WebPanel 1. Values associated with the Great Lakes


Michigan Sea Grant

US retail expenditures on recreational fishing in the Great Lakes (GL) in 2011 were nearly $3 billion, and the total economic effect of the fishery was estimated at $7 billion (Southwick Associates 2012). National surveys of fishing effort found that approximately 1.4 million anglers fished in US waters of the GL in 2006 (USFWS and USCB 2006), and an additional 395 000 anglers participated in recreational fishing in Ontario waters of the GL in 2005 (DFO 2008).


Michigan Sea Grant

Great Lakes beaches and sandy coastlines experience an estimated 8 million swimmers and 80 million swimming days annually (Austin *et al.* 2007), with an estimated recreational value of US$1.1–1.4 billion in the US (Shaikh and Tolley 2004) and CAN$200–250 million in Canada (Krantzberg and de Boer 2008).


Michigan Sea Grant

Recreational boating is an important contributor to the US economy, generating $30.4 billion in sales and services in 2010 (NMMA 2011). An estimated 911 000 individuals participated in recreational boating on the GL in 2003, spending an estimated $2.36 billion on boating trips; $1.44 billion on boats, equipment, and supplies; and supporting 60 000 jobs (USACE 2008).


The Nature Conservancy

The GL region is home to an estimated 5 million birding enthusiasts who frequent shoreline "hotspots" during all seasons of the year (Austin *et al.* 2008), as this region lies at the intersection of multiple migratory flyways and provides habitat essential to support these migrations (Ewert *et al.* 2012). One recent survey of 1100 birders at six birding hotspots along Ohio's Lake Erie shoreline estimated expenditures totaling $26 million, including $4.6 million on travel (Xie 2012).


Michigan Sea Grant

Parks and protected areas along the GL shoreline of the US and Canada provide opportunities for visitors to participate in camping, hiking, fishing, hunting, and viewing wildlife and nature scenery. Neher *et al.* (2013) estimated total willingness to pay for visits to US national parks in 2011 at US$28.5 billion, with a 95% confidence interval of US$19.7–$43.1 billion. In 2008 and 2009, Parks Canada's visitor spending accounted for CAN$2.7 billion (CPC 2011).

WebTable 1. Metrics, spatial scale, and time period for five recreational services quantified and mapped for the five Great Lakes and their connecting waters[1]

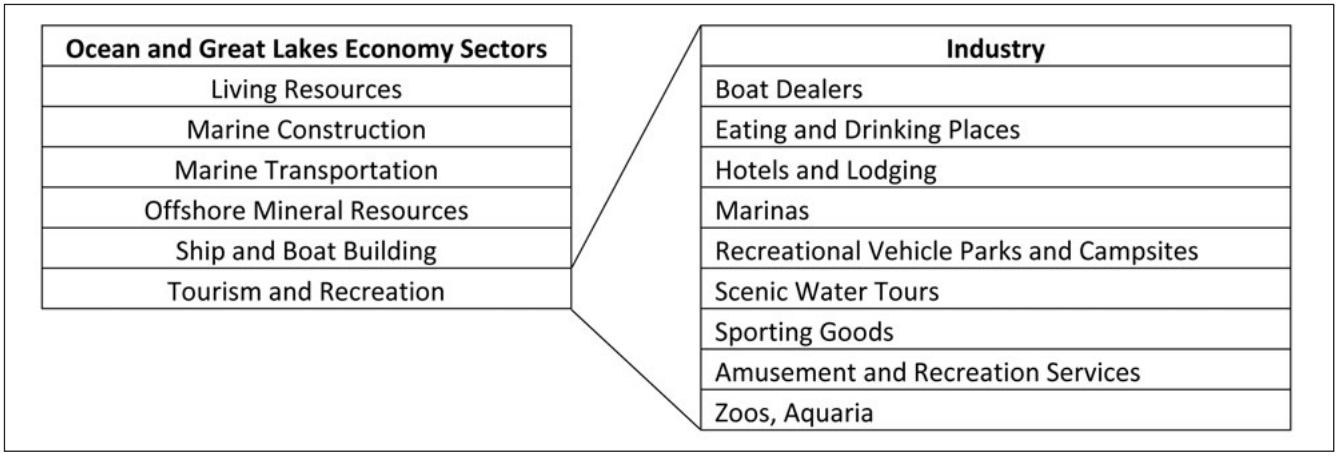
Recreational service	*Metrics*	*Scale*	*Time period*
Sport fishing[2]	Private effort (angler hours)	Agency reporting units	2009–2011 average
	Charter effort (angler hours)		
Boating[3]	Number of marina locations	Point locations	As of 2010
	Number of marina boat slips		
Beach use[4]	Number of public beaches	Beach mid-points	As of 2009
	Number of Flickr photos per beach		2005–2012
Park visitation[5]	Number of parks	Park boundaries within 5 km of lakeshore	2002–2010
	Number of park visitors		2005–2010 (US) 2008–2011 (Canada)
Birding[6]	Number of eBird locations	Point locations	1999–2012
	Number of visits per eBird location		

Notes: [1]Terminating at the Lake Ontario outlet. [2]Data were obtained from annual reports by individual state agencies and the Ontario Ministry of Natural Resources, and through direct communication with data managers. [3]Marina locations were identified from internet sites and confirmed using aerial imagery in Google Earth. The number of boat slips at each marina was determined from websites or by counts of boat slips (Allan *et al.* 2013). [4]Beach locations were obtained from the US Environmental Protection Agency BEACH Act geospatial database and Environment Canada, supplemented with provincial park beaches identified from Canadian protected lands databases. As a proxy for beach visitation, we used the InVEST model (NCP 2013) to count the number of geotagged Flickr photos within a 500-m buffer of each beach location (methodology in Wood *et al.* 2013). The model sources metadata from Flickr's public API, and calculates the total annual photo-user-days from the number of days a unique Flickr user uploads at least one photograph. [5]US parks were selected from the Great Lakes Conservation and Recreational Lands database (CARL), maintained by Ducks Unlimited Inc (DU 2008), and the Protected Areas Database (PAD-US) produced by the Conservation Biology Institute (CBI 2010). Additional data were obtained for Minnesota state parks from Minnesota Department of Natural Resources (Minnesota DNR 2002). Ontario provincial and national parks were selected from a Protected Lands database maintained by the Ontario Ministry of Natural Resources (OMNR 2012). Visitation records were compiled for the years 2005–2010 (US) and 2008–2011 (Canada). US visitation records were provided by individual state agencies, and national parks visitation records were accessed on the National Parks Service Visitor Use Statistics webpage (NPS 2013). Provincial park visitation records (2008–2011) came from OMNR (Ontario Parks 2008–2011), and Canadian national park visitation data were accessed on the Parks Canada website (Parks Canada 2013). [6]Actively used bird-watching locations were identified from the citizen-science database eBird (Sullivan *et al.* 2009). We selected eBird "hotspots" (eBird 2013) within 5 km of the lakes' shoreline and summed the recorded visits to each hotspot from 1 January 1999 through 31 December 2012.

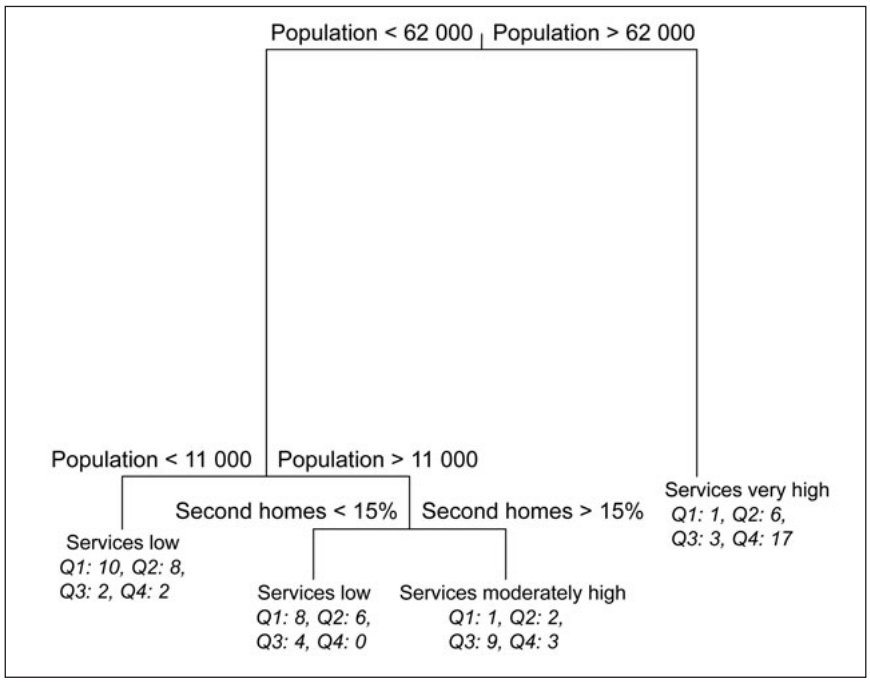
WebTable 2. The 34 environmental stressors used to compute cumulative stress in 1-km^2 pixels across the Great Lakes

Category	*Stressor*
Aquatic habitat	Hypoxia
	Industrial ports and harbors
	Light pollution
	Marinas/boating
	Shipping lanes
	Shoreline extensions
	Shoreline hardening
	Dams (altered flow, nutrient, and sediment regimes)
Climate change	Changing water level
	Decreasing ice cover
	Warming water temperature
Coastal development	Coastal development
	Coastal mines
	Coastal power plants
	Coastal recreational use
	Coastal road density
Fisheries	Aquaculture
	Commercial fishing
	Native fish stocking
	Non-native fish stocking
	Recreational fishing – charter
Invasive species	Ballast risk
	Invasive fish
	Invasive mussels
	Invasive wetland plants
	Sea lampreys (*Petromyzon marinus*)
Non-point pollution	Combined sewer overflows
	Nitrogen loading
	Phosphorus loading
	Sediment loading
Toxic chemicals	Areas of Concern
	Metals – biomagnifying
	Metals – non-biomagnifying
	Organics – biomagnifying

Notes: For convenience, the stressors are grouped into seven categories. Data were obtained or generated to map the intensity of each of the 34 stressors (Allan *et al.* 2013).



WebFigure 1. *Ocean and GL economic sectors, as defined by the NOAA Coastal Services Center. Industries that comprise the T&R sector are shown at right. Economic measures, including GDP and employment, were derived from the US Bureau of Labor Statistics (BLS), US Bureau of Economic Analysis (BEA), and the US Census Bureau (NOAA 2012a,b). BLS data are subject to disclosure limitations to protect the anonymity of establishments when the number of establishments within the reporting region is few or when one establishment contributes 80% or more of the employment within that region (NOAA 2012a). Thus, county data in this analysis are a minimum representation of the extent of the GL-region economy, but only about 3% of data on average were suppressed for the T&R sector at the county level. Because establishments in this sector (eg hotels and restaurants in a metropolitan area) benefit from non-lake-related business, the ENOW county totals for this sector are limited to shore-adjacent zip codes (NOAA 2012a). Five coastal counties had no lake-adjacent zip codes (Sandusky, Ohio), entirely suppressed data (Cook, Minnesota; Lake, Minnesota; Iron, Wisconsin), or no reported T&R economic activity (Cayuga, New York), restricting our analysis to 77–78 of the 82 coastal US counties. Because comparable data for Canada were not readily available, especially with the level of post-processing provided by NOAA's ENOW program, economic analysis was restricted to the US.*



WebFigure 2. *Classification tree (CART) analysis of service delivery of US counties versus several potential explanatory variables: human population (total of all shore-adjacent zip codes), median income (county average in US$), second homes (proportion of seasonal homes in shore-adjacent zip codes), and cumulative stress (average for county unit in a 5-km band around GL shorelines). Splits in the tree denote splitting of observations at the indicated thresholds of population and seasonal homes to form groups of observations homogeneous in service delivery (classified into quartiles). Cumulative stress and income levels were not used in the resulting model (misclassification rate = 36%, compared to 75% with null model). Social data were obtained from 2010 US census reports; cumulative stress data were from Allan* et al. *(2013). The tree was pruned by setting the minimum observations in resulting nodes (minimum to split = 26 observations, minimum for leaf = 13 observations). The vertical length of branches indicates amount of variation explained. Terminal leaves are displayed with predominant service delivery (verbally described as low, moderately low, moderately high, and high for the four quartiles of service delivery, respectively) and the actual number of counties in each quartile (Q1–Q4, italicized) in that node.*

WebReferences

Allan JD, McIntyre PB, Smith SDP, *et al.* 2013. Joint analysis of stressors and ecosystem services to enhance restoration effectiveness. *P Natl Acad Sci USA* **110**: 372–77.

Austin JC, Anderson S, Courant PN, *et al.* 2007. Healthy waters, strong economy: the benefits of restoring the Great Lakes ecosystem. Washington, DC: The Brookings Institution.

Austin JC, Dezenski E, and Affolter-Caine B. 2008. The vital connection: reclaiming the Great Lakes economic leadership in the bi-national US–Canadian region. Washington, DC: The Brookings Institution.

CBI (Conservation Biology Institute). 2010. Protected areas database of the US. Corvallis, OR: CBI. http://consbio.org/products/projects/pad-us-cbi-edition. Viewed 9 Jun 2015.

CPC (Canadian Parks Council). 2011. The economic impact of Canada's national, provincial and territorial parks in 2009. Stella, Canada: The Outspan Group Inc.

DFO (Fisheries and Oceans Canada). 2008. Survey of recreational fishing in Canada: selected results for the Great Lakes fishery 2005. Ottawa, Canada: DFO – Economic Analysis and Statistics Policy Sector.

DU (Ducks Unlimited Inc). 2008. Great Lakes conservation and recreational lands (CARL) gis layer. Ann Arbor, MI: Ducks Unlimited. www.ducks.org/conservation/glaro/carl-gis-layer. Viewed 9 Jun 2015.

eBird. 2013. eBird basic dataset. Version: ebd_relmay-2013. Ithaca, NY: Cornell Lab of Ornithology. www.ebird.org. Viewed 9 Jun 2015.

Ewert DN, Doran PJ, Hall KR, *et al.* 2012. On a wing and a (gis) layer: prioritizing migratory bird stopover habitat along Great Lakes shorelines. Upper Midwest and Great Lakes Landscape Conservation Cooperative. www.greatlakeslcc.org/wp-content/uploads/2012/09/LCC-PhaseIStopover-Report_Final.pdf. Viewed 9 Jun 2015.

Krantzberg G and de Boer C. 2008. A valuation of ecological services in the Laurentian Great Lakes basin with an emphasis on Canada. *J Am Water Works Ass* **100**: 100–11.

Minnesota DNR (Department of Natural Resources). 2002. State park statutory boundaries. St Paul, MN: Minnesota DNR. http://deli.dnr.state.mn.us/metadata.html?id=L220000190201. Viewed 2 Jun 2015.

NCP (Natural Capital Project). 2013. InVEST (version 2.5.6). Stanford, CA: NCP. www.naturalcapitalproject.org/InVEST.html. Viewed 2 Jun 2015.

NMMA (National Marine Manufacturers Association). 2011. 2010 recreational boating statistical abstract. Chicago, IL: NMMA.

Neher C, Duffield J, and Patterson D. 2013. Valuation of national park system visitation: the efficient use of count data models, meta-analysis, and secondary visitor survey data. *Environ Manage* **52**: 683–98.

NOAA (National Oceanic and Atmospheric Administration) Coastal Services Center. 2012a. NOAA report on the ocean and Great Lakes economy of the United States. http://coast.noaa.gov/digitalcoast/_/pdf/econreport.pdf. Bethesda, MD: NOAA. Viewed 2 Jun 2015.

NOAA (National Oceanic and Atmospheric Administration) Coastal Services Center. 2012b. Regional summary: the Great Lakes economy in the Great Lakes region. http://coast.noaa.gov/digitalcoast/publications/econreport. Bethesda, MD: NOAA. Viewed 2 Jun 2015.

NPS (National Park Service). 2013. Visitor use statistics. https://irma.nps.gov/Stats/. Washington, DC: NPS. Viewed 2 Jun 2015.

OMNR (Ontario Ministry of Natural Resources). 2012. Protected lands database. www.mnr.gov.on.ca/en/Business/LIO/index.html?x=15&y=13. Peterborough, Canada: OMNR. Viewed 2 Jun 2015.

Ontario Parks. 2008–2011. Ontario provincial parks statistics. Peterborough, Canada: OMNR. www.ontarioparks.com/statistics. Viewed 2 Jun 2015.

Parks Canada. 2013. Parks Canada attendance 2007–09 to 2011–12. Ottawa, Canada: Parks Canada. www.pc.gc.ca/eng/docs/pc/attend/table3.aspx. Viewed 2 Jun 2015.

Shaikh S and Tolley G. 2004. Assessing the benefits of reducing Chicago-area beach closure days. Chicago, IL: The Joyce Foundation Environmental Program.

Southwick Associates. 2012. Sportfishing in America: an economic force for conservation. Alexandria, VA: American Sportfishing Association.

Sullivan BL, Wood CL, Iliff MJ, *et al.* 2009. eBird: a citizen-based bird observation network in the biological sciences. *Biol Conserv* **142**: 2282–92.

USACE (US Army Corps of Engineers). 2008. Great Lakes recreational boating. In response to public law 106-53, Water Resources Development Act of 1999, section 455(c), John Glenn Great Lakes Basin Program. Washington, DC: USACE.

USFWS (US Fish and Wildlife Service) and USCB (US Census Bureau). 2006. National survey of fishing, hunting, and wildlife associated recreation. Washington, DC: USFWS and USCB. FHW/06-NAT.

Wood SA, Guerry AD, Silver JM, *et al.* 2013. Using social media to quantify nature-based tourism and recreation. *Sci Rep* **3**: 2976.

Xie PF. 2012. Socio-economic impacts of birdwatching along Lake Erie: a coastal Ohio analysis. Bowling Green, OH: Ohio Sea Grant. OHSU-TS-061.

