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Updated census in the Laurentian Great Lakes Watershed: A framework for determining the relationship between the population and this aquatic resource ☆

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ABSTRACT

The Laurentian Great Lakes Watershed (LGLW) is a complex socio-ecological system that spans the United States and Canada and includes Anishinaabe Nations, the Haudenosaunee Confederacy, and Métis Nations. However, this system contains overlapping political and ecological boundaries that do not conform, obscuring a true geographic definition of the LGLW and complicating the inclusion of population data in policy and social-ecological systems research. In this Short Communication, we provide a spatial framework for assessing the LGLW population using the watershed footprint under the Great Lakes Commission's jurisdiction with international consistency to support regional science and policy, and discuss challenges in accurately assessing Indigenous areas. Using the best available sources, we estimate a population of 38,327,681 people (2015–2019) within the watershed and 133,737 residents within government-delineated Indigenous, First Nation, and Métis census areas of 2021.

Introduction

A better understanding of the sociodemographic landscape of the Laurentian Great Lakes Watershed (LGLW) allows for targeted policy to more efficiently allocate resources to enhance resilience amidst social and environmental change, all while reducing social vulnerabilities and exposure to risk. The LGLW is a complex socio-ecological system that spans the United States and Canada and includes Anishinaabe Nations, the Haudenosaunee Confederacy, and Métis Nations. Environmental governance in the region requires flexible multi-national governance structures such as the International Joint Commission, the Great Lakes Indian Fish & Wildlife Commission, and the Great Lakes Commission (GLC), to name a few. Climate change has presented a number of challenges for the region, from the more sudden impacts of storm surges and flash floods to the more gradual impacts associated with increasing temperatures (e.g., algae blooms, heat waves, wildfires). These disturbances threaten peoples' personal safety and livelihoods, along with infrastructure critical to local economies, exacerbating the ability of communities to effectively and efficiently respond to such disturbances. The region is expecting a population increase as cities in the region are being recognized as "climate havens" (Bartolai et al., 2015; Pierre-Louis, 2019), and the current U.S. Presidential Administration has signed legislation designating billions of dollars to water infrastructure and remediation efforts (Stinchcomb, 2021), all of which suggest an increasing exposure of risk to environmental change for the region.Fig. 1..

The objective of this Short Communication is to describe and document a method for computing the watershed-level population under jurisdiction of the GLC within a tiered spatial framework with international consistency to support regional science and policy. Without a cohesive framework to assess the LGLW population, it remains unclear if practitioners, policymakers, and researchers

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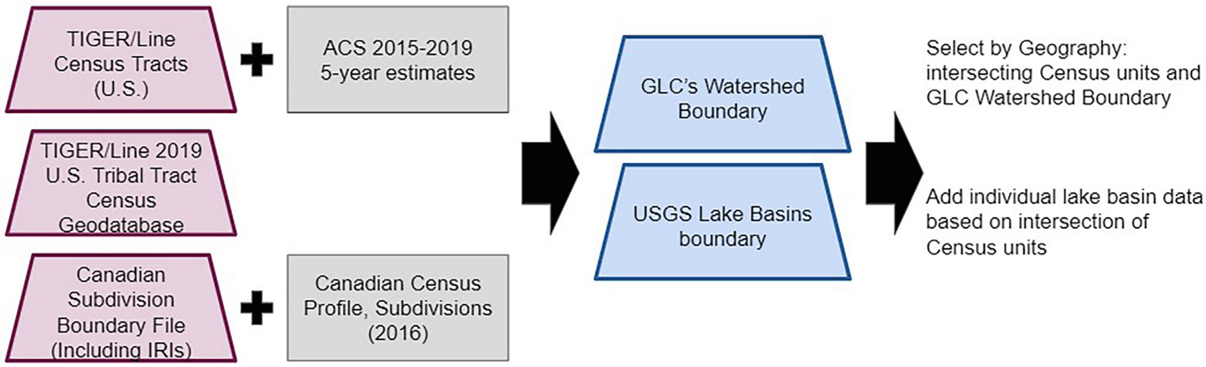


Fig. 1. Framework for incorporating Geographic Information Databases.

are counting and referring to the same people when discussing regional population characteristics.

Approaching the Great Lakes as a social-ecological region is necessary to understand the relationship between environmental change and social responses, and the widely recognized need for region-wide data requires sociodemographic information that reflects its many environments. Sociodemographic variables such as population density, economic structure, and human value systems are frequently included in socio-ecological models and interdisciplinary frameworks as important drivers of environmental change and risk management (Méthot et al., 2015; Ducey et al., 2018). Population attributes are critical in understanding who gets what, where, and why. Social and environmental justice issues in a technology-oriented democratic society are based on divisible and indivisible goods with partitioning largely determined based on population in a given area (Franklin, 1999). Critically, population attributes often drive how federal and state policies allocate financial and political resources. In the U.S., population numbers from the census counts are used for redistricting political units which directly influences national and state policies and representation in political structures, and affects how resources get distributed across and within communities. In Canada, census counts are used by governments and nonprofits to identify goals for legislative mandates, provide specific localized services (e.g., language translation services), and identify socioeconomic and health disparities across people and places.

Collaborative research efforts have assembled Great Lakes data into organized spatial frameworks to assess, understand, and predict these climate-driven disturbances, but there is a lack of spatial frameworks for incorporating sociodemographic data for the U.S., Canada, and Indigenous communities within the watershed, let alone approaches that include all nations. Many existing efforts include political boundaries far beyond the watershed of the region (e.g., states, provinces), or have limitations in the ability to easily connect new data to existing frameworks. For example, the Great Lakes Aquatic Habitat Framework provides a spatially comprehensive and standardized database of jurisdictional, infrastructure, ecological, biological, and environmental data for the Great Lakes that allow researchers to examine a suite of complex interactions of intersecting boundaries that can be used to compile data (Wang et al. 2015). However, the provided boundaries contain no sociodemographic data, and the boundaries highlighted in this framework emphasize jurisdictional and bureaucratic management units (townships, counties, provinces, major cities), and not finer spatial scales nor units that reflect Indigenous communities. This limits the ability to incorporate timely sociodemographic data specific to certain environments and relevant to objectives and outcomes of climate change policy and development.

Challenges incorporating population data

The first challenge in accurately estimating the population of the LGLW is getting timely data that reflects the current counts and conditions of a population across various data sources. Official counts are collected on a 10-year basis (2000, 2010, 2020) in the U. S., and a 5-year basis in Canada (2011, 2016, 2021), which creates a temporal offset in our most complete population numbers. While American Community Survey (ACS) estimates can be used in the U.S. between census counts, there is no equivalent for Canada, leaving many to rely on previously reported numbers (Table 1). Even over a single year, data releases can significantly change the values used to characterize a population. At the time of this writing (September of 2021), the US 2020 Census populations for cities and metropolitan statistical areas are available but do not provide any further information for other geographies (state, township, county) and are not manipulatable.

Exacerbating the above challenge is the issue of accessing and assembling these complex datasets, particularly because one must navigate multiple sources and programs to assemble population figures within ecological boundaries. Both the U.S. and Canada census programs provide spatial frameworks and massive dataset tables within data portals that must be matched using geographic identifiers, and access options for these datasets are subject to change. For example, the U.S. Census recently retired their online navigation tool "American FactFinder", and the available Canadian Census files that adequately cover urban and rural areas are at the census subdivision level, as the population ecumene files only provide data for cities while aggregating rural data. This leaves valuable sociodemographic information only accessible to experts and researchers, requiring partnerships to fund, create, and maintain mapping tools to access and know what is in a given community. Furthermore, U.S. and Canadian data are rarely presented together, creating discrepancies for ecological boundaries for the Great Lakes region by only including data for one side of the international border. Furthermore, the U.S. and Canada have developed their own models and analyses for watersheds, which has created a number of discrepancies. Recognizing discrepancies in hydrological datasets, several harmonizing efforts have been developed and actively managed (Forsyth et al., 2016; Mason et al., 2019), but include areas beyond GLC jurisdiction.

The second challenge in accurately estimating the population of the LGLW arises as a result of social-ecological unit mismatch and multiple methodologies used to aggregate a regional population estimate. The geographic units used in analyses can significantly affect and influence who is being counted and how patterns of wellbeing (health, poverty, income) manifest and are tracked at the community and regional level. For example, multiple geographic units and methods have been used to assess population

Table 1
Population Estimates for the Laurentian Great Lakes Watershed.

Agencies and Governments		
Source	**Geography**	**Population Estimate**
Wikipedia (2021)	8 U.S. states and the province of Ontario	99,766,742
NOAA (2021)	All 8 U.S. state coastal counties (N = 158)	27.3 Million
EPA Great Lakes (2021)	None mentioned	30 + Million
National Wildlife Foundation (2021)	None mentioned	35 + Million
U.S. Climate Resilience Toolkit (2019)	U.S. Great Lakes Basin; 225 counties	23 Million
Sea Grant Michigan (2021)	U.S. and Canada Hydrological Basin	34 Million
Gov't of Ontario Great Lakes Guide (2020)	Hydrological Basin	~40 million
Urban Institute (2018)	MN, WI, MI, IL, IN, and OH, whole states, 2010 Census	52 Million
GLISA (2016)	None mentioned	35 Million
NOAA Great Lakes Regional Team (2015)	None mentioned	30 + Million
Brookings Institute (2008)	"Great Lakes Economic Region", Authors own calculations with 2006 ACS data	118,377,375
Scholarly Articles		
Source	**Geography**	**Population Estimate**
Talukder and Hipel, 2020	Hydrological Basin - Population reliant on drinking water	40 Million
Wuebbles et al., 2019	Basin, citing University of Wisconsin Sea Grant Institute 2018 (broken link),	34 + Million
Mailhot et al., 2019	Basin, citing Mackay and Seglenieks, 2013	40 Million
Ducey et al., 2018	MN, WI, MI, IL IN, and OH, whole states, 2010 Census	52 Million
Méthot et al., 2015	Hydrological Basin and St. Lawrence River, 2010 Census and 2011 Statistics Canada	40 Million
Bassil et al., 2015	Hydrological Basin, citing IJC (broken link)	35 Million
Wang et al., 2015	U.S. Census 2000 and Statistics Canada 2002; does not describe scale of data (province, state, community, county)	33.5 Million
MacKay and Seglenieks, 2013	Hydrological Basin, no citation	40 Million
Breffle et al., 2013	Hydrological Basin, no citation	+40 Million
This Study	Great Lakes Commission Watershed Jurisdiction Boundary 2010 USGS Great Lakes Basin Maps 2016 Census of Canada - Census Subdivisions 2019 ACS 5-year estimates - Census Tracts TIGER/Line U.S. AIAN Tribal Tracts Shapefile	**38,327,681**

estimates in the U.S. and Canada for the LGLW, with different sources reporting figures from 27 to 52 million, a range of 25 million people (Table 1). Furthermore, there is limited information on the specific geographies included for many of the population references, whether it contains both Canadian and U.S. populations, or if it is even accurately capturing the population living within an ecologically defined unit (Environmental Protection Agency's (EPA) Great Lakes, 2021; GLISA, 2016; NOAA, 2015; National Wildlife Foundation, 2021; MacKay and Seglenieks, 2013). Other population estimates for the LGLW include entire U.S. states (Ducey et al., 2018), but frequently exclude New York and Pennsylvania (Urban Institute, 2018; NOAA, 2015).

These varying geographic units lead to a misrepresentation of people living within the LGLW because some counted people live in jurisdictions beyond the hydrological boundary of the LGLW. It is important to minimize spatial error when matching ecological data and spatial frameworks to the social landscape in order to accurately assess relationships between the environment and the people that live there. Matching sociodemographic data specifically to ecological boundaries using the smallest available units of reporting can be a vital first step in modeling the interactions between climate change and sociodemographic patterns. In the U.S., census tracts are used to represent sociodemographic information for groups of 1,200 to 8,000 people, and publicly available sociodemographic data at this scale can more accurately map across ecological boundaries than county or state-level approaches. The census subdivision in Canada represents one scale to incorporate sociodemographic data that adequately covers urban and rural areas as each unit is designed to reflect a municipality or equivalent. United States American Indian Alaskan-Native census tracts designed for Indigenous reservations and Canadian subdivisions that identify Indigenous reserves and territories provide units for statistical purposes that allow for spatially disaggregated data more relevant to local decision-making.

A third challenge of integrating LGLW population data is the accurate assessment of Indigenous communities in the region. Population data are critical for needs assessments and the formation of local and national policy, which are dependent on census data to manage relationships between Indigenous and federal governments and develop programs and policies related to a variety of social services (healthcare, education, business development, emergency services, etc.; Andersen 2008). For example, Indigenous communities outgrowing their reservations may experience future land-use conflict with adjacent territories, and ceded territories with majority-white populations may struggle to have Indigenous issues addressed at the local and regional levels. This stresses the importance of using both Indigenous demographic spatial frameworks with the general census counts that aggregate population in ways that do not always reflect how these communities exist.

Population counts for Indigenous people and places remain difficult to assess for both the U.S. and Canadian governments, leading to constant revamping in the methodologies and government departments used to manage this data in the past 10 years (Lujan, 2014). federally recognized Indigenous territories and communities have historically been undercounted and poorly surveyed, resulting in unreliable facts and figures for government agencies, non-profit organizations, and researchers (U.S. Census, 2012; Lujan, 2014; Urban Institute, 2019). Furthermore, low response rates, particularly from rural and Indigenous communities, create high margins of error for counts and estimates, and data for small towns and sparsely populated rural areas may not be disclosed if they reveal identifying information, resulting in the aggregation of population data. For example, the Census of Canada retracted figures for the 2016 census on the Akwesasne Reservations due to the undercounting of habitable structures and people (Statistics Canada, 2019). Additionally, reservations and off-trust lands are not always contiguous and some of these units have no population associated with them or are non-disclosable due to low response rates while Indigenous people in urban environments can be difficult to get responses from (Lujan, 2014). The Canadian Government dissolved the Indian Affairs and Northern Development Canada and replaced it with two other organizations (Indigenous Services Canada and the Crown-Indigenous Relations and Northern Affairs Canada) to restructure the approach to engagement to be more equitable. The U.S. created new census tracts and American Indian tribal subdivisions nested within federally recognized reservations and off-reservation trust lands because these communities are not always contiguous and do not conform to the geographic boundaries in the standard state-county tracts (United States Census Bureau, 2019).

To resolve the challenges identified above, we use this spatial framework to calculate a current population for the LGLW (2015–2019) with specific attention to the identification of Indigenous census boundaries. We define the region in reference to the hydrological boundary of the Great Lakes and St. Lawrence River populations according to Annex 2 of the Great Lakes Water Quality Agreement (IJC, 2012). Furthermore, we highlight how to better incorporate Indigenous communities for the U.S. by using the American Indian Alaskan Native Tribal Tracts that more accurately reflect these places that are not captured by the standard U.S. Census Tract. By examining the previous methods used to determine and discuss the people and places of the LGLW, a more structured spatial framework is developed to link the social landscape to the ecological watershed and allow for a better framework for social-ecological systems research to inform regional and local policy development.

Methods and results

We have developed a spatial framework for incorporating sociodemographic data that better reflects the people and places that encompass the LGLW. The Great Lakes watershed boundary here is used to highlight areas under the International Joint Commission's jurisdiction to better align watershed-scale, international policies and programs with a population framework that highlights the people and places living within the region. This framework is attentive to the unique characteristics of the social landscape, at a size relevant to social community structures and spatial patterns, but can be aggregated to address larger scales. Furthermore, this spatial framework aligns with other spatial datasets that allow for a better spatial match with existing ecological data for the region.

To calculate a population estimate for the Laurentian Great Lakes Watershed, we mapped the ecological boundary of the watershed to select geographic units and linked the map to the current counts and estimates for the U.S., Canada, and Indigenous reserves and reservations. First, a TIGER/Line shapefile of U.S. census tracts and the 2019 American Indian Tribal Tracts was linked to the 2019 ACS 5-year estimates in ArcMap 10.8.1 (United States Census Bureau, 2020). Census tracts were selected for the U.S. because they represent a geographic unit with detailed demographic information, roughly broken into areas containing approximately 4,000 people per tract. Second, the 2016 Canadian Census Subdivision Boundary File (Statistics Canada, 2018) was downloaded and linked to 2016 census counts using the Statistics Canada website and added to the U.S. database. Subdivisions were selected because Canadian census tracts are only available for metropolitan areas and agglomerations with 50,000 people or more, whereas subdivisions provide coverage for all municipalities or areas treated as equivalents (i.e., Indigenous reserves) for statistical purposes (Statistics Canada, 2015).

After population data were collected and joined with the spatial datasets, the GLC's Watershed Boundary of the Great Lakes was added to the demographic data, where the "selection by geography" tool was used to identify census tracts in the U.S., subdivisions in Canada, and the Tribal tracts and First Nation reserves that intersect with the watershed and were identified as the LGLW demographic area (GLC, 2017). To allow for intra-regional comparisons, the U.S. Geological Survey's (USGS) Great Lakes Basin shapefile was added to the demographic data, and census subdivisions and tracts were attributed a value that corresponds with the lake-specific basin (USGS, 2010). Census tracts and subdivisions intersected by multiple lake basins were assigned to the basin encompassing the largest area.

Fig. 2 represents the proposed spatial framework to identify and understand characteristics of the people and places in the LGLW, utilizing the GLC's Great Lakes Watershed jurisdictional boundary, Canadian Census Subdivisions, U.S. census tracts, and specific Indigenous/First Nation datasets and is consistent with Lakewide Management Plans (LAMPs) in Annex 2 of the Great Lakes Water Quality Agreement (IJC, 2012).

Laurentian Great Lakes watershed population estimate

Approximately 38,327,681 residents are living within the Great Lakes Watershed across Canada and the U.S. (2015–2019; Fig. 2). Nearly two-thirds of this population lives in the United States (62.44 percent), with over one-third of the population (37.56 percent) residing in Canada, primarily along the eastern LGLW. Although Canadian subdivisions have less spatial fidelity than the U.S. census tract, some general trends can be observed (Fig. 2).

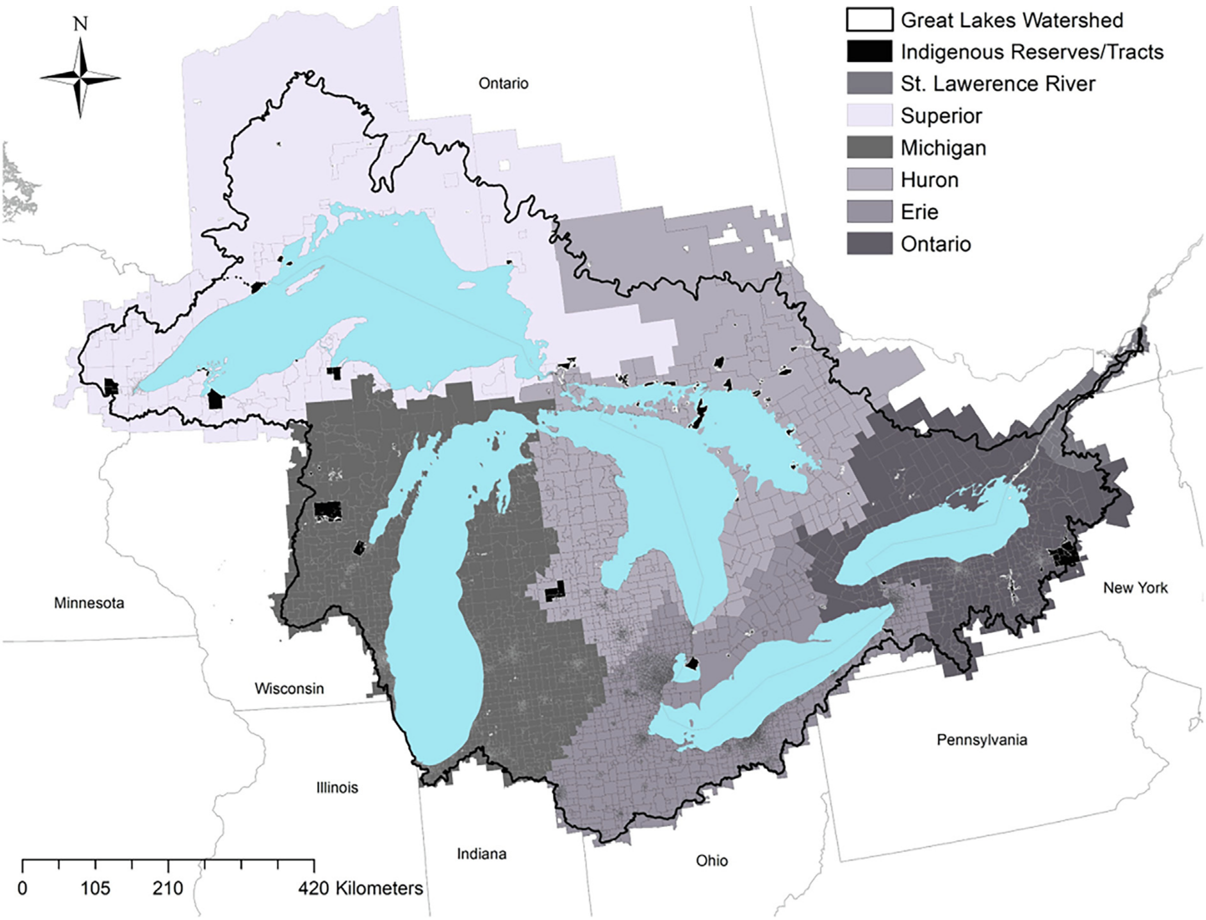
The Lake Erie basin is the most populated, with roughly 34.44 percent of the LGLW population (Fig. 2). A majority of the population resides in the U.S. (82.48 percent), which includes the metropolitan statistical areas of Cleveland, OH (2,048,449), Buffalo, NY (1,127,983), and Detroit, MI (4,317,848). Major regional municipalities in the Canadian-Erie watershed include Waterloo (535,154), London (383,822), and Windsor (217,188), Ontario (ACS 2019; CC 2016).

The Lake Ontario basin is the second-most populated, with 27 percent of the LGLW population (Fig. 2). A substantial majority (76.25 percent) of the population resides in Canada, which includes the Greater Toronto Area (6,417,516), one of the most populous metropolitan areas in Canada, and includes the regional municipalities of Durham, Halton, Peel, and York. The remaining 23.75 percent that reside in the U.S. live almost exclusively in the state of New York.

The Lake Michigan basin is the third-most populated part of the LGLW, lies completely within the U.S., and makes up 22.17 percent of the LGLW population (Fig. 2). Major metropolitan statistical areas (MSAs) include Chicago (9,458,539), Milwaukee (1,575,179), and Green Bay (319,441), although the population estimate for the Chicago MSA contains areas outside the LGLW and the entirety of this MSA is not included in the framework. Only census tracts from the MSA that intersect with the LGLW are included. Significant portions of the Chicago MSA lie outside the watershed proper. This may be the most difficult region to assess demographically as the two major cities of Chicago and Milwaukee sprawl well beyond the hydrological watershed and their incorporation into demographic counts can significantly influence the results as these census tracts have high population densities.

The Lake Huron basin is the fourth-most populated, home to about 8 percent of the LGLW population (Fig. 2). It is also the most evenly split watershed between the U.S. and Canada, although slightly more people (51.5 percent) reside on the U.S. side. The Lake Huron watershed is mostly rural but includes two large MSAs in the U.S.: the Flint (405,813) and Saginaw MSAs (200,169), and two in Canada: Sarnia (71,594), and Owen Sound (21,314), Ontario.

The St. Lawrence River jurisdiction of the GLC extends along a narrow corridor between the U.S.-Canadian border, containing roughly 7.1 percent of the watershed population. While the U.S. side of this area is relatively rural, making up 2.92 percent, the Canadian portion is home to over 2.5 million residents. The water-



Nations includes Indigenous peoples	Watershed*						
	Superior	Michigan	Huron	Erie	Ontario	St. Lawrence River	Totals
U.S.	463,474	8,498,718	1,582,002	10,881,623	2,428,950	79,311	23,934,078
Canada	155,754	0	1,489,639	2,311,096	7,799,887	2,637,227	14,393,603
Totals	619,228	8,498,718	3,071,641	13,192,719	10,228,837	2,716,538	38,327,681

Note: 2019 American Community Survey's 5-year estimates census tract level is used for the U.S.
2016 Census of Canada population numbers are used for Canada.
** Populations along connecting waters are assigned according to Annex 2 of the Great Lakes Water Quality Agreement.*

Fig. 2. Census Tracts and Subdivisions for Estimating the Population of the Laurentian Great Lakes Watershed.

shed extends into the city of Montreal (1,704,690) and includes the Mohawk Nation of Akwesasne located across the U.S.-Canadian border in the communities of Akwesasne, NY, and the Akwesasne Indian Reserve in Ontario, although they consider themselves one community (23,000).

The Lake Superior basin is the least populated of the five Great Lakes watershed, containing only 1.62 percent of the total LGLW population. A significant majority of the Superior watershed (74.85 percent) reside in the U.S., primarily in the Twin Ports area of Duluth, MN, and Superior, WI (291,638). The remaining 25.15 percent in Canada reside primarily in Thunder Bay, Ontario (121,621), which is home to roughly 78.1% of the Canadian-Superior-watershed population.

Indigenous and first nation/métis census tracts and reserve population estimates

Approximately 133,737 people are living on Indigenous, First Nation, and Métis census tracts and reserves in the LGLW, with a majority of this population (86,686, or 64.8 percent) in the U.S. (Table 2). While this count is not a reflection of the total Indigenous population of the LGLW, it provides a population number of Indigenous residents residing on Tribal tracts and Canadian reserves. Of people living in these tracts and reserves, 47,349 identify as Native American/Indigenous/First Nation/Métis based on available figures. Data for more sparsely populated areas are listed as non-disclosable if data does not meet the avoidance disclosure requirements.

Table 2
Population Estimates for the Three Most Populous Indigenous Communities/Territories by Basin.

Basin	Population	Indigenous/First Nation/Métis	%
Huron			
Isabella Reservation (U.S.)	27,339	1,970	7.21%
Wikwemikong Unceded Territory (CAN)	2,500	2,425	97.00%
Sault Saint Marie Reservation (U.S.)	2,294	1,066	46.47%
Michigan			
Oneida Reservation (U.S.)	25,228	4,384	17.38%
Menominee Reservation (US)	3,269	2,962	90.61%
Ho-Chunk Nation Reservation (U.S.)	1,621	1,218	75.14%
Superior			
Fond du Lac Reservation (U.S.)	4,156	1,617	38.91%
L'Anse Reservation (U.S.)	3,640	786	21.59%
Bad River Reservation (U.S.)	1,643	1,250	76.08%
Erie			
Cattaraugus Reservation (U.S.)	2,361	1,909	80.86%
Bkejwanong (also known as Walpole Island) (CAN)	1,589	1,550	97.55%
Tuscarora Nation Reservation	1,102	756	68.6%
Ontario			
Cayuga Nation TDSA	2,976	5	<0.001%
Tyendinaga Mohawk Territory (CAN)	2,524	2,080	82.41%
Curve Lake First Nation 35 (CAN)	1,059	745	70.35%
St. Lawrence River			
Mohawk of Akwesasne (Akwesasne Reserve No. 59, Akwesasne Reserve No. 15 (CA), Saint Regis Mohawk Reservation (US))	23,000	More in adjacent unceded territory	Unknown

*Data for Akwesasne was collected from The Mohawk Council of Akwesasne due to the difficulty of accurately characterizing the nation split by international borders, identity as a single community, and under-enumeration in Canada's 2016 Census.

The largest population of residents on Indigenous/First Nation/ land is in the Lake Huron basin with 46,032 people, of which 64.53 percent reside in the U.S. and 35.47 percent on the Canadian side (Table 2). There is a substantially lower proportion of Indigenous residents within the U.S. Tribal tracts (10.3 percent) compared to Canada (88.7 percent). The largest Indigenous community in the Huron watershed is the Isabella Reservation, with 27,339 residents, but has a relatively lower percentage of residents who identify as Indigenous/Native American/First Nation (7 percent) compared to the more rural areas of the Wikwemikong unceded territory (97 percent) and Sault Saint Marie Reservation (46 percent). In Ontario, the Crown recognizes the Métis Nation but does not recognize any Métis territory; the U.S. does not recognize Métis in U.S. territory.

The Lake Michigan basin contains the second-highest population living on Tribally designated tracts, with 33,601 residents, 32.95 percent of which identify as Indigenous. The most populated community is the Oneida Reservation, with 25,228 residents, of which 17 percent identify as Indigenous. The Menominee Reservation is the second-most populated area, with 3,269 residents, of which 90.61 percent identify as Indigenous; while the third-largest community, the Ho-Chunk Reservation, has 1,621 residents, of which 75.14 percent identify as Indigenous.

The Lake Superior basin contains 15,936 residents on Indigenous and First Nation-designated tracts, with 81.42 percent in the U.S. and 15.58 percent in Canada. There is a higher percentage of residents who identify as First Nation, Métis, or Indigenous within the Canadian reserves (91.2 percent) than U.S. Tribal tracts (47.4 percent), although this translates to a larger Indigenous population within the U.S. The most populous place is the Fond du Lac Reservation (4,156 residents, 38.91 percent Indigenous), followed by the L'Anse Reservation (3,640 people, 21.59 percent Indigenous) and Bad River Reservation (1,643 residents, 76 percent Indigenous), all in the U.S.

The Lake Erie basin, with 7,451 residents across 3 Tribal tracts and 10 First Nation reserves, has the highest percentage of the population identifying as Indigenous or First Nation (83.9 percent). The most populated community is the Cattaraugus Reservation (2,361) in the U.S., followed by Bkejwanong (Walpole Island 46) (1,589 residents, 97.55 percent) in Canada and the Tuscarora Nation Reservation (1,102 residents, 68.6 percent Indigenous) in the U.S.

The Lake Ontario basin has approximately 7,717 people living across two Tribal tracts and five First Nation reserves, of which a substantial majority (4,571; 96 percent) reside on the Canadian side. The three most populated Indigenous/First Nation/Métis places include the Cayuga Nation Tribal Designated Statistical Area (TDSA), followed by the Tyendinaga Mohawk Territory (2,524 residents, 82.41 percent Indigenous), and the Curve Lake First Nation 35 (1,059 residents, 70.35 percent Indigenous). Cayuga Nation TDSA stands out as this census tract registers 2,976 residents, with only 5 identifying as Native American/Indigenous.

The St. Lawrence River section of the GLC's jurisdiction has four Tribal tracts and Indian reserves, one of which (Kahnawake Indian Reservation) has no reported population count. The Mohawk Nation of Akwesasne contains three ceded contiguous tracts, home to roughly 23,000 people, with more in the adjacent territory.

Discussion

Approaching the Great Lakes as a social-ecological region is complicated due to the difficulty of tracking down timely population data across different government agencies, mismatch of ecological and political units, and including sociodemographic data and community profiles of Indigenous and First Nation census units. As a result, no clear methodology has been described to provide such a framework for sociodemographic data, and the misrepresentation of the people and places in the watershed limits social-ecological approaches to the emerging challenges for the region. Few studies specifically measure and count the populations living within a defined ecological boundary across multiple nations, and rely on dated citations or aggregate populations beyond the Great Lakes environment for multi-national management (Urban Institute, 2018). Without a cohesive framework to assess the LGLW population and incorporate it with other ecological data, it remains unclear if practitioners, policymakers, and researchers are counting and referring to the same people and places. Climate change has created significant challenges for governance in the region and the ability to measure and track sociodemographic variables within the watershed, along with other ecological data, improves our understanding of social-ecological systems. Communities in the LGLW are anticipating significant changes, from population influxes for cities dubbed "climate havens" to others relocating away from the constant exposure of climate-driven disturbances, complicating our understanding and future projections for this landscape.

We describe a method that overcomes these challenges by identifying the relevant sociodemographic data frameworks necessary to assess the people and places that exist within the LGLW and uses the framework to provide a population update for the ecological region. This framework is critical for both climate change adaptation and the distribution of resources to protect the most socially and ecologically vulnerable populations, and it can help predict which type of resources are most needed based on these characteristics (e.g., language services, evacuation plans for nursing homes, or car mobility). Furthermore, this framework can contribute to other efforts to integrate smaller, watershed-level sociodemographic data to achieve adaptive management objectives in management plans (IJC, 2012).

By incorporating sociodemographic data with spatially explicit ecological data, science can better understand how human variables are associated with a range of ecological phenomena. For example, this spatial framework can be used to identify emerging forms of environmental justice by examining the demographic landscape on top of problematic ecological processes. Additionally, this framework can be aligned to highlight specific census tracts at multiple scales, using other resources such as GLAHF to link relevant ecological and environmental data at more localized levels (e.g., lake basins, local watersheds, or specific wetlands) to improve our understanding of the synchronicity of climate-driven disturbances and social change.

The use of U.S. census tracts, Canadian subdivisions, and improved census units for Indigenous places across the region provides the best way to spatially match publicly available sociodemographic data to the ecological boundaries of the LGLW at a scale that reflects how people live. The U.S. census tract-level data is a compromise between the county-level and neighborhood block-level, with census counts occurring every 10 years, and is comparable to the Canadian Subdivision. The specific inclusion of American Indian Alaskan Native Tribal tracts in the U.S. is required to more carefully consider Indigenous places and communities as distinct units that are not always considered using the standard census tract, but it is also important to mind the limitations of this data. With the 2020 U.S. Census and 2021 Canadian Census slated to be released throughout the year 2022, frameworks like this provide a way to organize and synthesize emerging demographic data for the region (U.S. Census, 2021; Statistics Canada, 2021).

The urban–rural gradient is better reflected with a census tract-subdivision approach compared to the use of counties (U.S.) which are based on a Euclidean grid structure less influenced by population. Additionally, census ecumene for Canada has a focus on metropolitan areas, but their coverage for smaller geographies (municipalities under 50,000) are not adequate for the entirety of the LGLW, while the census subdivision unit offers less spatially detailed data for improved coverage. The Canadian Census occurs every 5 years, allowing for detailed profiles for each subdivision, while other estimates may be available at the ecumene level, although this data tends to over-aggregate rural areas. ACS 5-year estimates are rolling averages produced each year through sample data, and these estimates provide the most timely demographic data that can be integrated with census tracts, but may suffer from the higher margin of errors for tracts with lower response rates, particularly in rural areas and communities of color.

When discussing Indigenous communities and places in the U. S., researchers and practitioners should reference Tribal tract data but understand the challenges and shortcomings of these assessments that lead to continual undercounting and underrepresentation. Several developments in the past decade have modified methodologies of data collection to increase response rates and better reflect the sociodemographic contexts on government-delineated lands and reserves, but challenges remain with disaggregating data from smaller geographies, as some counts are non-disclosable due to privacy concerns for the smaller populations. Related to this point, Indigenous/First Nation places may be non-contiguous and exist in and outside the watershed, but are aggregated in the reporting files (e.g., the Ho-Chunk Nation Reservation and Off-Reservation Trust Land in the U.S.). As noted above, the Métis Nation in Ontario has no designated territory, yet possesses some harvesting rights on lands and waters in the Canadian portion of the Great Lakes watershed. It should also be noted that historical Métis communities are being rediscovered and acknowledged as part of the legal requirements for establishing Métis' rights protected by s. 35 of The Constitution Act, 1982, and these rediscoveries could shape how we perceive the Indigenous populations and communities in the region, while others have raised more general issues of counting and assessing the Métis identity in census enumerations (Andersen, 2008; Kwan-Lafond and Winterstein, 2020; Métis Nation of Ontario, 2021).

Three points are worth noting while describing the people and places of the Great Lakes. First, the spatial boundaries for the GLC's Jurisdiction and the Great Lakes watershed are different, with the individual lake basins extending beyond GLC jurisdiction. This study was focused on the GLC's jurisdiction specifically for policy planning that incorporates local demographic information for LAMPs to their respective populations (IJC, 2012). However, socio-ecological research investigating larger demographic patterns (e.g., Great Lakes Basin) may want to capture demographic data beyond joint-jurisdictional boundaries.

Second, other units of analysis may be more pertinent to specific geographies within the Great Lakes (e.g., census tracts of larger cities in Canada) or may only offer data at higher levels of organization (e.g., counties in the U.S.), but the use of Canadian subdivisions and U.S. Census tracts allows for a balance between spatial and temporal accuracy. Furthermore, county-level and metropolitan/micropolitan statistical area data can be used to investigate regional trends and efforts to understand sociodemographic trends in major cities of the Great Lakes (e.g., Chicago, IL) in ways that incorporate the communities that are socially connected and proximate, but exist just beyond these ecological boundaries. In cases where the metro area is the unit of analysis, it may be more beneficial to expand these boundaries, but this framework is specific to the social landscape within the watershed.

Third, it is important to understand demographic trends for Indigenous/First Nation/Metis communities and how the evolving nature of their representation in census counts shapes aid and policy. However, it is also important to note that secondary datasets such as census counts and population counts often highlight and use data points to describe places in constant deficit and ongoing deterioration (e.g., poverty, education, or health disparities). Understanding social change over time is important, but the narrative placed on the data is equally meaningful when discussing people in places and recognizing one's own position in this process. Furthermore, there are several Indigenous census tracts that are non-contiguous and expand beyond the watershed, but are included in this framework. This is due to the inability of disaggregating certain census tracts, demonstrating the ever-present need to identify more meaningful ways of accounting for Indigenous people and places.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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