtotal	\$572,148	\$8,531,243
Reproductive value (~16 calves)	\$4,605,000	\$68,600,000
TOTAL ESTIMATED VALUE	\$5,177,148	\$77,131,243+

Note: The social cost figures above are conservative. Including grandcalf generations pushes the total well above \$100 million at social cost of carbon prices.

1. Background and Methodology

1.1 The Whale Pump: How Whales Drive Ocean Productivity

Whales are increasingly recognized as powerful ecosystem engineers. Through their normal feeding and resting behavior, whales transport nutrients vertically through the water column in a mechanism known as the "whale pump" (Roman & McCarthy, 2010). Whales dive to depth to feed on krill and copepods, then return to the surface to breathe and defecate. Their fecal plumes, rich in nitrogen, phosphorus, and iron, are released in the photic zone where sunlight enables phytoplankton to use these nutrients for photosynthesis.

Roman et al. (2016) documented this process in North Atlantic right whales in the Bay of Fundy, finding that ammonium and phosphate concentrations in whale fecal material were orders of magnitude higher than typical coastal water values. Their experiments demonstrated that nutrients from whale feces directly stimulated phytoplankton growth, approximately doubling chlorophyll-a concentrations in enrichment experiments.

Smith et al. (2013) extended these findings by demonstrating that pygmy blue whale feces stimulated the photosynthetic performance and growth of three marine phytoplankton species in a dose-dependent manner. This was the first study to show that faecal nutrients deposited by baleen whales in the photic zone are bioavailable and will directly stimulate phytoplankton growth.

In addition to the vertical whale pump, whales also transport nutrients horizontally through the "whale conveyor" (Roman et al., 2014), migrating from nutrient-rich high-latitude feeding areas to nutrient-poor low-latitude calving areas, redistributing nitrogen and other limiting nutrients across ocean basins.

1.2 Valuation Framework

This report follows the market-based valuation framework developed by Chami et al. (2022) at the International Monetary Fund, which treats individual natural resources as capital assets that produce streams of ecosystem services with market-assignable values. The value of the asset is calculated as the discounted present value of all future service flows over the organism's expected lifetime.

A 2% real discount rate is used throughout, consistent with Chami et al.'s analysis showing that the price of carbon is not significantly correlated with other asset returns, making the long-term risk-free rate the appropriate discount rate.

1.3 Market Price vs. Social Cost of Carbon

This report presents all carbon-related calculations at two price points:

- **EU ETS Market Price (~\$25/tonne CO₂):** This is the price companies currently pay for emission permits in the EU's cap-and-trade system. It reflects regulatory supply and demand for permits, not the actual damage caused by emissions.

- **Social Cost of Carbon (~\$500/tonne CO₂):** This represents the total economic damage caused by each additional tonne of CO₂ emitted, including healthcare costs from heat-related illness and air pollution, agricultural losses from drought and flooding, property damage from sea-level rise and extreme weather, lost labor productivity, increased mortality, and ecosystem degradation. Peer-reviewed estimates (e.g., Rennert et al., 2022 in Nature) place the SCC at \$185/tonne or higher; estimates incorporating worst-case scenarios and intergenerational equity range from \$400–\$600/tonne. This report uses \$500/tonne as a representative high-end estimate.

The gap between the market price and the social cost represents the extent to which current carbon pricing fails to account for the true damage of emissions. This gap is the central argument for treating whales as enormously valuable climate assets.

2. Species Parameters

The following biological and physical parameters for the humpback whale are drawn from Chami et al. (2022), Pershing et al. (2010), Smith et al. (2019), and Taylor et al. (2007):

Parameter	Value
Average body mass	~33 tonnes (adult)
Carbon content of body	5.4842 tonnes C
CO ₂ equivalent (C × 11/3)	20.11 tonnes CO ₂
Age at first reproduction (AFR)	6 years
Oldest reproducing age	55 years
Interbirth interval (IBI)	2.36 years
Calf survival rate (S ₀)	0.76
Adult survival rate (S _a)	0.96
Expected lifespan (rescued scenario)	70 years
Discount rate	2% (real, risk-free)
EU ETS carbon price	\$24.72/tonne CO ₂
Social cost of carbon	\$500/tonne CO ₂

3. Service 1: Carbon Sequestered in Whale Biomass

Whales are among the largest animals on Earth, and their bodies contain substantial amounts of carbon. When a whale dies naturally and its carcass sinks to the ocean floor (a "whale fall"), this carbon is effectively sequestered for centuries to millennia in deep ocean sediments.

A living whale maintains this carbon stock throughout its lifetime, preventing it from entering the atmosphere. A stable or growing population of whales therefore represents a standing stock of sequestered carbon.

3.1 Calculation

Carbon on body: 5.4842 tonnes C (from Pershing et al., 2010 / Chami et al., 2022)

CO₂ equivalent: $5.4842 \times 11/3 = 20.11$ tonnes CO₂

Metric	Market (\$25/t)	Social (\$500/t)
Value of carbon on body (living stock)	\$497	\$10,055
Value of whale fall sequestration	Included above	Included above

While this is the smallest individual service category, it represents permanently sequestered carbon that would otherwise have entered the atmosphere through decomposition at the surface. At the social cost of carbon, even this single service exceeds \$10,000 per whale.

4. Service 2: Phytoplankton Carbon Capture Enhancement

This is by far the most valuable ecosystem service provided by a living whale. Through the whale pump (vertical nutrient transport via fecal plumes) and the whale conveyor (horizontal nutrient transport via migration), whales fertilize phytoplankton across vast ocean areas. Phytoplankton are responsible for capturing approximately 37 billion tonnes of CO₂ annually, equivalent to the carbon capture of 1.7 trillion trees, or roughly four Amazon rainforests.

4.1 Scientific Evidence

Roman et al. (2016) found that North Atlantic right whale fecal material contained ammonium and phosphate concentrations orders of magnitude higher than typical coastal waters. At least 10% of particulate nitrogen in whale feces became available as ammonium within 24 hours, and phytoplankton growth experiments confirmed that these nutrients directly enhanced productivity.

Smith et al. (2013) demonstrated dose-dependent stimulation of photosynthesis and growth in three phytoplankton species exposed to pygmy blue whale feces, with clear increases in quantum yield, electron transport rate, chlorophyll-a, and cell counts within 7 days. Whale feces contained iron at concentrations approximately ten million times that of Southern Ocean surface water.

Lavery et al. (2014) estimated that restoring blue whales to pre-whaling levels in the Southern Ocean would increase primary production by 0.23%. Ratnarajah et al. (2016) estimated that three whale species returning to pre-whaling populations would increase Southern Ocean primary production by nearly 1%.

4.2 Calculation

Following Chami et al. (2022), we attribute 1% of global phytoplankton carbon capture to the current global whale population. This is conservative given the evidence summarized above.

Global phytoplankton CO₂ capture: 37 billion tonnes/year

1% attributable to whales: 370 million tonnes CO₂/year

Total global whale biomass (carbon): ~4,550,000 tonnes

One humpback's biomass share: $5.4842 / 4,550,000 = 0.000001205$ (0.00012%)

Annual CO₂ capture per humpback: $370,000,000 \times 0.000001205 = 446$ tonnes CO₂/year

Present value annuity factor (70 years, 2%): 37.5 (approximately)

Metric	Market (\$25/t)	Social (\$500/t)
Annual phytoplankton CO ₂ capture	446 tonnes	446 tonnes
Annual value of capture	\$11,025	\$223,000
Present value over 70 years	\$413,438	\$8,362,975

At the social cost of carbon, a single humpback whale provides more than \$8.3 million in phytoplankton-mediated carbon capture over her lifetime. This makes the whale pump the dominant source of whale economic value and demonstrates that a living whale is, in effect, a self-sustaining ocean carbon capture system.

5. Service 3: Fisheries Enhancement

The phytoplankton stimulated by whale activity forms the base of the marine food chain. Increased primary production cascades upward through zooplankton, forage fish, and commercially harvested species. Chami et al. (2022) attribute 1% of global commercial fishing revenues to whale-driven productivity enhancement.

5.1 Calculation

Global commercial fishing revenue (FAO, 2020): \$150 billion/year

1% attributable to whales: \$1.5 billion/year

Per humpback (biomass share): $\$1,500,000,000 \times 0.000001205 = \$1,808/\text{year}$

Present value over 70 years at 2%: \$67,800

Note: This value does not change with carbon pricing, as it is based on fisheries revenue rather than carbon value. However, the underlying mechanism (whale-driven phytoplankton production) is the same.

6. Service 4: Ecotourism Revenue

Whale watching is a significant and growing global industry. The International Fund for Animal Welfare estimated global whale-watching expenditures at \$2.1 billion in 2008, and Cisneros-Montemayor et al. (2010) estimated the industry could generate up to \$2.5 billion if fully developed worldwide.

6.1 Calculation

Current global whale-watching revenue: \$2.0 billion/year

Per humpback (biomass share): $\$2,000,000,000 \times 0.000001205 = \$2,411/\text{year}$

Present value over 70 years at 2%: \$90,413

Humpback whales are among the most popular species for whale watching due to their acrobatic breaching behavior, coastal migration patterns, and approachability. The per-whale ecotourism value for humpbacks is therefore likely higher than the biomass-weighted average used here.

7. Reproductive Value: The Female Premium

The value calculations above quantify only the direct ecosystem services provided by a single individual whale. A rescued female whale, however, provides an additional and enormous source of value through her reproductive capacity. Each surviving calf becomes an independent carbon-capturing, nutrient-cycling, fishery-enhancing asset for decades.

7.1 Reproductive Output

Reproductive years: Age 6 to age 55 = 49 years

Calves produced: $49 / 2.36$ (IBI) = 20.8 calves

Surviving calves: 20.8×0.76 (calf survival) = 15.8 calves

Each surviving calf will provide approximately the same direct lifetime ecosystem services as the mother (roughly \$572,000 at market carbon prices or \$8.5 million at social cost). However, calves are born over a spread of years, so their service flows must be discounted from their respective birth years.

7.2 Calculation

The average birth year across the reproductive span is approximately year 30 of the mother's life. Applying the discount factor at 2% for 30 years (0.55), the reproductive value is estimated as:

Metric	Market (\$25/t)	Social (\$500/t)
Surviving calves	15.8	15.8
Per-calf direct service value	\$572,148	\$8,531,243
Average discount factor	0.55	0.55
Total reproductive value	~\$4,605,000	~\$68,600,000

This is a conservative estimate because it counts only the first generation of calves. Approximately half of these calves will be female, and each of those females will produce her own calves, generating a compounding chain of ecosystem services. Including even one additional generation would substantially increase the total value.

8. Total Estimated Value

Combining all four categories of direct ecosystem services with the reproductive value of a female yields the following total valuation:

Service Category	Market Price (\$25/t)	Social Cost (\$500/t)
1. Carbon in whale body	\$497	\$10,055
2. Phytoplankton carbon capture (70 yr)	\$413,438	\$8,362,975
3. Fisheries enhancement (70 yr)	\$67,800	\$67,800
4. Ecotourism revenue (70 yr)	\$90,413	\$90,413
Direct services subtotal	\$572,148	\$8,531,243
5. Reproductive value (first generation)	\$4,605,000	\$68,600,000
TOTAL VALUE (one rescued female)	\$5,177,148	\$77,131,243

8.1 The Social Cost Perspective

The difference between the market price column and the social cost column represents the climate damage that current carbon pricing fails to capture. At the social cost of carbon, the phytoplankton fertilization service alone makes a single humpback whale worth over \$8 million, and her reproductive value pushes the total past \$77 million.

Including second-generation calves (grandcalves of the rescued female) would add approximately \$30–40 million at social cost, pushing the total value well above \$100 million. This reflects the self-replicating nature of the whale as a carbon capture system: she does not merely sequester carbon on her body, but actively creates new carbon-capturing organisms (both phytoplankton and calves) throughout her life.

Put differently, a rescued female humpback whale is a living, self-replicating, solar-powered carbon capture machine that fertilizes the ocean, feeds the food chain, generates tourism revenue, and produces approximately 16 copies of herself over her lifetime, each of which provides the same services for decades.

8.2 What the Social Cost of Carbon Means in Practice

The social cost of carbon is not hypothetical. It represents real economic damages: hospital admissions from heat waves, crop failures from drought, homes destroyed by stronger storms, coastal infrastructure submerged by rising seas, and lives lost to climate-related disasters. When a whale is allowed to die that could have been saved, the 446 tonnes of CO₂ that she would have helped capture each year remain in the atmosphere. At \$500 per tonne, that represents \$223,000 per year in real-world climate damage that society will bear.

Over 70 years, that cumulative damage from one lost whale exceeds \$8 million. Factor in her lost calves, and the damage from failing to rescue a single female humpback whale approaches or exceeds \$100 million in climate costs that will be borne by future generations.

9. Context and Implications

9.1 Comparison with Carbon Removal Technology

Current direct air capture (DAC) technology costs approximately \$250–\$600 per tonne of CO₂ removed. A single humpback whale facilitates the capture of 446 tonnes of CO₂ per year through phytoplankton fertilization at zero operating cost. The equivalent annual DAC cost to replicate this single whale's contribution would be \$111,500–\$267,600 per year, or \$4.2–\$10.0 million over her lifetime. A whale does this for free, while simultaneously enhancing fisheries, supporting tourism, and producing offspring.

9.2 Implications for Rescue and Conservation Policy

The cost of a whale stranding rescue operation typically ranges from \$10,000 to \$100,000, depending on the species, location, and complexity. Even at the conservative market carbon price, the value of a successfully rescued female humpback (\$5.2 million) exceeds the rescue cost by a factor of 50 to 500. At the social cost of carbon, the return on investment exceeds 1,000 to 1.

This analysis provides a strong economic case for investing in whale rescue infrastructure, training, and rapid-response capacity. Every successfully rescued female humpback represents millions of dollars in ecosystem services that would otherwise be lost.

9.3 Implications for Ship Strike Prevention

Chami et al. (2022) argue that fines for ship strikes that kill whales should be calibrated to the full economic value of the animal. A ship that strikes and kills a female humpback destroys an asset worth \$5–\$77 million or more. Current penalties are typically a fraction of this amount, creating insufficient incentive for shipping companies to invest in avoidance measures such as speed reductions and route modifications.

10. Sources and References

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