The Global Value of Freshwater Lakes

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October 19, 2023

Abstract

Lakes face threats from human activities like unsustainable development, population growth, and industrial technologies. These challenges impact the ecosystem services of lakes. Research has assessed the value of services from freshwater biomes annually. This article reviews these values, estimating lakes' global ecosystem services to be within the region of USD 1.5 to 5.5 trillion annually. Their natural asset value is estimated at USD 100 - 337 trillion, comparable to value of global real estate, assuming a relatively high social discount rate to account for future increased standard of livings. Considering environmental degradation, future generations may experience a lower living standard. Using a 0.1% discount rate, recognizing potential harm and aligning with indigenous values, raises the lakes' value to USD 1,500 - 5,500 trillion which is at least equal to the global value of wealth created. This valuation is shared by all, unlike the skewed distribution of created wealth.

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Authorship statement: Both authors agree to submit the manuscript to Ecology Letters. Both authors carry the responsibility for the accuracy, integrity and ethics of the manuscript and works described therein. Both authors made substantial intellectual contributions to a manuscript. The lead author, Mr. Xingming Li, is a graduate student and an early career researcher under Dr. Tsigaris' project supervision.

Data accessibility statement: Data used are available from the public domain at https://www.esvd.net/login/esvd

Short running title: The Global value of Freshwater Lakes

Keywords: Ecosystem services, Intergenerational Wealth, Discounting, Value of Nature

Type of article: Viewpoint

# of words in the abstract: 224 words

# of words in the main text: 1685 words

# of cited references: 31

# of tables and figures: None

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Lakes face threats from human activities like unsustainable development, population growth, and industrial technologies. These challenges impact the ecosystem services of lakes. Research has assessed the value of services from freshwater biomes annually. This article reviews these values, estimating lakes' global ecosystem services to be within the region of USD 1.5 to 5.5 trillion annually. Their natural asset value is estimated at USD 100 - 337 trillion, comparable to value of global real estate, assuming a relatively high social discount rate to account for future increased standard of livings. Considering environmental degradation, future generations may experience a lower living standard. Using a 0.1% discount rate, recognizing potential harm and aligning with indigenous values, raises the lakes' value to USD 1,500 - 5,500 trillion which is at least equal to the global value of wealth created. This valuation is shared by all, unlike the skewed distribution of created wealth.

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Introduction

Lakes face significant challenges and threats from the Anthropocene era (Heino et al., 2021). Homo sapiens have had an overwhelming impact on the planet's marine and terrestrial biomes through rapid, unsustainable economic development, population growth, and technology invented and used during the industrial revolution (Folke et al., 2021; Steffen et al., 2011). Lakes are no exemption from such human stressors and have been affected by ecological disruptions such as biodiversity and ecosystem services degradation (Mueller et al. 2016; Heino et al., 2021). Climate change leads to acidification and eutrophication of water, foreign marine species invade freshwater lakes, and humans alter the morphology and reduce water levels. These profound re-configurations negatively impact the functioning of the lakes' systems (Albert et al., 2021; Birk et al., 2020; Dudgeon, 2019; Smol, 2019). Lakes provide numerous ecosystem services to humans directly through provisioning (e.g., water supply, fish catch), indirectly through cultural services (e.g. recreation, spiritual, aesthetic appreciation), and through regulating and maintenance services (e.g., water purification by removing excess nitrogen by microorganisms, maintaining humidity patterns for climate equilibrium, habitats for marine life). Most of the ecosystem services lakes provide are not directly traded on the market to estimate their scarcity through the price system, so assessing them poses difficulties (Reynaud & Lanzanova, 2017). As a result, valuation methods have been developed to value these services to assist policy-makers in addressing biodiversity and ecosystem degradation losses as markets fail to value these services and regulate their over-consumption.

Given the importance of measuring the value of all our assets, be they physical, monetary, or those that nature provides, valuation methods have been developed to support the conservation of nature, ecosystem restoration, and sustainable land management decisions. A common method to assess the value of large-scale ecosystem services such as the world's ecosystem services of biomes is the benefit transfer method (Johnston and Rosenberger, 2010). The valuation of large-scale ecosystem services of biomes (e.g., lakes and rivers, open sea, wetlands, grasslands, etc.) cannot rely on a few studies or other non-market valuation methods, making the BTM applicable. To value the ecosystem services of the world's lakes, an average estimate of the price per hectare (ha) per year is transferred from assessing values from numerous studies and multiplying the price by the area represented by the number of ha (Costanza et al., 2014).

There are already a number of studies that attempt to assess the value of lakes globally. A global meta-analysis of the value of ecosystem services lakes provide was based on a worldwide dataset from 133 studies with 699 observations (Raynaud and Lanzanova, 2017). The study estimated a value transfer function that depends on geospatial and ecosystem services with interactions. Raynaud and Lanzanova (2017) estimated the average value of ecosystem services at US$140 in 2010 prices per person per year, 95% CI [$121, $160], for stated preference studies, and US$403 per property per year, 95% CI [$228, $578], using studies that were based on the hedonic pricing model. Another assessment based on price per hectare per year is from Costanza et al. (2014). In an earlier study, Costanza et al. (1997) estimated the value of rivers and lakes at $14,786 per ha per year, while in an updated study Costanza et al. (2014) estimated $15,517/ha/year (in 2020US$), a 5% increase from the last time. The 2023 ecosystem services valuation database (Brander et al. 2023) reports 345 values for freshwater lakes across the world from various studies with an estimated average value of USD $16,456/ha/year which is within the same range estimated by Costanza et al. (2014).

The value to the value of ecosystem services per year

Costanza et al. (2014) estimated the area size of ecosystem services of both rivers and lakes at 200 million ha using the GlobCover data from the European Space Agency and the United Nations Food and Agriculture Organization. This would yield $3.1 trillion per year of ecosystem services. However, recent studies show that freshwater lakes occupy a much larger space. In terms of the surface area of lakes globally, six studies since 2014 including smaller lakes greater than or equal to one ha, range from 300 million to 500 million ha with a mean of 356 million ha (Messager et al., 2016; Verpoorter et al., 2014). Verpoorter et al. (2014) provided the highest valuation at 476 million ha but including lakes with surface areas greater than 0.2 ha, which translates to 500 million hectares, 3.7% of Earth's non-glaciated land surface (Verpoorter et al., 2014). Using the price of $15,517/ha/year from Costanza et al. (2014) in 2020US$s and 356 million ha of freshwater lake surface the value of ecosystem services lakes provides increases to $5.5 trillion per year. With a world population of 8 billion people, this yields approximately $690 per person per year of ecosystem benefits from the world lakes biome.

Using the prices found in the Raynaud and Lanzanova, (2017) study and after converting these to 2020 using the CPI index of 1.38 and a world population of 8 billion, the value of ecosystem services is USD 1.5 trillion. Using the revealed preference estimation from the meta-analysis and using as an estimated 2.3 billion properties worldwide the valuation is USD 1.3 trillion (Architecture news, 2021). These are the annual flows, but what is the value of these flows today? The valuation of the natural asset is answered in the next section.

The value of lakes worldwide as a natural asset

Ecosystem services of lakes occur every year as a flow and continue in perpetuity. Hence, to find the value of the lakes today, we need to discount future $ benefits of ecosystem services to the present. Discounting these benefits that accrue to current and future generations can be controversial and may even conflict with Indigenous values (Ebel and Rinke, 2014). Famous economists and philosophers have puzzled and debated over this issue. A conventional discount rate that has been used for discounting future ecosystem services is 3.5% per year for industrial nations and higher for developing nations (Boardman et al., 2010; Haacker et al., 2020). We discount the future from a social perspective for a few reasons. First, we are impatient and prefer consumption today to tomorrow. Second, there is a very small likelihood of a catastrophic event happening, destroying the planet and wiping out civilization. Third, we discount due to intragenerational equity between the current and future generations. Future generations could be richer (or poorer) than the current generation; hence, a $ of benefit to them is not worth the same as a $ to the current generation from the perspective of the current generation. Although discounting usually reduces the future benefits perceived today, the value of benefits is not constant over time but could increase, offsetting the impact of discounting. The value of ecosystem services lakes provide will increase over time if the standard of living increases as demand for such services increases. It is reasonable to assume that the value of yearly services of lakes grows around two percent per year, an average growth rate of the world's standard of living as measured by the growth rate of GDP per capita worldwide over the long run. Using the estimated values of USD 1.5 - 5.5 trillion per year, the value of all lakes worldwide is USD 100-337 trillion (e.g., $5.5/(.035-.02)). These values are comparable to the value of real estate worldwide. The value of residential real estate worldwide is estimated at USD 258.5 trillion, and all real estate at USD 326.5 trillion (Tostevin, 2021). Also, a recent study by Chambers et al. (2021) shows that the implied annualized real total return, net of costs, is 2.3% for residential houses, which translates to an annual service value from houses at $5.9 trillion annually. Thus, lakes provide services to the world that are compatible with the services houses provide worldwide.

It is important to note that a social discount rate of 3.5% assumes that future generations will be richer than the current generation. This may not be true given the significant environmental and ecological damage the Industrial Revolution is causing to the planet (Fleurbaey and Zuber,2012; Kubiszewski et al., 2013 Weitzman, 2011, Ebel and Rinke, 2014). It could be the case that future generations may be worse or equally well off than the current generation (Ebel and Rinke, 2014, Grigoroudis et al. 2021). If there is no long-run economic growth, then the appropriate social discount rate is much lower than 3.5% and determined only by the social rate of time preference (i.e., social impatience). Discounting based on impatience for intergenerational distribution of public projects and assessing the value of natural assets is morally wrong. Not discounting for impatience is also in line with most famous economists who stated the following: Ramsey (1928. p.543) is "ethically indefensible and [arising] merely from the weakness of the imagination." Pigou (1920, pp 24-25) referred to it as implying that "our telescopic faculty is defective." Harrod (1948, pp 37-40) described it as a "human infirmity" and "a polite expression for rapacity and the conquest of reason by passion." Solow (1974, p.9) wrote "we ought to act as if the social rate of time preference were zero (though we would simultaneously discount future consumption if we expected the future to be richer than the present)." Nicholas Stern (2008), on the Economics of Climate Change, used a 0.1% rate for the social rate of time preference in case a catastrophic event happens over the next 1,000 years, resulting in humanity becoming extinct. Hence, using a 0.1% discount rate, the value of lakes ranges from USD 1,500 - 5,500 trillion. This value is at least equal to the value of all assets created for wealth at USD 1,540 trillion from the global balance sheet (Woetzel et al, 2021). Of important notice is that the value of assets created for wealth accumulation is very unevenly distributed amongst us, but everyone has an equal share of the value of lakes, which amounts to $187,500 - $687,500 for each one of us humans. We are all rich when measured by our natural assets, but many are poor when measured against assets created for monetary wealth.

References

Albert, J. S., Destouni, G., Duke-Sylvester, S. M., Magurran, A. E., Oberdorff, T., Reis, R. E., Winemiller, K. O., & Ripple, W. J. (2021). Scientists' warning to humanity on the freshwater biodiversity crisis. *Ambio*, 50 (1), 85–94. https://doi.org/10.1007/s13280-020-01318-8

Architecture news & editorial desk, How many houses are in the world, *Architecture and design*, September 2021, Retrieved from https://www.architectureanddesign.com.au/features/list/how-many-houses-are-in-the-world

Birk, S., Chapman, D., Carvalho, L., Spears, B. M., Andersen, H. E., Argillier, C., Auer, S., Baattrup-Pedersen, A., Banin, L., Beklio˘glu, M., et al. (2020). Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. *Nature Ecology & Evolution*, 4 (8), 1060–1068. https://doi.org/10.1038/s41559-020-1216-4

Boardman, A., Moore, M., & Vining, A. (2010). The Social Discount Rate for Canada Based on Future Growth in Consumption. Canadian Public Policy / Analyse de Politiques, 36(3), 325–343. Retrieved October 14, 2023, from https://www.jstor.org/stable/20799660.

Brander, L.M., de Groot, R., Guisado Goñi, V., van 't Hoff, V., Schägner, P., Solomonides, S., McVittie, A., Eppink, F., Sposato, M., Do, L., Ghermandi, A., and Sinclair, M., Thomas, R., (2023). Ecosystem Services Valuation Database (ESVD). Foundation for Sustainable Development and Brander Environmental Economics. Accessed on October 14, 2023 from https://www.esvd.net/

Chambers, D, Spaenjers, C, Steiner, E, 2021, The Rate of Return on Real Estate: Long-Run Micro-Level Evidence, *The Review of Financial Studies*, Volume 34, Issue 8, 3572–3607, https://doi.org/10.1093/rfs/hhab028

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Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R. V., Paruelo, J., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387 (6630), 253–260. https://doi.org/10.1038/387253a0

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Dudgeon, D. (2019). Multiple threats imperil freshwater biodiversity in the anthropocene. *Current Biology*, 29 (19), R960–R967.

Ebel, A., Rinke, T. (2014). Listening to the Voices of Young and Future Generations. In: State of the World 2014. State of the World. Island Press, Washington, DC. https://doi.org/10.5822/978-1-61091-542-7_8

Fleurbaey and Zuber, 2012, Climate policies deserve a negative discount rate. Chicago Journal of International Law, 13, 565.

Folke, C., Polasky, S., Rockstr¨om, J., Galaz, V., Westley, F., Lamont, M., Scheffer, M., Osterblom, H., Carpenter, S. R., Chapin, F. S., et al. (2021). Our future in the anthropocene biosphere. *Ambio*, 50, 834–869. https://doi.org/10.1007/s13280-021-01544-8

Grigoroudis, E., Kouikoglou, V. S., & Phillis, Y. A. (2021). SAFE 2019: Updates and new sustainability findings worldwide. Ecological Indicators, 121, 107072. https://doi.org/10.1016/j.ecolind.2020.107072

Haacker, M., Hallett, T. B., & Atun, R. (2020). On discount rates for economic evaluations in global health. Health policy and planning, 35(1), 107–114. https://doi.org/10.1093/heapol/czz127

Harrod, R.F. (1948), Towards a Dynamic Economy (London: McMillan).

Heino, J., Alahuhta, J., Bini, L. M., Cai, Y., Heiskanen, A.-S., Hellsten, S., Kortelainen, P., Kotam¨aki, N., Tolonen, K. T., Vihervaara, P., et al. (2021). Lakes in the era of global change: Moving beyond single-lake thinking in maintaining biodiversity and ecosystem services. Bi*ological Reviews,* 96 (1), 89–106. http://doi.org/10.1111/brv.12647

Johnston, R. J., & Rosenberger, R. S. (2010). Methods, trends, and controversies in contemporary benefit transfer. *Journal of Economic Surveys*, 24 (3), 479–510. https://doi.org/10.1111/j.1467-6419.2009.00592.x

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T., & Aylmer, C. (2013). Beyond GDP: Measuring and achieving global genuine progress. Ecological economics, 93, 57-68. https://doi.org/10.1016/j.ecolecon.2013.04.019

Mueller, H., Hamilton, D. P., & Doole, G. J. (2016). Evaluating services and damage costs of degradation of a major lake ecosystem. *Ecosystem Services,* 22, 370-380. https://doi.org/10.1016/j.ecoser.2016.02.037

Messager, M. L., Lehner, B., Grill, G., Nedeva, I., & Schmitt, O. (2016). Estimating the volume and age of water stored in global lakes using a geo-statistical approach. *Nature communications,* 7 (1), 13603. https://doi.org/10.1038/ncomms13603

Pigou, Arthur. The Economics of Welfare. Macmillan, 1920. Retrieved from https://oll.libertyfund.org/title/pigou-the-economics-of-welfare

Ramsey, F. P. (1928). A Mathematical Theory of Saving. The Economic Journal, 38(152), 543–559. https://doi.org/10.2307/2224098

Reynaud, A., & Lanzanova, D. (2017). A global meta-analysis of the value of ecosystem services provided by lakes. *Ecological Economics*, 137, 184–194. https://doi.org/10.1016/j.ecolecon.2017.03.001

Smol, J. P. (2019). Under the radar: Long-term perspectives on ecological changes in lakes. *Proceedings of the Royal Society B*, 286 (1906), 20190834. https://doi.org/10.1098/rspb.2019.0834

Solow, R. M. (1974). The Economics of Resources or the Resources of Economics. The American Economic Review, 64(2), 1–14. http://www.jstor.org/stable/1816009

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., ... & Svedin, U. (2011). The Anthropocene: From global change to planetary stewardship. Ambio, 40, 739-761. https://doi.org/10.1007/s13280-011-0185-x

Stern, N. (2008). The economics of climate change. American Economic Review, 98(2), 1-37. https://doi.org/10.1257/aer.98.2.1

Tostevin P., (September 2021), The total value of global real estate, Savills World Research, Retrieved from https://www.savills.com/impacts/market-trends/the-total-value-of-global-real-estate.html

Verpoorter, C., Kutser, T., Seekell, D. A., & Tranvik, L. J. (2014). A global inventory of lakes based on high-resolution satellite imagery. *Geophysical Research Letters*, 41(18), 6396-6402. https://doi.org/10.1002/2014GL060641

Woetzel, J, Mischke J., Madgavkar A., Windhagen E, Smit S., Birshan, Kemeny, M., Anderson, R.J., The rise and rise of the global balance sheet: How productively are we using our wealth? November 15, 2021 | Report, *McKinsey Global Institute*, Retrieved from https://www.mckinsey.com/industries/financial-services/our-insights/the-rise-and-rise-of-the-global-balance-sheet-how-productively-are-we-using-our-wealth

Weitzman, M. L. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. Review of Environmental Economics and Policy, 5(2), pp. 275–292 http://doi.org/10.1093/reep/rer006