



Great Lakes Water Quality Agreement
2009–2011 Priority Cycle Report
International Joint Commission



T. Lawrence, GLFC

MICROBIOLOGICAL QUALITY
OF GREAT LAKES
BEACHES AND RECREATIONAL WATERS

2009–2011 Priority Cycle Report on
MICROBIOLOGICAL QUALITY
OF
GREAT LAKES
BEACHES AND RECREATIONAL WATERS

Prepared by the
Beaches and Recreational Water Quality Work Group

For the
INTERNATIONAL JOINT COMMISSION
Canada and United States



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Canada and the United States, as the Parties to the Great Lakes Water Quality Agreement, are responsible for restoring and maintaining “the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.” Throughout the Agreement, reference is made both directly and indirectly to microbiological contamination, which includes pathogens. Pathogens are any micro-organism or virus that can cause disease. Annex 2 identifies beach closings as an impaired beneficial use. High numbers of fecal indicator bacteria and pathogenic organisms are among the reasons that a beach may be closed. Annex 1 contains the following objective for microbiological contaminants:

Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections.

Microbiological water quality has been a long-standing issue in the Great Lakes basin. One of the first references from the Parties—a formal request for investigation and advice dated August 1, 1912—asked the Commission to investigate “[t]o what extent and by what causes and in what localities have the boundary waters ... been polluted so as to be injurious to the public health and unfit for domestic or other uses.” The Commission’s investigation was noteworthy for its organization, breadth, and depth and for the quality of data developed. The Commission issued its *Final Report of the International Joint Commission on the Pollution of Boundary Waters* Reference on September 10, 1918. The report described the extent of microbiological contamination and provided specific advice to prevent or remedy pollution from human and other point and non-point sources.

Nearly 100 years later, microbiological contamination continues to be a significant Great Lakes issue, particularly in regard to recreational water quality. Over the years, the Commission’s boards and investigative

groups have provided advice, and the Parties have implemented actions in response to the Commission’s recommendations. Yet, the many issues remain unresolved and are more complicated than originally perceived. In 2007, the Canadian and U.S. co-chairs of the Great Lakes Water Quality Board and the Great Lakes Science Advisory Board established a joint Work Group to provide advice about recreational water quality issues. The Work Group’s *2007–09 Report on Beaches and Recreational Water Quality* recommended, through the Boards and Commission, that the Parties:

- conduct additional research to determine sources of contamination, especially non-point sources, the human versus non-human contributions, and the resulting risk to human health;
- develop novel indicators of human fecal contamination that are rapid and reliable to increase the efficiency of the decision-making process for beach advisories;
- undertake a head-to-head comparison of the true predictive value of a suite of real-time and forecasting models versus the persistence model at a set of Great Lakes beaches that span the full range of ambient conditions;
- develop binational, standardized, basin-wide surveillance and monitoring protocols in conjunction with preventive risk management strategies;
- adopt binational standardized criteria for beach postings; and,
- develop a binational, systematic, centralized, and timely way to evaluate and report waterborne illness in the Great Lakes and track what is happening on the local, regional, state, provincial, and federal levels.



Environment Canada

“High numbers of fecal indicator bacteria and pathogenic organisms are among the reasons that a beach may be closed.”

WORK GROUP OBJECTIVES AND INVESTIGATION DURING THE 2009–2011 PRIORITY CYCLE

The Commission focused on two key issues from the Work Group's 2007–2009 report and decided to include these in its 2009–2011 priority cycle:

- the relationship between fecal indicator bacteria, including those from wildlife sources, and public health; and,
- management actions that improve beach quality, with special emphasis on controlling excess gull populations.

These issues relate directly to the need for relevant “tools” to assess nearshore conditions. The Beaches and Recreational Water Quality Work Group was charged under the priority with addressing these issues and undertook to:

- identify problems associated with current indicators of recreational water quality;
- locate, compile, and review existing information on the relationships between human health and the presence of fecal indicator bacteria from birds, other wildlife, and livestock at Great Lakes beaches.
- review and document beach improvement activities;
- identify priorities for research and implementation actions; and,
- develop relevant recommendations for the Parties' consideration.

To investigate these issues and to obtain insight and advice, the Work Group developed background information and consulted experts. Work Group activities included a beach experts workshop, development of six white papers on selected issue topics, and conduct of three evaluations of the qualitative and quantitative state of knowledge about avian effects on swimmers.

The Work Group convened a Beaches and Recreational Water Quality Expert Consultation, held in Erie, Pennsylvania on October 21–22, 2010. The consultation brought together a diverse group of recognized experts from a cross section of sectors—including representatives of the medical community, academia, governments, and industry—to discuss the state of the science, risks to human health, and management of recreational water quality.

The Work Group also commissioned six background reports that addressed recreational water quality monitoring in the Great Lakes; sources, persistence, and human health risk potential of waterborne pathogens and indicators; livestock as a source of pathogen contamination of Great Lakes beach water; avian impacts on recreational water quality; *Cladophora* as a source and sink of indicator bacteria and pathogens in the Great Lakes; and best management practices benefiting recreational waters.

Lastly, the Work Group established a second-order science (SOS) investigation focusing specifically on the impact of waterfowl on recreational water quality and associated public health risks. Three reports were prepared. An SOS analysis is described below.



Provision of advice associated with use of recreational waters and protection of human health requires data and information about sources of specific microbiological contaminants impacting a particular beach, the microbiological quality of the beach, and the incidence of human illness resulting from contact with the beach water and sand.

The Work Group's discussion and advice are presented below. Chapter 3 reflects the Work Group's priority advice and is accompanied by four ranked priority recommendations. Chapter 4 presents additional advice and three lower priority recommendations. The consultation, background, and SOS reports are listed in the Appendix. Copies are available on request from the Commission's Great Lakes Regional Office.

HUMAN HEALTH PROTECTION AND ILLNESS RELATED TO RECREATIONAL WATER EXPOSURE

Human Health Protection

Swimming in ambient recreational waters naturally carries a risk.

Epidemiological studies demonstrate that swimmers have a higher incidence of illness than non-swimmers, presumably from waterborne disease. However, an acceptable level of risk has not been established, nor is scientific consensus likely. Nonetheless, the heightened risk resulting from exposure to human sewage is recognized and well established.

Incidence of Illness Related to Recreational Water Exposure

Little relevant data and information exist about the incidence of illness resulting from recreational water exposure, and there is a disconnect between and among health professionals, researchers, planners, and others who may possess such information and those who would benefit from it.

Good data on the incidence of recreational water illness is not collected in a systematic way nor made available to front-line healthcare providers to raise their awareness of these illnesses. The absence of a credible illness database also impacts scientists who are studying potential causes of illness in beach users.

“...there is a disconnect between and among health professionals, researchers, planners, and others who may possess such information and those who would benefit from it.”

The Work Group recommends that the Parties:

- I. **Develop a mechanism to obtain, compile, and share existing information about human illness resulting from exposure to recreational water and/or beach sand.**

Through the Beach Act, the United States channels funds, coordinates standards, and gathers information. In Ontario, however, local agencies are responsible for beaches. The province would benefit from a similar coordinated program.

Overall, however, health data about incidence of human illness resulting from exposure to recreational water are limited.

Since many people who develop gastrointestinal illness do not seek treatment, the tracking of illness and compilation of relevant information is a challenge. However, information could be acquired through primary care surveillance and surveys of beach users. The Canadian College of Family Physicians has a cohort of doctors who gather information from patients one day a week and who forward that information to a central location. That model may be applicable for primary health care providers—emergency rooms, walk-in clinics, and family physicians—to gather information about water-related illness directly from patients at the time of treatment.

Adequacy of Information about the Cause of Human Illness Arising from Recreational Water Exposure

Current health data about the cause of illness experienced by beach visitors due to exposure to microbiological contaminants at beaches are not adequate.

Epidemiological studies converge on the conclusion that exposure to sewage poses a risk to human health. The linkage of risk to human health is weaker for other sources. The published literature addresses a range of point and non-point sources of *indicator* organisms, and some studies report illness outbreaks, but no relationship with water exposure is made. In addition, research to date has been unable to quantify the relationship between animal-derived fecal indicators and public health risk.

DISCUSSION AND RECOMMENDATIONS

The issue is, however, that links between *specific* pathogens that occur in beach water and the health of swimmers has not been firmly established. The inability to establish links is compounded by analytical challenges and the lack of data on specific pathogens in recreational water and beach sand.

“...links between specific pathogens that occur in beach water and the health of swimmers has not been firmly established.”

CONTAMINANT SOURCES

Microbiological quality at a beach reflects the characteristics of sources and land uses in the “beachshed.”

To identify contaminant sources and their significance, information is required about the “beachshed,” that is, the environmental characteristics of the watershed and land uses and human activities therein that contribute microbiological contaminants and interact with beach water. A wide spectrum of point and non-point sources and pathways contribute. Sources include municipal and industrial effluents, storm water runoff, combined sewer overflows, agricultural land runoff, concentrated animal feeding and other livestock operations, groundwater, waterfowl, wildlife, and domestic animals and even humans at beaches. Algae, beach sand, and mussels may be significant secondary sources. Sources and microbiological contaminants differ from one watershed to another, and the human health risk at beaches also differs. In particular, faulty septic systems are often overlooked as a significant source of microbiological contamination to groundwater, which often discharges at beaches in the Great Lakes basin.

Sewage, storm water, and combined sewer overflow outfalls are known significant sources of pathogens to beach and recreational waters. Without question, infrastructure remediation and implementation of

beneficial management practices (BMPs) for these sources would significantly improve microbiological water quality at recreational beaches. Climate change trends indicate that the Great Lakes will be exposed to more extreme and frequent storm events, increasing the occurrence and severity of potentially pathogenic loadings and releases via these pathways. In addition, expansion of urban land use increases the amount of impervious surface, reducing infiltration and compounding the above problems that are intensified by climate change.

Livestock manure contains bacteria and viral pathogens, but the extent to which contaminants from manure threaten human health at downstream recreational beaches is usually not considered. Selection and implementation of BMPs for manure storage must consider environmental persistence and transport of microbiological contaminants to downstream beaches.



Jake Rome, NRDC

Overall, the significance of most sources of microbiological contamination on beach and recreational water quality has not been established, and data are not available to identify and correlate potential sources with incidence of human illness. Some host-specific source tracking methods exist but require further validation. Determination of the significance of microbiological contaminant sources is confounded by other factors, including the level of risk associated with human fecal contamination compared with other animal sources, shoreline characteristics such as contour and water depth, and the interaction of hydro-meteorological conditions and recreational water quality.

The Work Group recommends that the Parties:

II. Develop and validate practical, rapid, reliable, and standardized methods to identify, track, and quantify pathogens and relevant indicators from all fecal sources.

The methods should be designed for binational implementation and must consider water, beach sand, and bottom sediment. Some studies are under way, but further research is necessary.

WATERSHED PLANNING AND COLLABORATION TO PROTECT BEACH USER HEALTH

Lakes and associated watersheds are invariably multi-use resources. Beach water quality and protection of human health are collective issues that must be incorporated into the environmental decision-making process regarding use and protection, including decisions for beach management and advisories. Informed decision making requires the sharing and merging of environmental, health, scientific, and other data sets. Water and beach managers, health authorities, the research and scientific community, and watershed planners and managers must communicate and cooperate, for example, through a multi-disciplinary team approach. In addition to data access and sharing, networking would facilitate communication about issues, responsibilities, and responses. Watershed planners and beach managers would, for example, better understand and appreciate that requirements and actions taken by one can benefit both.

To elaborate, sanitary surveys and watershed management plans contain relevant information about watershed characteristics, land uses, and human activities. Assessment of data and information leads to identification of principal remediation actions and implementation of targeted beneficial management practices (BMPs) tailored to remediate and protect not only particular watersheds but also to protect beach recreational water quality. Decision-makers would benefit from a “tool box” that contains information about sources, potentially applicable remedial

measures and BMPs, and the extent of past success of such measures to protect human health during use of recreational water.

Remedial measures and BMPs implemented upstream in a watershed are usually keyed or customized to the types of contaminant sources identified, their applicability and feasibility, and their effectiveness to address those particular watershed issues. The consequences for beach quality are not taken into account. Again, a significant challenge is to communicate and create awareness that all watershed interests, including those well upstream in a watershed, have a stake in, and contribute to improvement of downstream water quality. Because upstream watershed sources impact downstream beaches, microbiological quality of downstream recreational waters must be a criterion in the process to select, fund, and implement remedial measures and BMPs. A “tool box” and decision tree approach can facilitate decision-making. Beach-related cost-benefit analysis ties in to watershed management planning. Cost-benefit analysis must also take into consideration microbiological contamination arising at the beach from gulls, people, and poor facility and beach design.



Overall, the development of a nearshore adaptive management framework would improve current governance structures by integrating the efforts of the multiple stakeholders involved, including watershed planners and beach managers, in protecting beaches in the Great Lakes basin

ADEQUACY OF MICROBIOLOGICAL MONITORING

***E. coli* and other currently monitored indicators provide a good base for tracking water quality changes but do not necessarily represent health risk. These indicators are not adequate to establish exposure and to assess and protect human health, nor do they detect the presence of viral or other pathogens or illness associated with exposure to recreational water. The fate of *E. coli* in the environment is not well characterized and the time frame for analysis is too long. At present, analysis takes at least 18 hours, rendering resulting data essentially useless for same-day beach management decisions. Management practices to reduce *E. coli* do not necessarily reduce risk.**

Science and research must shift to identify and quantify specific pathogens that cause human illness and establish the ability of those pathogens to impact human health. Basic information is required about which pathogens present a risk to human health at a particular beach. This, in turn, necessitates information about land use and human activities in the watershed that impact a particular beach, as well as information about actual illness that results from recreational use of a given beach. Such information would allow development of monitoring protocols tailored to protect human health. The procedures can be customized, based on identified needs at a particular beach. Sample collection and analysis must provide real or near-real time, user friendly, and comparable data among beaches and across jurisdictions.

At present, limited understanding of health risks associated with recreational water quality derives from a handful of studies at specific beaches. The studies indicate that health risks vary widely in manifestation and severity.

Regulations in both Canada and the United States mandate use of *E. coli* and other indicators long recog-

nized to be of limited value. Science and decision-making needs have moved far beyond regulations promulgated on growth of microbial indicators. Indicators must be directly linked to pathogen presence, abundance, viability, and infectivity. Monitoring must be conducted for pathogens that reflect the characteristics of the watershed that impacts a specific beach.



Robert F. Beltran, EPA

Key research needs are enumerated here. Studies must:

- determine whether pathogens associated with *E. coli* and other indicators are similarly affected by environmental processes occurring at beaches;
- understand processes influencing survival and infectivity of pathogens in water and beach sand;
- understand the risk associated with pathogens;
- determine the role of “naturalized” pathogens living in the beach environment;
- establish infective dose-response relationships;
- compare risks across different types of beaches;
- assess the influence of swimmers themselves on recreational water quality;
- characterize incidental exposure and pathogen occurrence; and,
- determine health risk associated with non-point sources and contact with beach sand.

The Work Group recommends that the Parties:

III. Develop information that will provide understanding about the occurrence of pathogens and the associated risk to humans at recreational beaches.

WATERFOWL

Effective management of beaches at which waterfowl are a significant contributor of microbial contamination requires a thorough understanding of their impact on recreational water quality and, in turn, on human health. In particular, the large number of gulls present at many recreational beaches poses a concern. Gulls can acquire microbial contaminants during exposure to contaminated areas. However, because of the wide range of feeding locations and habitats—including *Cladophora* mats, landfills, and livestock pasture land—the types of microbial contaminants that gulls might acquire is not well established. Likewise, the types of pathogens and the risk to beachgoers are also poorly understood.

Several studies addressing waterfowl impact have been published, but their conclusions often pertain only to local conditions and are, therefore, sometimes contradictory. The Work Group established a second-order science (SOS) investigation to determine if the published studies, taken collectively, might provide additional insight. An SOS analysis, a type of meta analysis, is the statistical analysis of a collection of analytic results for the purpose of integrating the findings to produce a generalized estimate of the effect of a particular factor, not possible to determine from using the results of individual studies in isolation.



Literature reviews were undertaken to identify studies investigating:

- the source and/or distribution of fecal indicator bacteria or pathogens at recreational beaches;
- the impact of waterfowl on a surface water body;
- the prevalence, incidence, or risk of developing adverse health effects or illnesses associated with recreational water quality exposure; and,
- contaminant sources through various source tracking techniques or the development and application of waterfowl markers.

Details are contained in the three SOS reports listed in the Appendix. The findings and conclusions drawn from the SOS analyses were:

Despite increased investigation of the impact of waterfowl on beach health in recent years, adequate data do not exist to establish the link between waterfowl fecal contamination and adverse human health effects. However, the existing literature does provide evidence to establish that waterfowl can be a significant source of indicator bacteria at beaches.

There is a need to conduct an epidemiological study to assess swimmer health risk. Seasonal fluctuations and geographic differences must be taken into account. The research should investigate the gastrointestinal flora of wild birds, catalogue and quantify the fecal and pathogen contributions of waterfowl to beach and recreational water environments, and establish the ability of avian fecal material to be transported within and among beaches.

If properly designed and conducted, the findings at specific geographic locations can be extended and applied to other locales. With information confirming links, adaptive management strategies can be devised and implemented to deter waterfowl at beaches and thereby contribute to protection of human health.

The Work Group recommends that the Parties:

IV. Determine the impact of waterfowl on recreational water quality and the potential risk for adverse human health effects.

DATA AND INFORMATION REQUIREMENTS FOR PROVISION OF ADVICE

Regulatory agencies are developing criteria and models that forecast recreational water quality, but limited data availability could preclude their application for a panoply of pathogens. Monitoring protocols, numerical standards, and criteria for pathogens newly introduced to the decision-maker's "tool box" should be consistent and afford equivalent protection across all Great Lakes jurisdictions. The Annapolis Protocol, developed under the auspices of the World Health Organization Health Organization, provides a framework for action. Significant challenges to better monitor pathogens and measure health risk are the cost and the sensitivity of methodologies and the speed of conducting tests.

Supplemental tools to detect both animal and human sources of pollution are under development. Molecular markers will greatly help track microbial sources and allow public agencies to better assess risk and remediate pollution sources. In addition, revision of recreational water quality criteria—using health-based risk assessments—is under consideration by the United States. Epidemiological studies have been completed for the U.S. portion of the Great Lakes basin, and follow-up research is under way. Real-time measurements and posting are under development. These include molecular techniques, real-time nowcasting modeling, and sanitary surveys. Web-based notification to inform the public of a beach advisory is under way or planned. The Parties should encourage this research and implement this technology when appropriate.

The Work Group recommends that the Parties:

- V. Encourage the use of supplemental tools so that beach managers can make accurate decisions about beach postings in order to protect public health.**

COMMUNICATION OF RISK AND SAFETY TO THE PUBLIC

Various mechanisms are used to communicate information about recreational beach water quality and associated human health risk to the public: signage, brochures, hot lines, Internet web sites, and social marketing tools. However, information does not necessarily reach beach users. Further, information is often untimely, not well understood, and incomplete and, as such, a disservice.

To communicate possible human health effects resulting from exposure to microbiological contaminants in beach water and sand, scientific and technical information must be translated into clear, non-technical, common sense terms. Sound information must be based on specific relevant pathogens and provided in a timely manner through mechanisms accessible to and used by the public. Simple communication tools, such as universal signage, would allow the public to make informed decisions about an acceptable level of risk to them personally. Feedback is required to determine beach user awareness of the communication tools and their perception and understanding of the risk associated with recreational beach activities. Several local predictive modeling projects, including the Illinois Swimcast, Indiana Safe, and Ohio Nowcast systems may be worthwhile to implement at other beaches within the Great Lakes basin.

The "tool box" must contain necessary and sufficient information that will assist beach managers to make sound decisions. The "tool box"—preferably interactive and web-based—should contain information about fecal indicator bacteria; pathogens; source tracking markers such as viruses, fungi, protozoa, and parasites; the ability of a pathogen to cause infection; and prior beach sanitary surveys and ecological assessments that impact decision-making. The "tool box" should be applicable across the basin, but managers must have the latitude to choose measures appropriate to local conditions and considerations.

ADDITIONAL DISCUSSION AND RECOMMENDATIONS

Some predictive models are available to supplement limited monitoring and enhance decision-making, but current models are calibrated against indicators. Models developed and validated against health outcomes would provide a valuable tool contributing to better prediction of water quality and health risk, thereby better protecting human health.

"Various mechanisms are used to communicate information about recreational beach water quality and associated human health risk to the public: signage, brochures, hot lines, Internet web sites, and social marketing tools. However, information does not necessarily reach beach users. Further, information is often untimely, not well understood, and incomplete and, as such, a disservice."

The Work Group recommends that the parties:

- VI. Integrate Canadian and U.S. beach monitoring data bases and develop approaches to effectively communicate relevant information about recreational water quality risks to the public.**



GREEN ALGAE (CLADOPHORA)

Cladophora has been a long-standing beach-fouling issue in the Great Lakes. Although historically an aesthetic problem, *Cladophora* mats are both a reservoir and a source of microbiological contaminants. However, the significance for recreational water quality and the potential for impact on human health is unclear. Such information would facilitate the selection and implementation of relevant remedial measures to protect recreational water quality.

The Commission's Nuisance Algae Priority Work Group is working on this nearshore issue. Harmful algal growth is a cross-cutting issue that, for the first time in many years, is re-emerging as a concern for beach safety and human health.

CYANOBACTERIA (BLUE-GREEN "ALGAE")

Grand Lake St. Mary, Ohio's largest inland lake, is a case study that demonstrates the link between cyanobacterial blooms and beach recreational water quality. Grand Lake St. Mary is experiencing prolific growth of harmful cyanobacteria as a result of excess loading of nutrients, organics, and sediments to the lake. Phosphorus, the primary contributor to blooms in this lake, has created a hypereutrophic ecosystem with phosphorus levels exceeding 100 micrograms per litre. The cyanobacteria can produce neurotoxins and hepatotoxins that attack the nervous system and the liver, leading to concern for human health. *Microcystis* is a group of cyanobacteria that produces toxins and that emerged in Grand Lake St. Mary in 2010. As a result, the Ohio Department of Natural Resources has issued several water quality advisories including a no-contact advisory, a toxin advisory, and a bloom advisory.

The Work Group recommends that the Parties:

- VII. Establish the microbiological significance and impact of nuisance algae and cyanobacteria on recreational water quality.**



CHALLENGES

Implementation of the Work Group's advice will ensure that people are better protected from microbiological contaminants that harm human health. The Work Group acknowledges the challenges posed by political obstacles, regulatory constraints regarding which microbiological indicators to measure and how to measure them, and funding limitations to expand or modify monitoring and reporting protocols. The Work Group believes that, with the current renegotiation of the Agreement, the Parties will take into consideration what is in the best interest of the Great Lakes and its residents, and be more favorably disposed to act on the advice provided.



Jennifer Janson

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APPENDIX

List of reports prepared for the beaches and recreational water quality work group

Expert Consultation

- Report on the International Joint Commission Beaches and Recreational Water Quality Work Group Expert Consultation

Background Reports

- Recreational Water Quality Monitoring in the Great Lakes: A Status Report. Prepared by Matthew Kerwin.
- Waterborne Pathogens and Indicators: An Overview of Sources, Persistence, and Associated Human Health Risk Potential. Prepared by R.M. Slawson.
- Livestock as a Source of Pathogen Contamination of Beach Water in the Great Lakes. Prepared by Colleen M. McDermott.
- Avian Impacts on Recreational Water Quality. Prepared by Gregory T. Kleinheinz and Kimberly Busse.
- *Cladophora* as a Source and Sink of Fecal Indicator Bacteria and Pathogens in the Great Lakes. Prepared by Satoshi Ishii and Michael J. Sadowsky.
- A Review of Best Management Practices Benefitting Great Lakes Recreational Waters: Current Success Stories and Future Innovations. Prepared by Adrian Koski and Julie Kinzelman

Second Order Science Reports

- Second Order Scientific Evaluation of the Impact of the Abundance of Waterfowl on Recreational Water Quality and Associated Public Health Risks. Prepared by Cheryl Fossani.
- IJC1: Assessing Pathogenic Risk to Swimmers in the Great Lakes. Prepared by Tegan Porter, Anthony Lapp, and Jess Tester.
- Human Health Risks Attributed to Waterfowl Abundance at Beaches within the Great Lakes Basin. Prepared by Adrienne Ball, Megan Donahoe, and Deanna Lacharity.

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