REVIEW OF HABITAT SUITABILITY INDICES (HSIs) FOR PRIORITY AND COMMON FISH SPECIES IN THE ATHABASCA OIL SANDS REGION

Context

Habitat models that are based on Habitat Suitability Indices (HSIs) are commonly used to quantify and qualify habitat of freshwater fish species. HSIs are developed for different abiotic habitat variables (e.g., water depth, velocity, substrate, water temperature, dissolved oxygen), and are species and life-stage dependent. Values of HSIs range from 0 (not suitable at all) to 1 (perfectly suitable), and are typically presented as the dependent variable plotted against a range of the relevant habitat variable. Fish habitat models are used to quantify and budget habitat losses and gains from development projects. The reliability of habitat modelling is, in part, dependent on assigning well-defined and accurate HSIs to each species and life-stage included in the modelling.

The Fisheries Sustainable Habitat (FiSH) Committee, a task group of the Oil Sands Developers Group (OSDG) Environment Committee, includes representatives from Fisheries and Oceans Canada (DFO), the Provincial Government, and oil companies operating in the Athabasca oil sands region of northeastern Alberta. To improve efficiency and effectiveness, and to facilitate compliance with existing *Fisheries Act* authorizations, the FiSH Committee has undertaken a validation of the existing fish HSIs developed for the Alberta Oil Sands Region (Golder 2008) as a standard methodology for discussing fish habitat, impacts and offsets.

In 2013, Phase 1 was completed. It included creation of a database of existing fish and habitat data collected between 2006–2011 from Oil Sands operators, identifying gaps and compatible data as inputs to the process of refining and validating HSIs.

Phase 2 included the design and implementation of a three-year study (2013–2015) to collect habitat and fish data for key riverine species (six priority and eight common species) to facilitate validation and refinement of the HSIs. These refinements are detailed in a draft technical report (Hatfield Consultants in prep.) entitled, Refinement of Fish Habitat Pre-Disturbance Models Draft Technical Report – Phase 2.

Fisheries Protection Program (FPP) has requested Science evaluate the model validation approach, methods, data, analyses, results and proposed revisions to the regional HSIs in the Hatfield Consultants Draft Technical Report – Phase 2 to ensure that they are scientifically sound.

The objectives of the peer review are to evaluate whether the approaches and methods used and the refined HSIs developed in the report for the Athabasca oil sands region of northeastern Alberta are scientifically valid and defensible when used to calculate fish habitat loss and gain for projects. The review is to include recommendations and discussion of uncertainties. It should also consider whether these HSIs are applicable to other areas within DFO's Central and Arctic Region.

This Science Response resulted from the Science Response Process of October 2016 on the Review of Habitat Suitability Index (HSI) model input parameters and model results for priority and common fish species in the Athabasca oil sands region.

Analysis and Response

The objectives identified in the Phase 2 report on the Refinement of Fish Habitat Pre-Disturbance Models Program were to;

1. collect additional fish habitat use observations to address the data gaps identified in Phase 1;
2. integrate the data from Phase 1 into the Phase 2 analysis;
3. conduct scientifically-credible fish habitat modeling on the Phase 1 and Phase 2 integrated data; and
4. use the fish habitat analysis results to refine and validate the existing HSI models.

The report authors did not undertake fish habitat modelling (as per objective 3). They took HSI curves from Golder (2008) and compared them to new curves developed from additional field sampling. There was no application of the curves to predict fish distribution related to habitat quality and quantity. Perhaps the objectives should be revised to more clearly align with the approach taken or the authors should clearly define what they mean by 'fish habitat modelling'.

Table 1.1 provides a list of high priority and low priority species with some explanation as to why they were ranked as such. However, it is not clear how many species in total exist in the systems and therefore how many may be excluded from the analyses. In addition, it is not clear why those were really selected as high priority except that low priority species were largely restricted to large river habitat (i.e., Athabasca River). Reviewers questioned whether some of the low priority species are not found in abundance in the tributaries. Reviewers recognized that collecting comprehensive sampling data on the entire fish community may not be feasible, but more transparency on the focus species, and the implications of those selections to the final analysis, should be provided. Also, Longnose Dace appears on both high and low priority lists.

This report focused on riverine species and habitats. Lacustrine HSI curves were outside the scope of the review. This limits the application of existing models to riverine habitats, and should be recognized in the report.

Methods

Reviewers pointed out that in some places the report did not provide sufficient detail to fully evaluate the objectives. For example, what constituted a regionally significant watercourse and how were they defined? How were sampling sites selected (e.g., random, systematic)? Were sufficient sites sampled within each stream to provide a representative sample of the available habitat (e.g., Simonson et al. 1994, Reynolds et al. 2003)? How many reaches were fished per site? How was the number of sites determined? Site selection can influence HSIs and non-random site selection could introduce bias that could hamper development of scientifically defensible HSIs. Details on site selection and sampling design and implementation should be included in the report as these are important considerations when designing studies for building well-defined and accurate HSIs.

The authors state that a mesohabitat unit was subdivided when necessary using a minimum length of 50 m, but that smaller habitat units were sampled in their entirety. Was there a minimum mesohabitat size (reach length or total area) at which point the patch was considered too small to be included in the analysis?

Why were only the first 100 fish weighed, when evaluating gram-per–unit-effort (GPUE) and gram-per-unit-area (GPUA)?

It is understandable why different gear types (boat vs backpack electrofishing) and methods (fence versus no fence) were used but it leads to uncertainty in comparability of the data.

Why were only two life stages, juvenile and adult, studied in Phase 2? Will other life stages be addressed at a later point (e.g., eggs, fry)?

Reviewers asked why habitat and fish data were only collected during the winter (1 month) and summer. How does this correlate to life functions (e.g., spawning, rearing, foraging, and overwintering). For all species, were spawning periods covered?

Results

The Study Reaches (section 3.1) under Fish Catch Results belongs in the methods section of the report. Why were fish caught in fall and not at the same time when the habitat variables were sampled? Were fish actually using the reach/area when habitat variables were sampled?

Was there sufficient sampling of reaches to provide a representative sample of fish occurrence and abundance, as well as available habitat? More details on site selection should address sampling scale over time and space for the original and revised HSIs.

Reviewers questioned the use of relative biomass as a response variable for HSIs. How were differences in productivity among sites controlled? The same number of fish in one stream could be in better condition than another, due in part to higher productivity, and would provide different results.

In developing length-weight regressions, was there a minimum number of individuals included in the regression before it was used to estimate weight for species with missing data? Were length-weight regressions specific to the reach, or were data pooled by species across the region? Were young-of-the-year individuals included in the length-weight regressions?

A typical habitat variable considered in stream-dwelling fishes is water velocity, if it was used in this program it should be added to the list of habitat variables that were measured. For missing water velocity data, can the authors provide the strength of the model (r^2 by mesohabitat assuming they are linear) used to predict missing velocity?

Reviewers pointed out that several water/sediment quality variables that would impact the post development scenarios would be turbidity/siltation and contaminants in addition to dissolved oxygen (DO), water temperature and pH. How would impacts to these variables on habitat quality be addressed?

If any normalization is used it should be outlined.

Some comment should be made about the complete lack of larger high priority species (Arctic Grayling, Burbot, Northern Pike, Walleye plus the smaller Longnose Dace) captured during the Pre-Phase 2 sampling (Tables 3.3 vs 3.4) despite sampling a similar number of medium quality pools and a reasonable number of run mesohabitats in the pre-period. Why were absolutely no individuals captured of these species in any mesohabitat? Were the reaches in Phase 1 too small? A default fish list for the area may need to be used to account for sampling deficiencies. Even if sampling deficiencies occurred, the habitat association information gained for the species that were sampled is corroboratory and valuable.

The authors should determine if the capture data for some large-bodied target fish species were limited as a result of the sampling design or if these species are, indeed, rare across this area. The fish captured for modelling refinement from 2006–2015 included eight species with fewer than 100 captures, four of which had fewer than 10 captures. If they are rare, then developing HSIs will be difficult. If the issue is sampling design, then additional sampling will be required to develop more appropriate HSIs for these species.

The authors indicated that small sample size (n = 21 fishing units) for Arctic Grayling, limits the ability to make strong inferences from the Phase 2 data. Regardless of why this happened, this is an issue for this species and warrants further effort to resolve low sample size. In many instances, Arctic Grayling show spatial and temporal autocorrelation within streams across watersheds. What the authors are seeing here could be a reflection of both spatial and temporal bias in sampling design.

The authors also noted Arctic Grayling were only found in the larger streams sampled during Phase 2, indicating stream width is an important predictor of Arctic Grayling presence. However, it is important to note that this trend is only valid for this particular fall sampling period. Based on first-hand knowledge and data from the literature, it is known that in many systems the juvenile presence is higher in small streams during the late spring and early summer than late summer/early fall. Given the small sample size, this is important to note. Additionally, adult abundance often declines in smaller streams over the course of the summer.

Reviewers also noted the lack of HSIs for juvenile Arctic Grayling. This is a significant data gap for a high-priority species that could likely be addressed over one spring/early summer sampling season with an appropriate level of effort applied. However, a single sample period will not account for inter-annual variability.

Authors noted that Northern Pike were not frequently caught during Phase 2, despite attempts to sample in watersheds with known occurrences. This seems to be a recurring theme, especially for high priority species and calls into question the suitability of the sampling design over both time and space. It seems odd that crews had trouble catching this species in watersheds where they are known to occur. Authors should clarify details of the sampling design (e.g., how sites were assigned, how many were assigned in each stream) and the rationale for setting the program up this way.

With respect to habitat variables, the need to reduce the large number of these variables is understandable due to degrees of freedom, and the approach of reducing collinear variables is acceptable. However, why were there such disparate approaches used depending on the variable? For stream size, bankfull width seems to have been ‘chosen’ based on expert opinion. Velocity was averaged to make one variable. Substrate was subject to a Principal Component Analysis (PCA) analysis and new variables were generated based on the loadings on the first Principal Component axes. The rational should be presented for the range of approaches.

The model selection analysis did not show a strong positive relationship between bankfull width and Arctic Grayling catch-per-unit-effort (CPUE), GPUE, or GPUA. Authors recognized that the lack of significant positive relationships may be simply because of limited power in the model to detect more than two to three parameters with a low sample size; therefore, this Suitability Index (SI) was assigned conservatively; streams ≥10 m in bankfull width were assigned a SI value of 1.0, and streams <10 m bankfull width were assigned a SI value of 0.5. However this doesn't seem like a conservative estimate, as it is characterized as excellent. An SI value of 0.75 would constitute a conservative estimate and be more appropriate here.

The bullet providing guidance for the Suitability Index (SI) gradient led to questions from the reviewers. It is not clear why the relative variable importance (RVI) score of a habitat variable has an impact on the assigned SI score range. Why would habitat variables with lower RVI scores and weaker relationships be allowed to have an SI score on the top end of the scale (i.e., only 0.5–1)? Whereas the habitat variables with strong relationships based on an RVI score >0.9 can be assigned a score that spans from 0–1. Why would a SI score for any habitat variable not deemed important be by default 1? Is this related to how the authors determined how different habitats and life-stages are weighted when generating an integrated habitat model (i.e., using the most limiting factor of all life-stages to dictate the HSI score)? This needs to be clarified in detail early in the document.

It is not clear how total instream and overhead cover was quantified depending on fish size. Why would an overhanging tree provide different cover depending on fish size? How was this judged in the field? Was there overlap of cover types (i.e., the same tree would be counted multiple times for each fish size class)? This has greater implications to the field manual, but the total cover variables are included in a number of refined HSIs, and therefore some additional explanation is warranted.

The reference to Zuur (2009) is missing from the list of references. Authors should ensure the references are cross-checked.

HSI curves for a variety of different habitat variables were developed. It is not clear what the purpose of these curves is as most of the variables are not commonly used in fish habitat models. Looking at the scatter box plots some variables appear to have very low explicative power for fish distribution. It would help to know the decision criteria for the process of both Phase 1 and 2 programs.

The approach chosen to validate the HSI curves appears sound, and the consultation with a statistician provides additional confidence in the approach. The multi-lines of evidence approach in building the HSIs were useful. The data and statistical analyses are very comprehensive. Therefore, it was surprising that a Delphi approach was used to reduce subjectivity. In some cases, the selection of an HSI curve is a an 'art' based on expert opinion, but this report is semi-transparent in that the authors indicate why they leaned one way or the other in terms of the final curve selected.

The refinement of original HSI curves using the new knowledge gained from this study was appropriate. However validation of habitat models is still needed rather than just comparing single HSI curves to each other.

The authors conducted a very intensive and comprehensive data collection and statistical analyses. However, reviewers were expecting different analyses particularly in regards to objectives 3 and 4. Expectations may have been due to the reference to the existing regional HSI curves that were developed using available data and professional judgment (Delphi approach; Golder 2008) and as a result of a different definition of the terms "fish habitat modelling" (Objective 3) and "validation" (Objective 4) from that of the authors. Refining the HSI curves with regional data is definitely a valuable exercise, however, as a true validation of fish habitat modelling, there should be an evaluation of whether or not fish are actually using or occurring in higher abundances in areas that the model predicts to be good habitat and are absent or in lower abundance in poorer suitability habitat areas. DFO (2010) identified similar concerns with the dependence on appropriate selection of fish habitat data and development of HSI curves that had not been field validated. At the time of the earlier review, there were no HSI curves available for most smaller-bodied and rare species (including juvenile life-history stages and prey species). They recommended priority field testing/validation the predictions of HSI curves for particularly sensitive life-history stages (e.g., predicted Longnose Sucker habitat) to provide additional confidence regarding the habitat preferences for various species.

It is concerning that the majority of SIs included in the original HSI curves were not validated, with many new habitat variables arising as important, many existing variables requiring refinement, and many of those being retained simply because they could not be validated based on new sampling data. Therefore, the HSIs do not appear to be very robust.

In Appendix A1, why is ‘Wetted Width’ shown in each reach characteristics table, when ‘Bankfull width’ is the variable that falls out as highly important in many refined HSIs? Although they are highly correlated, the former would depend on discharge at time of sampling, whereas the latter would be more characteristic of the reach in general, regardless of the discharge.

Next Steps

The report did not provided information on how the HSI curves could affect determination of habitat quality and quantity. Consequently there is no link established with project impact/offset predictions.

The importance of accurate HSI curves depends on habitat model outcomes and their influence on management decisions. The next step in using the HSI curves developed in this report would be to undertake a case study (hypothetical even) whereby a select fish community is assumed to live in a reach of certain characteristics that will be affected by a typical oil sands project. This reach should be subject to both the regional and refined HSI curves and the resulting outcome in terms of the predicted impact on habitat suitability be clearly articulated.

A true validation of fish habitat modelling should be conducted. There should be an evaluation of whether or not fish are actually using or occurring in higher abundances in areas that the model predicts to be good habitat and are absent or in lower abundance in poorer quality habitat areas.

Conclusions

Reviewers indicated the report was generally well written and thorough, summarizing the fish and habitat data collections that were conducted in Phase 2 of the Program. In most cases, sufficient detail was provided to understand generally what was done (with the exceptions mentioned previously), but the report was still relatively concise given the volume of data and information provided per species.

Overall this process seems to have been reasonably thorough with respect to previous work developing HSIs for this region. However, there are still some data gaps and uncertainty regarding sampling design. In some instances, the process used to select sampling sites may have biased the results and also contributed to low sample sizes for some species. Without further knowledge of how these sampling sites were selected it is difficult to determine if the species with low sample sizes are indeed rare in this area, or were not sampled sufficiently. For example, only 29 Arctic Grayling were captured from 2006–2015, which is a relatively small sample for developing a regional HSI curve. If this species is rare in this area, then these data could be considered for HSI development. However, for this species it would be preferable to gather additional data.

The report authors recommended validation of the refined HSI curves as they are poor predictors of fish presence and abundance. Their conclusions also demonstrate that the HSI curves are not suitable for application to other areas outside the scope of this study. Reviewers agreed with this recommendation given that the exercise demonstrated the weakness of the regional HSI curves, and that the new curves are still the subject of incomplete data and professional opinion. There is a literature demonstrating that it is not prudent to transfer HSIs across regions and the results from this work support this notion (e.g., Thomas and Bovee 1993, Guay et al. 2003).

Reviewers recognized that a substantial amount of work went into gathering data, producing the report, and into validating existing HSIs. This level of effort is rarely feasible and therefore it would be important that some condensed version of the Hatfield Consultants Draft Technical Report – Phase 2 make its way into the primary literature as a caution about using HSIs, in general, without validation. They were in agreement that publishing the work would also provide future guidance to all involved.

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Sources of information

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