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Ontario and Prairie Region

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THRESHOLD APPROACHES AND STATUS OF METRICS SELECTED TO REPORT ON THE STATE OF FISH AND FISH HABITAT IN THE ONTARIO AND PRAIRIE REGION PRIORITY AREAS: PART 2

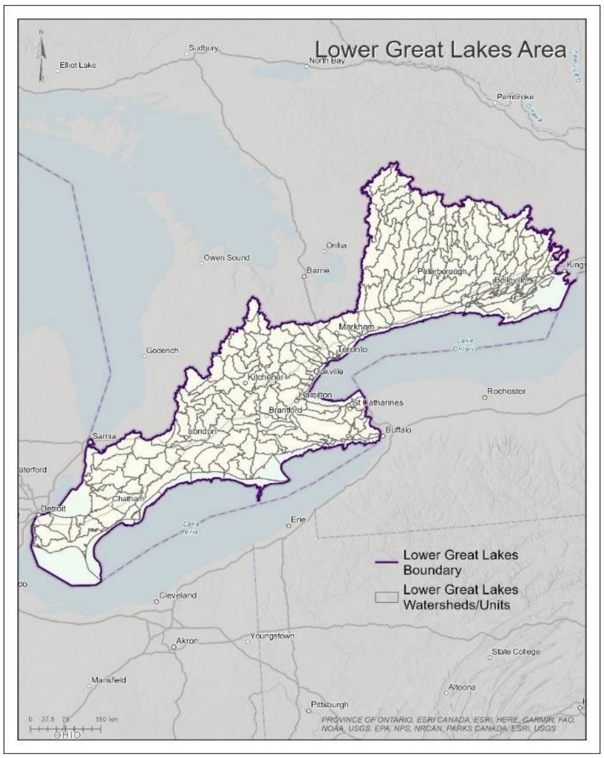

Figure 1. Map of the Lower Great Lakes priority reporting area.

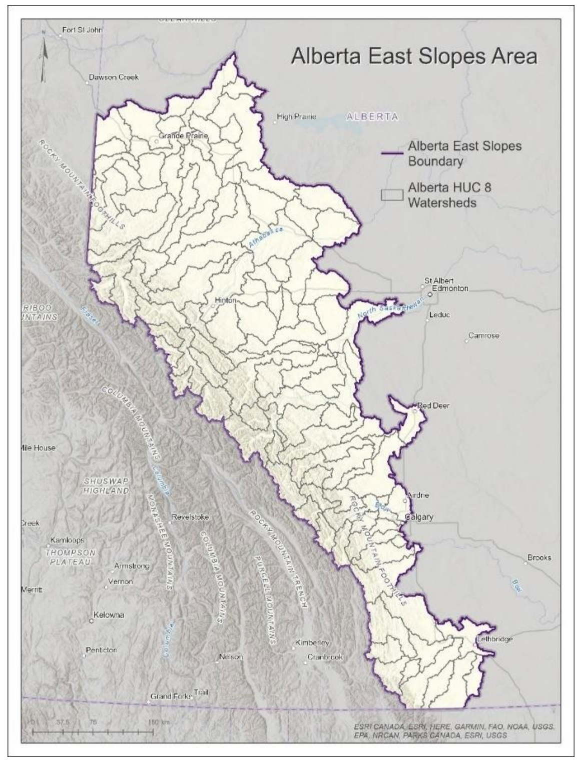

Figure 2. Map of the Alberta Eastern Slopes priority reporting area.

Context:

Fisheries and Oceans Canada (DFO) has committed to area-based reports on the State of Fish and Fish Habitat (SOFFH) in Canada by March 31, 2023. As part of this initiative, the Fish and Fish Habitat Protection Program (FFHPP) in the Ontario & Prairie (O&P) Region have selected two (2) priority areas to develop their own SOFFH reports: the Lower Great Lakes Area in Ontario, and the Eastern Slopes Region of Alberta. Based on an earlier CSAS peer-review meeting, five (5) indicators: biodiversity, water quality, connectivity, land use, and climate change were established, which would be quantified for each assessment unit (e.g., watersheds) within the two reporting areas. This Science Advice was requested to provide FFHPP with summaries of the metrics and indicators in each reporting area, as well as science advice on approaches that can be used to define classification schemes and associated thresholds for reporting on the SOFFH. In addition, science advice on quantifying and assessing the SOFFH is provided along with approaches to address uncertainties and fill knowledge gaps in the future.

This Science Advisory Report is from the August 23–25, 2022 regional peer review on Threshold Approaches and Status of Metrics Selected to Report on the State of Fish and Fish Habitat in the Ontario and Prairie Region Priority Areas: Part 2. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A synthesis of the available and relevant data on the State of Fish and Fish Habitat in the Ontario and Prairie Region (SOFFH-OPR), that focused on the Lower Great Lakes and Alberta East Slopes priority reporting areas, was conducted based on previously selected indicators (Biodiversity, Water Quality, Connectivity, Land Use and Land Cover, and Climate Change) and their constituent metrics (2 to 6 per indicator).
- The value of SOFFH-OPR metrics in the Lower Great Lakes and Alberta East Slopes varied among reporting areas and assessment units, but generally reflected geographical patterns in species richness and habitat, and the effects of agriculture, urbanization, resource extraction, and other development on watersheds.
- Data gaps limited reporting and led to uncertainty in the SOFFH-OPR for some metrics and assessment units. These gaps could be filled, and uncertainties managed, through increased spatial and temporal sampling and the continued development of standardized monitoring programs towards the measurement of metrics that influence and are sensitive to changes in aquatic ecosystem health.
- Overall scores of the SOFFH-OPR for each assessment unit or reporting area were not produced for this report. Combining metrics and indicators would require decisions related to the weighting of metrics to generate the overall scores. Additionally, the indicators and metrics selected may be differentially important to the various species, life stages, and habitat features.
- The development of reporting thresholds and classification schemes is not a requirement for reporting on the state of ecosystems (including SOFFH-OPR), but can support objectivity, simplify communication with non-specialist audiences, and can help to integrate data from multiple jurisdictions. However, developing classification schemes is associated with several challenges including ignoring important differences among habitat types, and exaggerating differences among data points that fall close to, but on opposite sides of, a reporting threshold value.
- Classification schemes for reporting on the SOFFH could be based on functional relationships with management objectives, thresholds established in other guidelines, policy, regulations or other reporting initiatives, relative ranking, or expert opinion.
- Where management objectives are quantitatively defined, and the relationship between management objectives and metrics is known, developing classification schemes based on management objectives is the recommended method as it allows for SOFFH reporting to be aligned with management activities. Comparing multiple metric approaches is valuable to ensure synergy across management and ecosystem objectives and thresholds.
- Reporting thresholds (i.e., values of a metric used to define different categories of ecosystem state) are not necessarily equivalent with ecological thresholds (i.e., values of a metric beyond which ecosystems show rapid or categorical change, also known as ‘tipping

points'). Not all metrics or indicators demonstrate ecological thresholds, and even when they exist, it will not always be appropriate to equate the two concepts.

- Reporting on the SOFFH-OPR should be accompanied by reporting on the quality, uncertainty, and representativeness of data. Similar reporting initiatives have used checklists that include sample size, the recency and temporal range, and the geographic coverage of the dataset to estimate the quality of data.
- Data quality considerations for SOFFH-OPR could include power analyses, species accumulation curves for fish species richness, and evaluation of data resolution and monitoring design.
- Data limitations and challenges with developing reporting thresholds resulted in a number of uncertainties related to the metrics within the reporting areas of SOFFH-OPR. Improved and expanded geospatial data, targeted research, and adaptive management can address uncertainties and knowledge gaps.
- The information presented here is a synthesis of data related to the current SOFFH-OPR. As conditions, environmental drivers, and scientific knowledge change, the SOFFH in the two reporting areas are likely to change and may need to be reassessed.
- Reporting on the SOFFH-OPR should also be informed by other sources of knowledge (including Indigenous and local knowledge), which could help address informational gaps and inform our understanding of historical and desired ecosystem states.

BACKGROUND

Fisheries and Oceans Canada (DFO) has committed to area-based reports on the State of Fish and Fish Habitat in Canada that will provide information about various areas across the country. DFO regions have independently developed their approaches for this reporting. Fish and Fish Habitat Protection Program (FFHPP) in the Ontario & Prairie (O&P) Region selected two (2) reporting areas to develop SOFFH reports: the Lower Great Lakes Area in Ontario and the Eastern Slopes Region of Alberta. These first State of Fish and Fish Habitat reports for O&P Region (SOFFH-OPR) were developed independently and will be combined with reports from other DFO regions in a national report in the future.

The Lower Great Lakes Area (LGLA) includes the area of southern Ontario where the watersheds drain into Lake Ontario and Lake Erie (Figure 1). The Alberta Eastern Slopes Area (AESA) encompasses the east slopes of the Rocky Mountains (Figure 2). The two reporting areas represent different ecozones and are influenced by both similar and differing pressures and activities. Though the intention of this science advisory process was not to compare the state of these reporting areas to each other, the differences between the two areas added to the evaluation of how the selected indicators and measures contribute to defining the SOFFH-OPR.

This science advisory process was the second part of a larger science advice effort to support the SOFFH-OPR. The first part consisted of a meeting on June 29–30, 2021, to establish possible indicators, metrics, and available data for the SOFFH-OPR (DFO 2022). Building on those findings, the focus of this second part of the process was to provide science advice about the application of available data to define the state of indicators and metrics for the selected reporting areas (LGLA and AESA). This second part also considered approaches to define classification schemes and associated thresholds for reporting on the state of fish and fish habitat.

The objectives of the Terms of Reference for this science advisory process were to: (1) present a synthesis of the available data and status of each environmental metric within the LGLA and AESA; (2) review the approaches used to categorize the status of each environmental metric, including approaches to determine threshold values for reporting; (3) review approaches used to categorize data quality for reporting on the SOFFH-OPR; and (4) identify uncertainties and knowledge gaps with respect to data availability and the methods used for developing classification schemes for the SOFFH-OPR.

This science advisory process involved the review of two Research Documents. The first Research Document, “Preliminary assessment of the State of Fish and Fish Habitat in Fisheries and Oceans Canada’s Ontario and Prairies Region” (Dey et al. in prep.[1]), presents the data gathered for the two reporting areas and provides both quantitative and visual analyses of the five indicators (described below). This document meets objectives 1 and 4 of the Terms of Reference. The second Research Document, “Methods for Establishing Classification Schemes and Thresholds for Reporting on the State of Fish and Fish Habitat” (Dey and Chu 2023) supports objectives 2 and 3 of this process by providing an overview of methods that could be of general use to this type of reporting, in most cases regardless of reporting areas.

ASSESSMENT

Objective 1 - Present a synthesis of the available data and status of each environmental metric within the Lower Great Lakes and East Slopes of Alberta reporting areas

Dey et al. in prep.[1] characterized the indicators in the two reporting areas and provided a synthesis of the available data for the chosen indicators and metrics that corresponded to this objective.

The analyses considered the state of five indicators for both of the reporting areas: biodiversity, water quality, connectivity, land use and land cover, and climate change. For each indicator, a set of metrics were selected as the specific variables to be quantified (Table 1). Most metrics were evaluated at the scale of assessment units, which were smaller spatial units nested within each reporting area. Watershed units were used as the assessment units for the two reporting areas, with quaternary watersheds and nearshore regions in Lake Ontario and Lake Erie used for the LGLA and Hydrologic Unit Code level 8 watersheds used for the AESA. The specific metrics used for each indicator were consistent between both reporting areas, except when data limitations did not allow for the evaluation of the metric in both reporting areas.

In both the LGLA and AESA, biodiversity was quantified using the metrics of: fish species richness; benthic invertebrates (the Ephemeroptera, Plecoptera and Trichoptera (EPT) index); Species At Risk (SAR) richness; and Aquatic Invasive Species (AIS) richness. In the LGLA, water quality was quantified using concentrations of chloride, nitrates, total phosphorus as well as conductivity, dissolved oxygen and temperature, whereas the water quality metrics for the AESA were chloride, conductivity, dissolved oxygen and temperature. For the LGLA, connectivity included density of waterfalls, dams, fishways, stream crossings, as well as a measure of barrier passability. These connectivity metrics were also summarized in the AESA, but an additional stream connectivity metric was also evaluated. The indicator land use and land

[1] Dey, C.J., Matchett, S., Doolittle, A., Jung, J., Kavanagh, R., Sobowale, R., Schwartz., and Chu, C. In prep. Preliminary assessment of the State of Fish and Fish Habitat in Fisheries and Oceans Canada’s Ontario and Prairies Region. Can. Sci. Advis. Sec. Res. Doc.

cover were represented in both areas by the type of land use and land cover, the proportion of disturbed cover within 30 m of waterbodies, the density of roads, and proportion of protected areas in the assessment units. The types of protected areas considered for this science advisory process included national, provincial and territorial parks, as well as designated wildlife areas and private land holdings that restrict human activity and are managed as such. Finally, the climate change metrics for both areas included forward and backward bioclimatic velocities and projected floodplain and flood heights.

Table 1. Metrics used for the SOFFH-OPR for each indicator for both reporting areas.

Indicator	LGLA metric	AESA metric
Biodiversity	Fish species richness EPT index Species at risk richness Aquatic invasive species richness	Fish species richness EPT index Species at risk richness Aquatic invasive species richness
Water quality	Chloride Conductivity Dissolved oxygen Nitrates Total phosphorus Temperature	Chloride Conductivity Dissolved oxygen Temperature
Connectivity	Waterfall density Dam density Fishway density Barrier passability Stream crossing density	Waterfall density Dam density Fishway density Barrier passability Stream crossing density
Land use and land cover	Land use and land cover types Riparian cover Protected areas Road density	Land use and land cover types Riparian cover Protected areas Road density
Climate change	Bioclimatic velocities Projected flood area and heights	Bioclimatic velocities Projected flood area and heights

Some data syntheses were conducted based on feedback from participants in part 1 of this science advisory process (DFO 2022). The remaining data were located and accessed through scans of relevant jurisdictions who may have existing data (e.g., provincial government departments, publicly available databases). As outlined above, most metrics used for these analyses were the same across the two reporting areas, but differences in some of the metrics represented variation in the data available between the LGLA and AESA. Efforts were made to ensure that common metrics across the reporting areas were analyzed and depicted in the same way. Some exceptions to uniformity in data quality between the two reporting areas were noted, e.g., water quality, where more sites were sampled for these metrics in the LGLA. Additionally, the sampling distribution (or representativeness) for these two metrics was uneven within both reporting areas, with more samples concentrated in urban zones of the reporting areas and some data had samples that were constrained to short time periods or specific seasons (e.g., the summer fieldwork season). These differences do not impact the overall conclusions of the SOFFH-OPR, but represent caveats to the interpretation of the SOFFH-OPR results.

Dey et al in prep.[1] summarized all the available data (Table 2) and provided a summary of the patterns found in both reporting areas. The work revealed variations in the metrics across the assessment units within both areas that generally corresponded to biogeographic differences in aquatic biodiversity and habitats (e.g., colder temperatures at higher elevations/latitudes and other geographic differences). The metrics did reflect the impacts of different land uses, including agriculture, urbanization, resource extraction, and other development on fish and fish habitats in watersheds.

Table 2. Summary of data compiled for the SOFFH-OPR. Minimum (min), median and maximum (max) values are shown for each metric, for each reporting area (LGLA = Lower Great Lakes Area, AESA = Alberta East Slopes Area). 'NA' indicates that data were not available for that metric within that reporting area. '-' indicates that data were available, but cannot be described in terms of a minimum, median and maximum value. See Dey et al. in prep.[1] for details.

Indicator	Metric	Scale of Evaluation	LGLA			AESA		
			Min.	Median	Max	Min	Median	Max
Biodiversity	Fish species richness	Assessment unit	8	47	103	1	17	32
	EPT index (%)	Sampling site	0	23.4	79.2	2.5	86.9	99.1
	Species at risk richness	Assessment unit	0	3	31	0	1	3
	Aquatic invasive species richness	Assessment unit	0	1	6	0	0	2
Water quality	Chloride (mg/L)	Sampling site	0.4	42.1	606	1.15	1.8	12
	Conductivity (μS/cm)	Sampling site	8	471	2,405	146	332	1,252
	Dissolved oxygen (mg/L)	Sampling site	2.3	9.8	13.4	4.94	10.3	11.42
	Nitrates (NO_3-N/L)	Sampling site	0.118	1.76	11.7	NA	NA	NA
	Total phosphorus (mg/L)	Sampling site	0.005	0.03	2.38	NA	NA	NA
	July-August Average Water Temperature (°C)	Sampling site	11.2	21.8	26.1	10.1	16.3	20.0

Indicator	Metric	Scale of Evaluation	LGLA			AESA		
			Min.	Median	Max	Min	Median	Max
Connectivity	Waterfall density (per 10 km river length)	Assessment unit	0	0	0.28	0	0	0.22
	Dam density (per 10 km river length)	Assessment unit	0	0.11	3.95	0	0.004	1.1
	Fishway density (per 10 km river length)	Assessment unit	0	0	0.16	0	0	0.008
	Barrier passability	Sampling site	-	-	-	-	-	-
	Stream crossings (per 10 km river length)	Assessment unit	0	5.3	30.3	0	1.2	15.4
	Stream connectivity metric (%)	Assessment unit	NA	NA	NA	14.9	44.9	99.9
Land use and land cover	Land use and land cover types	Pixel	-	-	-	-	-	-
	Riparian buffer disturbance (%)	Assessment unit	0	52.2	100	0	0.58	78.0
	Protected area coverage (%)	Assessment unit	0	0.05	78.8	0	0.6	100
	Road density (km/km^2)	Assessment unit	0.14	1.24	9.88	0	0.37	4.24
Climate change	Forward bioclimatic velocity for RCP 4.5 (km/year)	Assessment unit	1.60	3.12	5.31	1.19	2.56	12.52
	Forward bioclimatic velocity for RCP 8.5 (km/year)	Assessment unit	2.8	4.96	9.76	2.2	4.2	16.6
	Backward bioclimatic velocity for RCP 4.5 (km/year)	Assessment unit	1.6	2.7	11.06	0.59	2.43	5.31
	Backward bioclimatic velocity for RCP 8.5 (km/year)	Assessment unit	2.55	4.72	9.61	0.8	2.99	7.62
	Projected flood area and flood heights for 100 year flood	Pixel	-	-	-	-	-	-

Biodiversity

LGLA

Fish species richness varied from 8–103 species in the assessment units of the LGLA, with a median of 47 fish species per assessment unit. There was higher fish species richness in the Lake Erie watersheds compared to the Lake Ontario watersheds, with the lowest richness noted in the more northern areas of the reporting area. The EPT index ranged from 0% to 79.2% with lower EPT values in urban and agricultural sites of the LGLA. The number of fish and mussel SAR were also higher in the Lake Erie watersheds with up to 31 SAR. The number of AIS also displayed this pattern with a higher number recorded in the Lake Erie watersheds (maximum of six species).

AESA

Fish species richness ranged from 1–32 species with a median of 17 in the AESA assessment units. Fish species richness tended to be lower in the higher altitude, mountainous regions and greater in the eastern assessment units, principally foothill and prairie habitats. The majority of EPT index sites were within the western region of the reporting area, but for those sites where it was available, the index was greater in more mountainous areas. SAR richness was generally low for this reporting area with a maximum value of three SAR per assessment unit and a median of only one SAR per assessment unit. However, because some assessment units had relatively low total fish species richness, SAR made up a large proportion of the fish species in some assessment units. The listed AIS in this reporting area were limited to Prussian Carp (*Carassius gibelio*) and Goldfish (*Carassius auratus*).

Water quality

LGLA

Chloride concentrations were shown as higher in the western and central areas of the reporting area, with the highest values around the Greater Toronto Area and the city of Windsor. As per water quality guidelines for the protection of aquatic life, set by the Canadian Council of the Ministers of the Environment (CCME), 81.8% of sites with chloride data in the reporting area had a median value that met this guideline. For conductivity, eastern sites had lower conductivity and many sites in the western regions of the reporting area had sites that surpassed the 500 µS·cm-1 recommended for healthy aquatic systems. Dissolved oxygen was another metric where there is a recommendation for healthy aquatic systems (minimum value of 6 mg·L-1). For the LGLA, approximately 97% of sites sampled exceeded this minimum. Some sites in Prince Edward County were notable exceptions, where some measurements below this value were recorded. For the other two nutrients analyzed, nitrate and total phosphorus, concentrations varied across the reporting area with nitrate concentrations being the highest in the western regions, and with 65.7% of sites having nitrate concentrations that did not exceed the threshold that is considered environmentally healthy for nitrates. Total phosphorus also varied across the landscape with 51% exceeding recommended environmental thresholds. Finally, water temperatures were also variable, with average summer temperatures ranging from 11.2 °C to 26.1°C. Data were not readily available for other seasons.

AESA

Chloride concentrations for the AESA were highest near the cities of Calgary and Lethbridge though none of the chloride measurements in any of the assessment units exceeded the 120 mg L-1 threshold for protection of aquatic life. In this reporting area, conductivity values increased on a gradient from west to east, with five sites near urban centers (out of 55 total sites for this metric) having measurements that did not meet the recommended protective threshold for aquatic life. Dissolved oxygen varied across the reporting area but only one site for the whole area was found to be below the recommended minimum value of 6 mg L-1. Average summer water temperatures ranged from 10.06 °C to 20.02 °C.

Connectivity

LGLA

Waterfall density was expressed as the number of waterfalls per 10 km stretch of river/stream length, with assessment units in this reporting area varying from 0–0.278 waterfalls for the 10 km stretch. Waterfall presence does not represent an anthropogenic pressure but influences the maximum connectivity possible within some of the assessment units and may still be a barrier to passability for some aquatic organisms. Dam density was greater than waterfall density in 78% of the assessment units, with values up to four dams per 10 km stretch of river in some assessment units. In total, 2,262 of the total 2,452 dams and waterfalls in the LGLA are known to act as barriers to fish passage and there are also many dams where their capacity to act as barriers is uncertain. 75% of assessment units had crossing densities of greater than 3.7 crossings per 10 km of stream length.

AESA

Aquatic connectivity in the western part of the AESA was limited by waterfalls, with up to 0.22 waterfalls per 10 km stream length (this part of the area also corresponds with more mountainous terrain). The eastern part of the AESA had assessment units with up to 1.1. dams per 10 km stream length. In total, 26% of the assessment units across the whole reporting area had no dams, waterfalls or fishways. Stream crossing density was highest near urban areas with up to 15.4 crossings per 10 km of stream length, and a median of 1.2 crossings per 10 km stream length.

Land use and land cover

LGLA

Tree cover, flooded vegetation and crop cover were common land covers in this reporting area, along with significant built areas around the many large urban centers. Road coverage varied but was highest for assessment units near western Lake Ontario and eastern Lake Erie. Percent natural cover for riparian areas had a median value of 47.8% with only 25.1% of assessment units in the LGLA exceeded the 75% natural cover. Nearly half, 48.2%, of the assessment units in LGLA had no protected areas.

AESA

There was considerable spatial variability in land use and land cover across the AESA with trees and snow/ice dominating the western and northeast regions, and a mix of rangeland and crops in the other assessment units. Road density in the AESA varied with a median value of 0.37 km/km2. Only 1.9% of assessment units in the AESA contained no roads. Riparian areas in the AESA had a high percentage of natural land cover, with 83% of assessment units having riparian areas that exceeded 75% natural land cover. Protected area coverage in the AESA varied from 0–100%, indicative of the large national parks (i.e., Banff and Jasper National Parks) covering some of this reporting area (and some whole assessment units).

Climate change

LGLA

For the two emissions scenarios considered, forward bioclimatic velocities ranged from 1.6 km·yr-1 to 9.8 km·yr-1, with the higher velocities being in the Greater Toronto Area as well as in northern regions. Backward velocities ranged from 1.6 to 11.1 km·yr-1 with faster velocities in the southwestern assessment units and assessment units along the shore of Lake Ontario. Total flood volume is predicted to increase under both emissions scenarios in the LGLA.

AESA

Forward bioclimatic velocity in the AESA ranged from 1.2 km·yr-1 to 16.6 km·yr-1 while backward bioclimatic velocities ranged from 0.59 to 7.62 km·yr-1 for the two emissions scenarios. The emission scenarios considered for the AESA had limited impact on 100-year flood extent for these assessment units and total flood volume could slightly decrease for this area.

Status Assessment

Dey et al. in prep.[1] concluded that while the data synthesis provided significant information about the status of fish and fish habitat in each reporting area, they could not assign a classification to the status of each metric as called for in Objective 1. This review concludes that an overall status classification was not possible for two main reasons:

1. it is very difficult to tease apart the relative importance of the various metrics to different species and habitats within the reporting areas (e.g., species with migratory life history may be more impacted by fragmentation than those with resident life histories); and,
2. combining the measurements and values for all metrics into one master designation would involve numerous decision points, both from the perspective of scientific implications of generalizing or simplifying across metrics (e.g., weighting metrics) as well as differential data availability across assessment units, which could lead to low confidence in the assigned classifications.

Dey and Chu 2023 take up the issue of classifying the status of metrics in the second Research Document of this review.

Objective 2 - Review the approaches used to categorize the status of each environmental metric, including approaches to determine threshold values for reporting

While the analysis of the metrics within this science advisory process did not allow the overall designation of the state of each indicator for each reporting area, the second research document (Dey and Chu 2023) evaluated classification schemes that could be used to report on the state of fish and fish habitat within specific assessment units or reporting areas, depending on the overall objective of the reporting. Four methods for establishing classification schemes and reporting thresholds were suggested and discussed: using functional relationships with management objectives, use of existing thresholds or guidelines, use of relative ranking to categorize metrics, and eliciting expert opinion. Where possible, the application of multiple approaches for classifying metrics is recommended as there will be limitations associated with all approaches.

The water quality indicator was the only indicator with metrics where commonly used guidelines allowed for more straightforward statements about the overall state in a reporting area (e.g., “met or did not meet a guideline for the protection of aquatic life as set by the CCME”). While the measured value of these metrics relative to guidelines could provide insight about status at a particular site and point in time, more intensive spatial and temporal sampling would allow for generalizations across the assessment unit (watershed) or reporting unit. Further, the guidelines used for some metrics within the water quality indicator may not be appropriate or meaningful in all situations.

Jenks natural breaks were used to define reporting thresholds for many of the metrics analyzed above. This analytical classification approach maximizes among group variance while minimizing within group variance (Jenks 1967). The Jenks natural breaks categorization approach is based on the distribution of the data and might not result in ecologically meaningful categories, however such approaches are commonly used in ecosystem reporting when information on ecologically meaningful thresholds are not available Dey and Chu 2023.

For metrics for which it is possible to define reporting thresholds, a classification scheme for indicators can be developed based on measurements relative to those values. Figure 3 illustrates application of thresholds to classify three different metrics. An individual assessment unit can be assessed where it value falls relative to thresholds for each metric. In the example in Figure 3, two metrics result in a designation of “fair” and one in “excellent”. These measures are then combined in simple additive approach to provide an overall classification of “fair” for the indicator. While an illustrative example, the scenario includes only absolute thresholds and does not provide any information about weighting individual metrics in order to provide a more ecologically relevant overall classification for the indicator. As mentioned for objective 1, this is one of the reasons that an overall state was not provided for each indicator for the LGLA and AESA reporting areas in the SOFFH-OPR, because of the need for further work related to those types of weighting decisions.

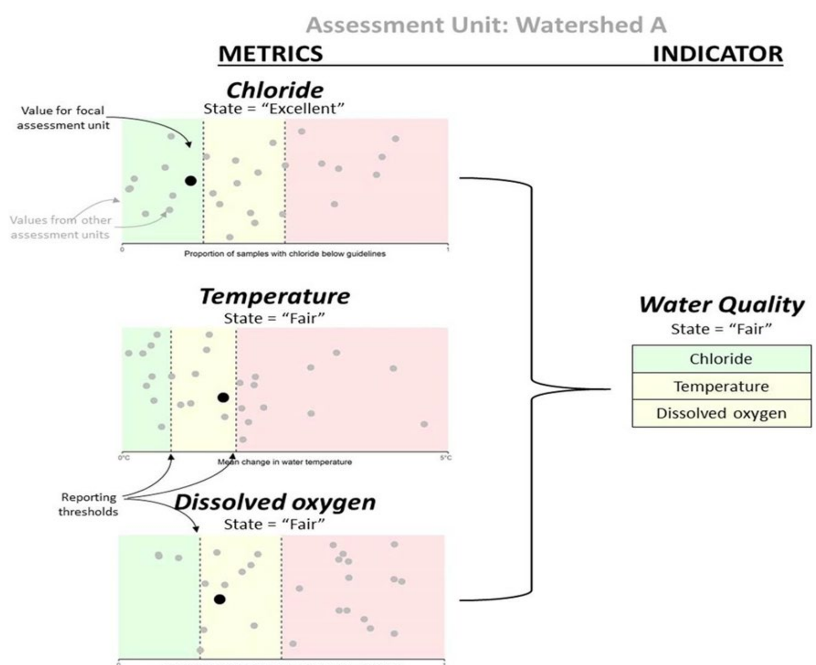

Figure 3. Illustration of classification schemes and reporting thresholds for metrics and indicators used in the SOFFH reporting. In this example, metrics are associated with a three-level classification scheme, each of which is defined based on two reporting thresholds. The values of the metric for the focal assessment unit are compared against the classification scheme to determine a state for each Metric, which are then synthesized to produce an assessment of state for the associated Indicator.

Classification schemes for assessing status of metrics and indicators would be most effective if based on functional relationships with management objectives. When management objectives are quantitatively defined and the relationship between those objectives and metrics can be determined then the resulting reporting will be aligned with management actions. In some cases, a management objective may be very clearly defined, for example, with a specific water quality guideline. But, management objectives are commonly not quantitatively defined. For example, a management objective may be to “conserve the function of a specific habitat,” without providing a baseline value of which function or a quantitative definition of what is meant by ‘conservation’. In situations where management objectives are indeed quantitative, it is recommended that classification schemes and reporting thresholds for SOFFH-OPR align with those management objectives so that there can be better understanding of the extent to which habitat states may correspond to management activities.

Ecological thresholds, which correspond to rapid or categorical change in ecosystems (e.g., changes of state or regime shifts), are also important when considering the general state of fish and fish habitat. However, linking individual metrics and indicators with ecological thresholds is not always appropriate or possible, and ecological thresholds may not always align with reporting thresholds based on management objectives. Understanding the differences and caveats associated with both reporting and ecological thresholds is a key finding from the work supporting this science advisory process.

In addition to ecological thresholds, there are other types of thresholds that may be considered in a toolkit of approaches. Absolute thresholds are those that define categories based on absolute values (e.g., the water temperature measurements in the example above) that can be measured across systems. These thresholds are easy to apply but caution is warranted as they may not be applicable or may represent different phenomena across different systems, species and life stages. Self-referent thresholds are those based on the amount of change within the specific system being examined. These thresholds are useful for tracking trends or changes in state for a specific system but can require a high degree of historical data and context, which may not be available. Finally, control-referent thresholds are those that define categories based on the difference between values for a metric at a site in question and a reference/control system. Using a control-referent threshold, like self-referent thresholds, has certain data requirements (in this case, data about the control system) and also requires assumptions about the control or reference system, e.g., that is an appropriate comparator system and that it has a state that might be considered pristine or desirable.

A decision tree was developed to guide the determination of the best methods for developing classification schemes for reporting on the state of fish and fish habitat (Figure 4). The decision tree uses the availability of data and information about objectives to provide a framework for determining how to best set reporting thresholds. The first question in the decision tree is whether there are already known relations between management goals for a particular ecosystem or reporting area and the metrics that are to be measured. If yes, then one can use these relationships to set reporting thresholds and designations for “states” of metrics and indicators. If there are not known relationships between management goals and the metrics (e.g., in a situation where reporting may not be stemming from an organization with management authorities or responsibilities) then one may set reporting thresholds based on thresholds available from the literature or existing recommendations. If existing thresholds are not available, thresholds could be set based on relative ranking, where individual assessment units are placed along a gradient based on comparison with other assessment units. This setting of assessment units along a gradient could be done in such a way that an equal number of assessment units fall into each category (e.g., using percentiles as thresholds) or using statistical methods to break assessment units along a gradient into groups with unequal numbers of assessment units (e.g., natural breaks). While potentially useful, relative ranking does have the potential to provide misleading information when trying to interpret trends. For example, an assessment unit with the best value in a given grouping may still not have a desired state but simply represents the best site for a given metric of a particular set of assessment units. In situations where a system has known ecological thresholds and where exceeding these known ecological thresholds are also relevant from a system management perspective, thresholds could be set based on ecological thresholds.

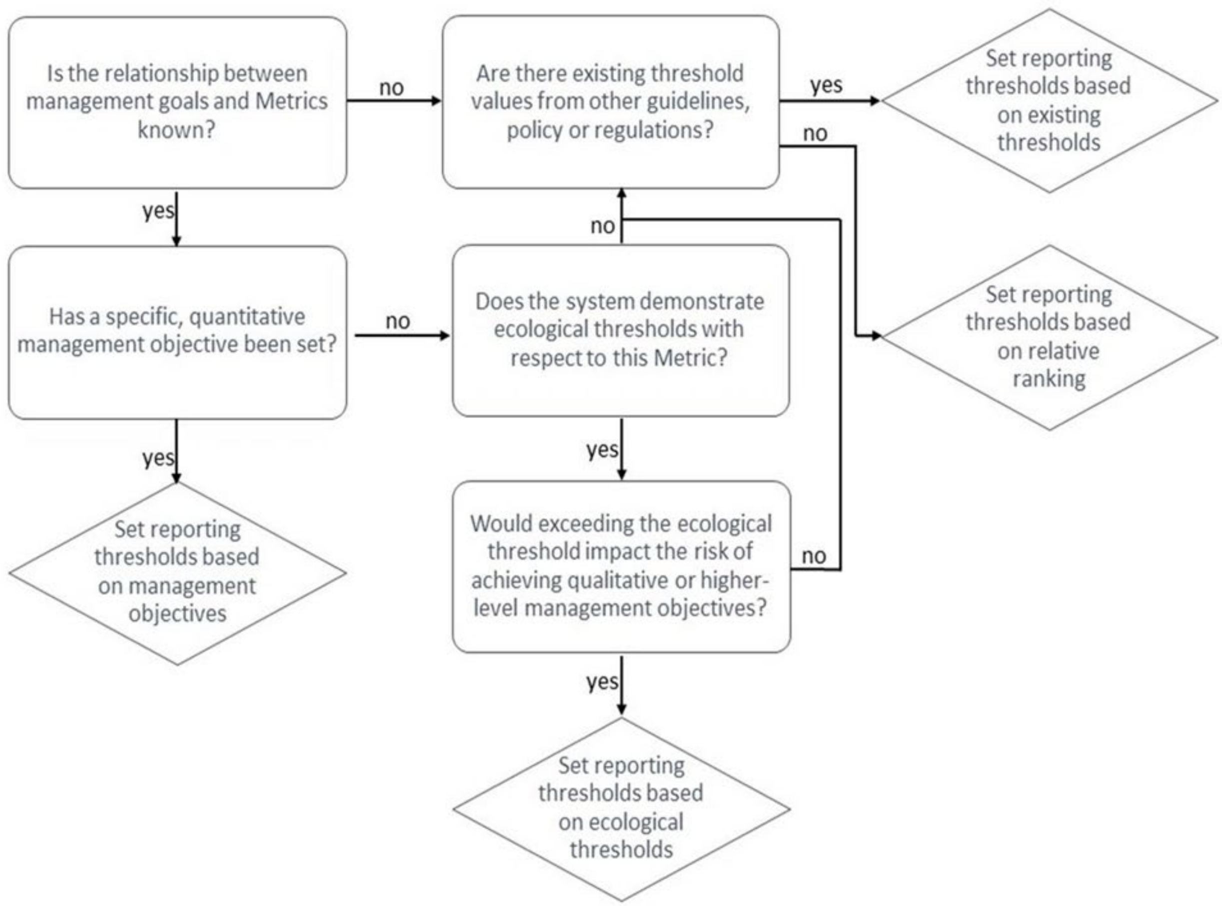

Figure 4. Example decision tree for selecting a method of developing classification schemes and associated reporting thresholds. Note that the method of developing classification schemes based on expert elicitation can be combined with other methods, or serve as an alternate approach to the data driven approach outlined in this figure.

Objective 3 - Review approaches used to categorize data quality for reporting on the SOFFH-OPR

Data quality was assessed for the water quality and fish species data. Conventionally, to achieve sufficient power to detect change (i.e., an 80% likelihood of detecting a 50% change (Cohen 1988, Lester et al. 2021) in a measure (e.g., the water quality metrics), assessment units would require a sample size of at least 25 sites. None of the assessment units in either the LGLA or the AESA met this threshold. Therefore, data quality for the water quality metrics in each assessment unit was not reported. Species accumulation curves were used to assign ‘high’ or ‘low’ data quality to the fish species data. High resolution (10 m) spatial data were analyzed for the land use and land cover metric because they were thought to more accurately reflect Land Use/Land Cover (LULC) in the reporting areas than low resolution (e.g., 100 m or 1 km) data.

Varying degrees of data quality, representativeness, and completeness remain for the metrics and assessment units. For example, the number of observations (both spatially and temporally) included for each water quality metric differed depending on the data available across assessment units and reporting areas, and the value for each metric represents a very isolated snapshot of the true variation. These ‘snapshots’ will often arise when undertaking this type of large-scale reporting activity and there are readily available methods for dealing with the need to assess data quality and standardize data across sampling units (Dey and Chu 2023). These methods include the use of sampling guides and checklists to report on e.g., sample size, and temporal and geographic coverage of the area. Collecting this type of information about the data in a systematic way ensures that one can provide commentary on data quality and interpretation of the results, and have a better understanding of problematic data that perhaps should be used or where additional verification is required.

Objective 4 - Identify uncertainties and knowledge gaps with respect to data availability and the methods used for developing classification schemes for the SOFFH-OPR

All data collected for the SOFFH-OPR came from sources using western scientific methods (government databases, conservation organizations, academic research, etc.). Information and knowledge that could have been contributed from Indigenous Peoples represent significant gaps in the synthesis provided here. In addition, knowledge from local organizations or communities (e.g., grey literature and datasets) were not included. These types of information would be useful in terms of contributing data relevant to the reporting but also in understanding historical ecosystem states and in providing insight into classification approaches and thresholds.

The synthesis of the metrics and indicators for the two reporting areas in this SOFFH-OPR did not allow for overall classifications for the indicators to define the state of fish and fish habitat. Along with missing information about management objectives for each indicator, gaps in the available data limited the ability to classify metrics. As such, decisions could not be made about how to classify the results of the synthesis. The review identified a number of ways that data limitations could be addressed to allow for classification. Additional data collection with expanded spatial and temporal scales using standardized methods would ensure that data availability and quality was uniform within and across assessment units. The availability of comprehensive and comparable data would provide additional information for the consideration of what types of thresholds to use for SOFFH-OPR. Reporting approaches may need to vary depending on information generated through SOFFH-OPR and targeted investigation of specific metrics, indicators or assessment units may help to adjust approaches for future reporting. The exercise also identified that the synthesis for the LGLA and AESA showcased here for the SOFFH-OPR, represent a static view of these systems and future reassessment of these systems would be needed if there is a desire to understand trends through time in the metrics and indicators, or if environmental conditions change.

Sources of Uncertainty

Recognition of uncertainty is a key finding of this science advisory process, both in terms of recognizing how uncertainty may shape decisions made regarding the use of approaches for classifying and setting thresholds for reporting on state of fish and fish habitat as well as the uncertainty underlying the metrics assembled for the indicators of the state of fish habitat in the two reporting areas. While the purpose of this science advisory process and the reporting on the metrics and indicators for the LGLA and AESA areas was not to compare the results for individual metrics or state of habitat between the two areas, collecting and visualizing the information for each of the areas in parallel, highlights differences in data availability and quality. For example, there were differences in the number of observations available for the water quality metrics between the two reporting areas.

Sources of uncertainty include spatial representativeness and completeness of the data, accuracy of the spatial information, error in the modelled data, and the categories applied for each metric. The implications of these uncertainties, from an ecological perspective, represent information gaps. These gaps can possibly be addressed with further research, standardized and extensive monitoring, and the development of methods to account for, or accurately communicate information about, uncertainties.

Interpretations of metric values relative to management objectives are also an important source of uncertainty. As discussed earlier, clarity around management objectives and the ability to identify and quantity relationships between management objectives and metrics would be needed to make generalizations about the state of fish and fish habitat in reporting areas and to draw conclusions about the effectiveness or impact of specific management actions. Additionally, absolute values or changes in certain metrics do not always reflect anthropogenic impacts in the same way. For example, while the presence of waterfalls may indicate barriers to fish passage, they may also represent a system in a more pristine state. Uncertainty around these linkages to management objectives are important gaps in knowledge that limit the development and evaluation of status statements for the SOFFH-OPR. Dey and Chu 2023 define a number of methods to resolve these linkages for future consideration.

CONCLUSIONS AND ADVICE

The focus of this science advisory process was to inform the Ontario and Prairie region’s assessment of State of Fish and Fish Habitat, SOFFH-OPR, which is a contribution to the national SOFFH report. While the synthesis of metrics and indicators for the two priority areas, LGLA and AESA, are specific to the SOFFH-OPR, these metrics and indicators are likely to have broad applicability across other areas and regions. The approaches for determining classifications based on these metrics and indicators are not specific to only one region or ecozone and, thus can be considered for application across the country. In addition, the data synthesis and advice from this process may also be applicable to the continued development of models for Pathways of Effects, and the establishment of environmental indicators useful for ongoing or future monitoring.

Objective 1

A synthesis of selected indicators of biodiversity, water quality, connectivity, land use and land cover, and climate change was developed for the LGLA and AESA reporting areas. A suite of metrics was used for each indicator based on available data at watershed-level assessment units. Metrics varied across the assessment units for each area but generally relate to patterns of land use and geography, where more degraded metrics were recorded in heavily modified or impacted areas. Increased temporal and spatial sampling as well as the development of standardized monitoring programs will provide data to allow future reporting to characterize changes in the state of systems and report on trends.

Considerations for future SOFFH iterations include:

- Include biodiversity metrics such as relative abundance, Jaccard dissimilarity index or species turnover may better reflect changing habitat conditions.
- Summarize and report on species traits relevant to state of habitats (e.g., functional diversity index).
- Scale biodiversity metrics for the various climatic areas or scale from a historical reference (i.e., deviations from state).
- Compile and summarize other water quality metrics such as total dissolved solids, total suspended solids, and selenium.
- Include metrics that describe the dynamic nature of habitats (e.g., flow and or thermal regimes or deviations around assessment unit averages).
- Include projections of future air temperature and precipitation because these are known drivers of water budgets and thermal regimes of aquatic ecosystems.
- Include summaries of anthropogenic activities (e.g., human footprint summaries available for both reporting areas).
- Compare individual metrics among assessment units by standardizing measures to the amount (e.g., surface area, linear distance) or type (e.g., lentic vs. lotic) of aquatic habitat found within individual assessment units.

Objective 2

Approaches to select types of reporting thresholds, to link thresholds to management objectives and to guide developing classification systems with which to evaluate the status of fish habitat were provided in Dey and Chu 2023. These approaches will be applicable across many regions and aquatic systems in Canada. The use of any type of threshold, whether absolute, self-referent or control-referent, will involve both benefits and caveats that will affect usability, interpretation and data requirements. The use of multiple approaches is recommended. Where management objectives are quantitative and can be clearly linked to metrics, the use of such objectives is recommended as reporting thresholds. A decision tree is recommended for selecting methods of developing classification schemes and associated reporting thresholds.

Specific advice about developing classification schemes and reporting thresholds in future SOFFH iterations includes:

- Functional relationships can be defined using habitat suitability and species biology.
- Outcome-based thresholds provide ready evaluations of management actions and may be more suitable for the integration of local and Indigenous knowledge.
- The time period for any data series needs to be considered when interpreting what baselines should be used for when thresholds are developed.
- Interactions among stressors can alter thresholds and classifications.
- Emerging stresses and stressors can alter thresholds and classifications.

Objective 3

Data quality considerations are very important for the SOFFH-OPR, as for any type of monitoring or data collection. The development of standardized approaches to characterizing data quality would support robust reporting and especially for reporting that will continue through time. Standardized data quality are needed to allow for the examination of trends through time for the state of fish and fish habitat. Statistical techniques such as power analyses can help one to make decisions about how to design a sampling program that will ensure robust data availability and quality.

Specific advice for future SOFFH iterations includes:

- Power analyses can be used to evaluate data quality of metrics.
- Species accumulation curves can be used to determine quality of fish and benthic invertebrate data.
- Evaluations of representativeness of measured data e.g., spread of sites throughout different stream orders or other habitat templates that may exist for the reporting areas can be used to determine data quality.
- Grey literature and grey datasets provided important information for these analyses and can be compiled and reviewed to fill data gaps.

Objective 4

Data availability was not uniform across the assessment units, reporting areas and metrics. Additional sampling could inform future reporting and help to fill information gaps, particularly in respect to some of the biodiversity and water quality metrics. Other sources of information, beyond the western scientific data sources consulted here, such as collaborations with Indigenous or other local groups could help to fill these information needs. Several uncertainties can be addressed through more extensive sampling, but others can be highlighted and addressed in the future.

Specific advice for future SOFFH iterations includes:

- Summarize metric data by ecotypes within each reporting area.
- Determine lower limits of species-specific and the protection of aquatic life for water quality metrics and other metrics e.g., connectivity.
- Further describe uncertainties in datasets summarized for SOFFH i.e., spatial representativeness of measured data, accuracies of spatial data, and nuances of modelled data.
- Develop methods to quantify uncertainty and understand implications of uncertainty when reporting on SOFFH.
- Consider how emerging stressors may be reflected in future SOFFH reports.

OTHER CONSIDERATIONS

The advice provided from this science advisory process about overall approaches and methods for state of fish and fish habitat reporting is likely to be applicable and adaptable across regions and reporting areas. The advice provided in reference to the indicators and metrics assembled for the Lower Great Lakes and Alberta East Slopes reporting areas is specific to the geographic coverage of the samples as well as the snapshot in time that the sampling represents. Future work will be required to apply classification schemes and to establish reporting thresholds with which to evaluate the status of fish and fish habitat in these and in other reporting areas. Any future work to understand changes or trends in these areas will likely require additional sampling.

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SOURCES OF INFORMATION

This Science Advisory Report is from the August 23–25, 2022 regional peer review on Threshold Approaches and Status of Metrics Selected to Report on the State of Fish and Fish Habitat in the Ontario and Prairie Region Priority Areas: Part 2. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Dey, C.J., and Chu, C. 2023. Methods for Establishing Classification Schemes and Thresholds for Reporting on the State of Fish and Fish Habitat. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/049. iv + 23 p.

DFO. 2022. Proceedings of the Regional Peer Review on the Validation of Metrics Selected to Report on the State of Fish and Fish Habitat in the Ontario and Prairie Region Priority Areas: Part 1. DFO. Can. Sci. Advis. Sec. Proceed. Ser. 2022/017.

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APPENDIX 1. GLOSSARY

Term	Description
State of Fish	The diversity, composition, and/or abundance of fish relative to the naturally occurring fish community.
State of Fish Habitat	The ability of areas to support the life processes of aquatic organisms relative to the natural function of the area.
Indicator	Physical, chemical and biological features of aquatic ecosystems used to describe the SOFFH-OPR. Based on DFO (2022), the primary Indicators of interest for the SOFF-OPR are Biodiversity, Water Quality, Connectivity, Land use and land cover and Climate Change.
Metric(s)	Variables that are directly measured to quantify an Indicator. Indicators may have one or multiple Metrics to describe them (DFO 2022).
Reporting thresholds	Values of a Matric or Indicator used to define the upper and/or lower limits of categories used in classification schemes.
Reporting Areas	The geographical areas of focus for reporting on SOFFH-OPR (DFO 2022).
Assessment Unit	The geographic area where Metrics are assessed against thresholds. The scale of the Assessment Units is dependent upon the scope and scale of the Reporting Area and data available. These units can range from individual lake or stream segments to entire watersheds (e.g., Tertiary Watershed level, HUC8) (DFO 2022).

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