Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2020/028

Central and Arctic Region

Proceedings of the Regional Science Peer Review of the Habitat Ecosystem Assessment Tool (HEAT) Software Development and Evaluation

Meeting dates: January 27–29, 2016
Location: Burlington, Ontario

Chairpersons: Gavin Christie and Sophie Foster
Editors: Sommer Abdel-Fattah and Susan Doka

Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Rd.
Burlington ON L7S 1A1, Canada

February 2021

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1701-1280

Correct citation for this publication:

DFO. 2021. Proceedings of the Regional Science Peer Review of the Habitat Ecosystem Assessment Tool (HEAT) Software Development and Evaluation; January 27–29, 2016. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2020/028.

Aussi disponible en français :

MPO. 2021. Compte rendu de l'examen scientifique régional par les pairs de la mise au point et de l'évaluation du logiciel de l'outil d'évaluation de l'habitat et de l'écosystème (HEAT); du 27 au 29 janvier 2016. Secr. can. de consult. sci. du MPO, Compte rendu 2020/028.

TABLE OF CONTENTS

SUMMARY

A Canadian Science Advisory Secretariat (CSAS) peer review meeting was held from January 27–29, 2016 in Burlington, Ontario, to evaluate elements of the Habitat Ecosystem Assessment Tool (HEAT). The Tool is designed to evaluate potential changes to suitable fish habitat area in any project that alters supporting habitats for fish. The Lake HEAT software package allows pre- and post-project assessment of limnological and physical habitat changes and their impact on fishes, through scenario-testing. The Tool aims to support decision-making processes with the development of quantitative metrics that can be coupled with decision criteria to assist Fisheries Protection Program (FPP) staff when determining the magnitude of impact and in evaluating offset plans.

The meeting goal was to evaluate HEAT to help in the assessment of proposed development projects and their potential risks to fishes and their supporting habitats. More specifically, the objectives were to:

1. review the offsetting calculation method in HEAT and its scientific basis;
2. assess how the Tools' features can be used most effectively and consistently to better inform current management decisions;
3. discuss whether updates or improvements to the Tool are needed to enhance outputs for users; and,
4. examine the applicability of the HEAT approach within a broader context given changes to the Fisheries Act and associated policies.

Participants were asked to examine the current version of HEAT and recommend changes to specific input variables, algorithms or outputs; as well as recommend additional elements or formats to be incorporated into HEAT to strengthen or even expand its capability as an assessment tool. Participants were asked to evaluate the applicability of the HEAT approach within a broader scientific, regulatory and operational context. Three documents were prepared for the meeting, one describing HEAT's history, case studies, and future studies; the second describing previous surveys and meetings regarding HEAT; and the third outlining the guidance to date for using HEAT with online instructions. A quick guide to running a HEAT scenario as well as the web-link to the Tool were also supplied to participants, and these also guided the discussions. The use of HEAT in light of changes to the *Fisheries Act* and FPP policies was scientifically discussed. Participants included staff from Fisheries and Oceans Canada (DFO) in both the Science Sector and FPP, staff from the Ontario Ministry of Natural Resources and Forestry (OMNRF), and external users and biological consultants familiar with background or the conceptual framework of HEAT-type approaches or the Tool itself.

This review process and elements of the Tool may complement current FPP initiatives to gather additional habitat information for Canadian fisheries and other impact and offset advice.

This Proceedings report summarizes the relevant discussions and presents the key conclusions reached at the meeting. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

INTRODUCTION

The Habitat Alteration Assessment Tool (HAAT), now renamed the Habitat Ecosystem Assessment Tool (HEAT), is an application of a quantitative fish habitat assessment method for use in evaluating changes affecting lacustrine fish habitats in the Great Lakes drainage. Lake HEAT incorporates fish distribution information, species and fish guild information, life stage-specific habitat associations, and determines suitability and weighted suitable area calculations based on a project's location and specific input files required on habitat-patch change descriptions. The Tool is customizable to user choices of fish lists, guild assignment, and other weighting factors to allow for the inclusion of habitat and fisheries goals. The software package allows pre- and post-"project" assessment of limnological and physical habitat changes and their impact on fish habitat supply. Each pre and post comparison is called scenario-testing. The main impetus for the original and continued development of the Habitat Ecosystem Assessment Tool (HEAT) was to provide the Fisheries Protection Program (FPP) with a quantitative tool that would standardize and streamline the evaluation process of projects that require Fisheries Act approval by using a uniform approach and Tool.

A peer-review meeting was held in Burlington, Ontario from January 27–29, 2016. The purpose of this meeting was to evaluate elements of HEAT to help in the evaluation of proposed development projects and their potential risks to fishes and their supporting habitats. The objectives of the meeting are as described in the Terms of Reference (Appendix 1) and were intended to address:

1. a review of the offsetting calculations in HEAT and their scientific basis;
2. how the Tools' features can be used most effectively and consistently to better inform current management fisheries and habitat decisions (case studies and a user package will be provided for the session);
3. whether updates or improvements to the Tool are needed to enhance outputs for users, and if so, what these updates are; and,
4. an examination of the applicability of the HEAT approach within a broader context (if and how could the Tool be applied spatially within a landscape context or be used nationally?)

Meeting participants included Fisheries and Oceans Canada (DFO) staff including emeriti from Science Sector and the FPP, the Ontario Ministry of Natural Resources and Forestry (OMNRF), consultants familiar with the approaches, and the Toronto Region Conservation Authority (TRCA) (Appendix 2). The meeting followed the agenda outlined in Appendix 3. This proceedings report summarizes the relevant discussions from the peer-review meeting and presents suggested revisions to the associated research and technical documents.

OPENING DISCUSSION

The Chairs welcomed participants and had each participant introduce themselves and their main interest in attending. They then presented the purpose of the meeting and reviewed the background of the HEAT application which was developed to assist habitat management around the Great Lakes and Ontario initially, but could then be advanced in future application to a broader regional or national application. The co-chair gave an explanation of the science advisory process and put a specific focus on the role of science and management application. The chairperson then discussed the Terms of Reference objectives and provided an overview of the meeting's agenda, and the presenters who would be speaking over the course of the meeting as well as how each of these presentations related to the Terms of Reference objectives. Three draft documents were provided to the participants in advance of the meeting. These three documents were to form the basis of discussion throughout the meeting and would provide context for the discussions forming the scientific advice. Participants were encouraged to ask questions and contribute knowledge and expertise towards developing a consensus on the conclusions, recommendations, and advice.

PRESENTATIONS

The Fisheries Protection Program and Changes to the Fisheries Act: A Regulatory and Policy Context

Presenter: Alwyn Rose

The speaker discussed the underlying foundations of the FPP as well as their role in a regulatory and policy context under the Fisheries Act. The two key policy pieces presented were the Fisheries Protection Policy Statement and the accompanying Offsetting Guide that were both released in 2013 (DFO 2013). The Application for Authorization under Section 35 of the Fisheries Act is a regulation released in November 2013 and sets out information requirements for proponents to submit when making an application and specifies specific deadlines for review of those applications by the Department. The Fisheries Protection Policy Statement has three important components:

1. a discussion of key elements of fisheries protection provisions;
2. the current interpretation of serious harm to fish and its scope of application; and,
3. a description of the factors to be considered prior to authorizing projects that cause serious harm to fish.

There are key elements in the prohibition against serious harm to fish that are part of or support a commercial, recreational, or aboriginal (CRA) fishery unless it is authorized by the Minster under Section 35-2. Section 6 sets out the decision factors which the Minister must consider in making these decisions. Serious harm is broken down into three component parts:

1. death of fish;
2. alteration of habitat that is of a spatial scale, duration or intensity that limits or diminishes fish use of that habitat; and,
3. destruction in which fish can no longer use that habitat at all.

The scope of application is broad and covers most waterbodies across Canada that contain fish, including all three Oceans, and all inland waters. Specifically the Minister, under Section 6, must be conscious of the contribution of relevant fish (i.e., with respect to how they contribute to fisheries) as well as to the public interest. Proponents must put measures and standards in place such that they have avoided, mitigated, and offset potential impacts to fish and met sustainability and ongoing productivity of fisheries standards.

The presenter also discussed the Guide to Offsetting from FPP. This outlines proponents' responsibility to avoid serious harm to fish. When impacts are unavoidable this guide provides options for mitigation and offsetting and it is designed to provide flexibility of options to find an approach that is most appropriate to the proponent but informed by science. This recognizes the importance and challenges of determining offsetting equivalency and identifying appropriate options in some environments.

The main guiding principles of offsetting include:

- offsets must be supportive of the fisheries management objectives or local restoration objectives where the project is occurring;
- the benefits of the offsets must balance the impacts of the project such that there is “no net loss” at a minimum;
- offsetting benefits must add additional benefits to the fisheries which means the offset cannot be the result of the project, it must be the result of additional actions taken; and,
- offsetting must have self-sustaining benefits over the long-term without ongoing intervention.

There are five main ways in which offsetting can be implemented:

1. habitat creation;
2. habitat enhancement;
3. habitat restoration;
4. chemical or biological manipulation; and,
5. complementary measures (where proponents use some of their offset dollars to do important research or data collection that aids in the local management of fish).

The presenter then discussed how the Tool being reviewed has been used by FPP in the past and the benefits of its use. HEAT was used to determine if ‘no net loss’ was being achieved by projects in the Central and Arctic Region, mostly in the Great Lakes area. It has been predominantly used for assessing infills and dredging and evaluating various compensation scenarios to evaluate which is most appropriate. The Tool has also been very useful for analyzing large habitat losses and the trade-offs associated with compensation (i.e., offsets) of unlike habitats, and evaluating several possible compensation scenarios. HEAT may be useful to quantify residual serious harm to fish or its characterization. It may also be useful to quantitatively determine if an offset plan is sufficient to counterbalance the residual serious harm to fish. The Tool can have great use for FPP and it is hoped that HEAT can have broader application in the future.

After the presentation, one participant raised a question regarding the concerns that FPP may have with the uncertainty associated with the assumptions of the model. The speaker responded that many users do not have a good understanding of the science of the inputs and underlying assumptions contained within the Tool. Users also sometimes obtain results that are contrary to their own individual mental model of what the results should be. There is flexibility built into the model, but this may cause sensitivities in the output to those inputs that may require additional training for FPP staff to understand. This flexibility also inserts some uncertainty in the variation and error in outputs to the manipulations of the models associated with the users’ choices. Users need to have a clear understanding of the base data, model assumptions, uncertainties, interpretation of the results, and how precise or accurate the model is in order to establish an appropriate level of confidence in the results.

A question was asked about what FPP is doing to monitor offsetting, and how effectively it is working. It was also asked if HEAT could be used as a tool to monitor offsetting. The speaker relayed that monitoring is currently the responsibility of the proponent; although DFO monitors this process. It was added that monitoring must include the persistence of long-term reports from proponents. It was noted there was a previous CSAS that examined offsetting effectiveness and what data can be collected from proponents (Bradford et al. 2016).

Another participant asked if there was policy documentation or some guideline that specified whether HEAT should be used by proponents when proposals are submitted to FPP. In response to this question it was stated that the guidance is currently informal and that if an infill is more than 200 square meters in the Great Lakes area you should run HEAT to assess impact. There is not a policy guideline or written mandate and only certain regions adhere to having proponents run HEAT scenarios. It is recommended that specific guidance on when, how, and why the model should be used be written into policy guidance.

A participant commented that there is a wide range of tools available to FPP but it is still unclear what the acceptance level of these different tools is with the Program and in the scientific community. There is a need for clear direction from Science across Canada in terms of the tools available and their requirements but also regionally on which tools are best to use through documentation of that advice. It was suggested by a participant that the algorithms, scientific basis and underpinnings of HEAT should be part of the RES document for this CSAS process.

A question was asked regarding whether Commercial, Recreational, and Aboriginal fisheries (CRA fisheries) are assessed individually in Fisheries Protection Policy. The speaker responded that in most instances, assessments are applied generally across all fisheries within the area of study and considered as a whole part of the fish community and that pulling them apart is almost impossible. It was noted, however, that HEAT does allow for proponents to assess different parts of the fish community. One participant indicated that this might be particularly useful when looking at the “weakest link” or most vulnerable members of the fish community.

A participant asked for clarification regarding the differences or similarities between “serious and permanent harm to fish or fish habitat” and “no net loss”. The speaker explained that in essence, it is the same concept; offsetting aims to achieve a no-loss result when comparing the before and after scenarios. It was also noted that it is important to clarify that it is serious harm to fish or fish habitat, not fisheries.

The Origins of HEAT

Presenter: Charles K. Minns

Creation of HEAT (a software which was initially called HAAT) was inspired by the “No Net Loss principle” of Productive Capacity of Fish Habitats in the DFO 1986 Policy in what was then called “Defensible Methods” (DM) in the original publications (Minns 1995, Minns 1997). This was an operational Tool to support the no-net-loss policy. The 1986 Policy was based on the guiding principle supported by the Green Plan under the growth of federal fish habitat management (FHM) in freshwaters (DFO 1986). The first project examined a gravel extracting process, where a back-of-the-envelope calculation lead to the No Net Loss (NNL) equation and then resulted in 50% of a marsh being saved with offset gains for losses incurred. The ultimate outcome was the creation of a conservation area.

The NNL plan was established using net-change equations as described in below:

- $P_{MAX} = p_{MAX} \cdot A_{ORIGINAL} = productive\ capacity$
- $P_{NOW} = p_{NOW} \cdot A_{NOW} = productivity\ now$
- $A_{NOW} = A_{ORIGINAL} - A_{ELIMINATED}$
- $dP_{NOW} = [p_{MOD} - p_{NOW}] \cdot A_{MOD} - p_{MAX} \cdot A_{LOSS} + [p_{COMP} - p_{NOW}] \cdot A_{COMP}$
- + modification - loss + compensation* (*compensation = offset)

Where: P = Productivity, A = Area of habitat impacted by development, and p = unit area productivity (measured as suitability). It is assumed $P_{MAX} = p_{MAX}$ for physical habitat, given that stressors do not change.

An expert panel also reviewed and agreed upon the habitat classification (modification type) and suitability assignments defined as:

- A_{LOSS} - permanently lost to project
- A_{MODD} - directly modified by project
- A_{MODI} - indirectly modified by project
- A_{COMM} - compensation by modification of other habitat (will be re-named A_{OFFM})*
- A_{COMC} - compensation by creation of new habitat (will be re-named A_{OFFC})*
- A_{UNCH} - habitat unaffected by project

* both should include direct and indirect modifications

If applied consistently for a defined area it leads to logically-defined development limits. If the habitat-fish productivity relationship is non-linear the approach is still valid, however, it is recommended to use the precautionary approach. The approach compares pre conditions (initial conditions) to post conditions (after project construction). The pre area has an assigned productivity per unit area; as does the productivity in the post scenario. The basic framework evaluates a space and its value and can be applied to productivity, biodiversity and habitat equally because of the assumptions.

The pre or baseline conditions were described as a flat, level baseline, however, in reality baseline conditions are always shifting mostly downward; so the offsetting should account for this by using the precautionary approach.

One of the major obstacles to overcome was how to translate the NNL equation into a scientifically-defensible operational tool because science databases of fish-habitat relationships are often fuzzy or incomplete particularly for a single species. This lead to the choice to draw upon the US Fish and Wildlife Service approach using Habitat Evaluation Procedures (HEP) and Habitat Suitability Indices which is defined as Weighted Suitable Area (WSA) = Area x Suitability. The basic idea is that habitats which are used preferentially by more species and life stages make a greater contribution to fish productivity and hence habitat suitabilities measuring the preference of the fish assemblage for different habitats are acceptable surrogates for indicators of fish productivity (Bradford et al. 2016).

A prototype of HAAT was initially developed as an excel spreadsheet of calculations and some Hamilton Harbour Remedial Action Plan fish restoration activities were used as a case study with the project receiving various funding. The basic approach was to build a Habitat Suitability Matrix (HSM) which included depth, substrate type and vegetative cover with habitat preferences developed for each species across three life stages, each rated by the documented strength of low, medium, and high habitat associations. This information was also peer reviewed (Coker et al. 2001).

The HSM creates many combinations of habitat features depending on the number of classes and features. Spatial GIS overlays of simple classifications create uniform patches for a site evaluation. Thermal groupings and thermal tolerance levels have also been established with preference ratings by group between 0–1 across a range of temperatures. This thermal suitability would be multiplied by the three suitabilities for depth, vegetation, and substrate and then rescaled so that the maximum possible combination was always 1 and the minimum was always 0 to create a matrix of suitabilities to apply.

DM included the ability to perform multiple combinations by using a weighted sum to get a composite fish community value across all fish groups at a site. In the nearshore habitats of the lower Great Lakes, several studies (e.g., Minns and Nairn 1995) have been able to show significant correlations between DM suitability values and fish community metrics (species richness, biomass, abundance) based on electrofishing data. The implementation of the Tool included a desktop version, and later a web-based application.

Several datasets were completed and included such information as life history characteristics of Canadian freshwater fishes, lake and stream habitat assignments for fishes in the Great Lakes region, a Newfoundland and Labrador region, a Pacific and Yukon region, and a Northwest Territories and Nunavut region.

The Tool has been used for applications such as mining projects in the Northwest Territories, Labrador, British Columbia, and Saskatchewan as well as numerous shoreline infilling activities (e.g., MacNeil et al. (2008) using HAAT). It has also been used for area-based habitat management planning in Severn Sound and the Bay of Quinte and habitat-supply driven fish population modelling in the Great Lakes including the assessment of water level regulation. Extensions of the original tool include a simplified Ontario stream model (Minns 2010), uncertainty and complexity in net-change assessments (Minns and Moore 2003), time lags and offset ratios (Minns 2006), and models linking fish populations dynamics and production to habitat supply and quality (Hayes et al. 2009). Future work involves adding habitat-ecotype productivity benchmarks, standardizing equivalencies across riverine and lacustrine habitats in single assessments, and use in habitat banking and conservation planning.

Operational use and continued development of the Tool has included:

- site assessment to inform FHM/FPP guidelines and improvements to the framework of model in its current R version;
- adding additional national bioregional information where water level fluctuations have been assessed and will inform scenario guidelines; addressing uncertainties in information and algorithms; an add-on for assessing time-lags between impacts and offsets (was developed for HAAT but has not been posted yet in HEAT); offset ratios to be used to account for productivity differences between development impacts to natural areas vs. created or improved man-made habitats;
- the addition of habitat-biodiversity and productivity links using the science that is rapidly developing in DFO to address habitat supply and quality conversions to ongoing fish productivity, if desired at the Great Lakes Laboratory for Fisheries and Aquatic Sciences in DFO; and,
- ongoing learning-by-doing with case studies has been very informative in the model's development and improvements.

Several participants were interested in the ability to add code to the HEAT program as a standalone R package. Although it would be useful to publish the code, there may be some issues as to how this would occur under oversite by DFO to ensure that the Tool continues to address regulatory needs in a standardized way. Issues may include unapproved changes to the base tables and therefore results compared to original or at least standard outputs. On the other hand, opening up the development of the Tool could also be beneficial as the user community and Science may upgrade, or create a subset of R programs that can be added to create new functionality and make improvements to existing code. There could be a "DFO supported/default" tool that would be used as a base model and if proponents or others alter this they would have to provide details or justification of these alterations upon submission for approval. The DFO-default Tool would also continue to be upgraded with new information of user generated modules upon expert review.

A discussion developed regarding the models' assumptions of presence and absence of fish in a particular area and how this information should be used at the regulatory level. For example, how are low numbers of fish species in a particular area from catch data provided by a proponent accounted for. The speaker explained that the maximum number of fish (i.e., the total fish list for the area) should be assumed when doing site assessments as the fishes could be moving around in the given area that may not be captured by one-time sampling.

The Science and Context for HEAT—Habitat/Ecosystem Assessment Tool

Presenter: Susan Doka

The speaker explained that the purpose for creating HEAT was to create a package for users that preserves the core HAAT functionally and calculations as well as expands the number of habitat variables, especially temperature. A user manual was also created that provides standards and guidelines for the Tool's use. The updated HEAT gives the user more flexibility for habitat assessment and scenario testing that can be applied to a range of different applications. In the recent evolution of HEAT; surveys, meetings, and critical reviews were conducted to obtain feedback on its development from experts and users. During the development the Great Lakes, application was prioritized as an important building block to complete first with expectations that the Tool will be expanded regionally next.

There have been some important technical updates. The Tool is now programed in R code after reviewing several different options of programing languages. HEAT is now hosted on its own website currently, but proposals have been submitted as business cases with several justifications for hosting the Tool in-house within DFO, which has not yet occured. Other technical updates include changes to regional databases in the Tool through comprehensive literature-based reviews of habitat associations by species, life stage, and habitat features. The ability of the Tool to process multiple scenarios at one time has been implemented to analyze examples such as multiple water level and temperature scenarios or physical habitat scenarios compared to a pre-state. This functionality gives flexibility in the model's use and the comparison of outcomes.

The speaker discussed some of the scientific components of the Tool. She stated that HEAT is a state comparison tool with standardized methods and units. It uses suitability and weighted suitable area (WSA) as the main output equivalent and changes in WSA define gains or losses in fish habitat supply between pre and post states.

The speaker then discussed the linkages between the Tool's science basis to policy. The Tool serves as a standardized measure of species' habitat and allows for the evaluation of all or just select fishes at all life stages (spawning, nursery, and adult) for a limited set of variables. The Tool allows evaluation of impacts and offsets as well as the user-defined weighting of fish guilds or life stages based on desired objectives for the area. Habitat surrogates are used to assess the changes to ongoing productivity at a location. It is possible to evaluate trade-offs in the analysis based on differential responses in underlying fish guilds, but generally the composition values for the entire fish community are used.

The speaker then noted that there are both benefits and challenges to the Tool. The benefits are that it is flexible, scalable, whole fish community inclusive, and the methods are transferable and standardized. The challenges are that there are several possible missing habitat variables of importance, as well as variability that is not captured in the dynamics of the spatial variables because it is a state-comparison tool, therefore the dynamic relationships between fish and their ecosystem have been summarized on average. These are the core model assumptions and uncertainties that must be considered in evaluations. An ideal free distribution of species is assumed and disaggregated, and independent habitat variables are assumed in the calculations for the time being (i.e., that variables are not co-varying or nested). There is uncertainty and sensitivity in the underlying fish-habitat associations and their functional effect on productivity.

Other assumptions include that time lags can be discounted and that constructed habitats can replace natural ones with or without offset ratios. The speaker advocated for the use of the precautionary principle in the application of the Tool given these aforementioned factors. A participant asked whether anything has changed with the basic habitat suitability index (HSI) calculations and the relationships between habitat and species since the inception of HAAT. The speaker noted that there have been no updates to how HSI calculations are performed but base table information has been updated.

Another question was posed regarding the addition of temperature and how this is accounted for within the model. The participant questioned since temperature is taken into account indirectly through depth, what the relationship between depth and temperature preferences will be and if this relationship will be an impediment to using it in other regions. The speaker noted that a temperature module is currently in development that may minimize the need for depth preference information. It is also possible to set different weights for thermal guilds, for example to increase the ratio used for weighting warmwater species in warmwater regions to account for regional differences in thermal tolerances or project goals.

Clarification was requested regarding the independence of the habitat variables and calculations. It was noted that the habitat variables are currently considered to be completely independent of each other. When temperature is added later, depth may become less useful as the two are largely correlated. The suitabilities are summed across the species using multiplicative methods, then rescaled and normalized. The model works by computing suitabilities for each habitat axis and then multiplying each and summing the total to then normalize the underlying suitabilities to be a value between 0 to 1.

Further clarification was needed regarding whether the model included a competitive component or invasive interactions between species. It was noted that the model does not include a competitive component (i.e., has no information on competitors in base tables) although it is possible to use the fish list and guild assignments to do a comparison between different groups if desired, including comparisons of invasives to natives or at the trophic level (i.e., piscivores to non-piscivores). However, there are several approaches and tools to investigating food web or competitive relationships including those that have the ability to assess food web dynamics if they are of interest.

The HEAT User Survey and Workshop

Presenter: Jane Tymoshuk

The speaker presented information on a survey and workshops that were held to inform HEAT development. The survey was sent to participants online, while the workshops were held in person in February 2013 in Burlington, Ontario and in Winnipeg, Manitoba in January 2014. All canvassing included potential users and programmers to discuss tool development. This included its scope, the needs for expanding functions, and methods for implementation of the Tool. The presenter shared an overall summary of the combined results from both the survey and meetings.

Users noted that the Tool was somewhat cumbersome as it was work-intensive to create the spreadsheets for input. Although users have the option to use several modules, many were difficult to use or find, such as the uncertainty and time lag modules. Condition factors (or quality adjustment factors) guidance was needed. The ability to change or replace suitability modules/matrices so that they can be combined with other tools was advocated. However, there remains a need to ensure structural consistency in the model particularly if used for regulatory purposes. Users also noted that the spreadsheet had a limited file size at 1,200 rows (the participants thought this only applied to the previous version of the Tool and was an Excel limitation). The current version has a limited number rows until software upgrades are made.

The survey also requested input on the preferred uses of the Tool. Users indicated that they would like the ability to create maps, obtain a user manual, and have online training and help support that includes having a FAQ section. Users were also asked how they would most likely use HEAT. The response suggested that it would largely be used for fisheries and habitat assessment and possibly climate change assessments once temperature functionality was advanced. Users suggested that other variables should be included beyond depth, substrate, and vegetation cover such as temperature, water level and elevation, light and oxygen profiles, and also the inclusion of invasive species habitat information into base tables. In total, 18 new functions or modifications were suggested for incorporation into HEAT. Users were asked to rank by importance which functionality to include in the next iteration of the model. Top ranking priorities were temperature, additional habitat layers, and habitat weightings beyond the condition factor.

A comment was made that survey results may change if done in another bioregion; but it was recognized that if the Tool is to be used across different ecosystems nationally there would need to be a common foundation with flexibility.

The Application of HEAT—Demo

Presenter: Sommer Abdel-Fattah

This presentation walked participants through the use of the current Tool online. Participants received an input data sheet prior to the meeting. The speaker directed participants to help videos, and navigated through the steps required to complete scenarios. First, users have the ability to choose a site’s fish list either by tertiary watershed, by lake, or by clicking on a map. This allows users to compile a basic species list based on the site chosen and then have the ability to deselect certain fish from that default list. It was clarified that the Tool is not currently designed for selecting individual fish species for assessment, but rather to examine the habitat supply changes for the entire community of fish in an area.

The next step gives the option of sorting and weighting the species by pre-set guilds (e.g., piscivore and non-piscivore) or life stages (e.g., spawning) or allowing the default of equal weighting across the guilds subsequent calculations. The speaker noted that if you have a small number of species in a certain guild then this group becomes highly sensitive compared to other more speciose groups, where a larger group is more resilient to habitat changes within the model likely because of habitat preference diversity. The amount of uncertainty regarding habitat associations also increases with small community numbers. Thus, it was advised to not assign a high weighting to a low-richness guild. This is especially evident when examining northern regions in Canada where there are much fewer species than in the Great Lakes and precaution should be used in interpreting the results in these areas. There should also be guidance on the minimum and maximum number of species that should be used and perhaps this could be part of a sensitivity analysis. Currently, the thermal guilds are classified based only on what is known of adult-stage thermal preferenda. Thermal guild habitat usage is linked to depth usage and is thus highly important when making weighting choices in different environments.

The final set-up step is the download of a spreadsheet based on the pre-selections made. Users can select the option to run multiple scenarios at this stage and the downloaded MS Excel file will contain multiple tabs to represent the number of scenarios chosen. The spreadsheet is somewhat data intensive and is completed in rows that represent habitat patches. A patch is considered a relatively homogenous area compared to adjacent areas. For example, depth classes change at this transition point or substrate composition is quite different between patches or vegetative cover changes. The idea is to classify each patch area as having mainly different variable compositions. How these areas are designated or delineated and the total resultant number of patches is decided by the user.

Users sometimes have difficulty completing the spreadsheet because of the spatial component and the level of detail required for each patch (area of depth x substrate x cover classes). For each of these patches, the user must also identify how each of these patches will change or be modified with development and the total areas of pre and post scenarios must be equivalent, excluding losses to infilling. Once the spreadsheet is completed, users upload it to the online HEAT program and the results can be displayed on screen or in a full processed report that can be downloaded. The results are displayed as suitabilities by patch, weighted suitable areas by patch, by habitat modification type, and by guild or life stage. The full report contains details of all inputs and outputs, and habitat summaries including all user modifications.

When re-running a scenario it is important to note that the model runs based on what is contained within the spreadsheet itself, not based on the selections online immediately prior. It is also important to note that the input file name must be changed when re-running a new scenario to avoid data or file loss.

It was noted by one of the participants that there should be a way to refine the output to show offsets as classified as new measures to prevent serious harm (i.e., as new projects); and to not include as benefits any indirect modifications that have resulted in a benefit from the original project. FPP policy may require that an offset be a new and separate action to mitigate serious harm from a project and thus offsets may require a new definition within the model, perhaps as a separate tab for FPP users. It was noted that it is possible to calculate this currently within the Tool by quantifying the modifications (both direct and indirect) from a project and comparing those with offset type improvements which capture any new project offset measures as a separate category in the scenarios.

The Science—Calculations of Suitability Indices

Presenter: Charles K. Minns

The presenter explained that much of the information on the calculations of suitabilities for individual species' habitat is contained within Minns 2001. Each species has three matrices that include the habitat requirements database for spawning, young-of-year (YOY) or nursery, and adult life stages of preferences based on associations of that species' life stage for various depth ranges, substrate classes, and vegetation categories. Preferences are rated as nil, low, medium, and high (and assigned 0, 1, 2, or 3, respectively) for depth, substrate, and cover classes. For most species and biogeographic regions, due to sparse data these depths were simply represented as nil (0) or high (3). Preference values were generated for a single category of a habitat feature per cell. These combined preference scores are summed over permutations of depth, substrate, and cover categories as a proportion of each possible combination based on the total. The default preference is 0 if no number was assigned. Species-level suitability matrices are pooled into fish group matrices by life stage and create a group matrix from the elements that belong to that group. Matrices are summed cell by cell and then the cell sums are standardized to a scale of 0 to 1 by dividing each by the total (i.e., they are normalized between 0–1).

A group's suitability is provided as well as the assigned weights for that group (default values are equal weighting; e.g., if there are three life stages then weights are 0.33 for each stage when combining). A composite suitability matrix is the result as well as each life stage having its own composite suitability matrices by guild. Proportions of each vegetative cover, substrate, and depth classes within a patch are then summed and multiplied by each other to create patch suitability.

(1) $Suitability = SUM\ (Ps^{*}Pz^{*}Pc^{*}Sszc)$

Where P = proportions, and then multiplied by area to get a weighted suitable area.

There are no known techniques to account for the complex interactions between habitat factors based on the way that the matrix is currently summed. An investigation of these interactions was done but yielded no concrete results at the time (C.K. Minns and J.E. Moore, DFO, unpublished data). During development of the Tool, different ways of summing to obtain suitabilities were examined (e.g., max, min, average) but these were not effectively different from each other. The issue was that if fishes are using a habitat that is not known, it might not be expressed in this nil model (i.e., the assumption is of no use if no information was found). It was assumed that all fish and habitat combinations are accessible and selection is expressed through ideal free distribution.

The presenter then discussed how Condition Factors (CFs), (now called Quality Adjustment Factors (QAFs) by CSAS recommendation), have been applied when using the Tool. QAFs are conditions or states that depress the productivity value of habitat patches and that are applied at the patch level for other non-physical characteristics. QAFs are scaled from 0–1 (to scale down the suitability of the patch) and applied as modifiers on the final composite suitabilities after group/life stage weighted summations have been completed by patch. QAFs for loss patches were assumed to be 1 but this application has varied. The assumption being that a QAF may be a temporary degradation that could be remediated but an infill in permanent. It is important to note that the use of a QAF requires a documented rationale for its use and application. Examples of when to use QAF include areas where there are water quality problems or areas where some patches are currently impacted by nutrients or sediment loads from storm water sewer overflows or other contaminants and toxic chemicals that may impair fish health and cannot be remediated in the near future. Degraded conditions often exist in the pre-scenario where substrate in some portions of the site are highly contaminated and most often proponents will cap the contaminated substrates or remove them in the post-scenario as part of remedial action plans (RAPs), for example.

QAFs can also be applied when there are changes in fetch or exposure of patches occurring between pre and post scenarios that affect habitat features or fish distributions. This will occur when previously open-lake patches are altered to become sheltered by new structures which reduce fetch and allow fine sediment accumulation and vegetation growth. Care should be taken not to duplicate post-construction benefits by adding vegetation and also using a QAF to reduce the pre-scenario condition, for example, as both are directly impacted by fetch or exposure. It is important to note when using QAF it is assumed that no man-made improvement can be better than the naturally functioning system. Offset ratios may be more relevant than using a QAF to reduce the benefits of the post scenario construction in this case.

Case Studies—Fisheries Protection Program and HEAT

Presenter: Andrea Doherty

This presentation discussed some of the case studies done by the FPP to assess projects requiring approval and using HEAT. FPP has primarily used HEAT for large infills in the Great Lakes Basin as part of its review when assessing projects and issuing an authorization for a harmful alteration, disruption, or destruction (HADD) or serious harm to fish habitat. FPP has used HEAT for 54 files where the size of projects ranged from 61 m^2 to over 500,000 m^2 as offsetting. Information requirements are now mandatory under the Fisheries Act to maintain or improve productivity of CRA fish. The types of mitigations and offsetting for evaluation in HEAT include direct or indirect habitat improvements or impacts, or restoration and enhancement (MODD, MODI, COMD*), habitat creation (COMC* -COM categories previously referred to compensation and now will be called OFFC and OFFD, OFFI under the new Act), or through biological or chemical methods of improvement that can be assessed using the QAF. Because many of the caveats of the offsetting requirements are met within HEAT, it is hoped that HEAT may be able to serve as a standardized evaluation methodology or tool with standardized operational definitions of ecological units used beyond infilling.

However, there are some improvements that may be necessary for adoption of HEAT as a standardized tool. The issues largely relate to a lack of understanding by FPP staff of the assumptions, uncertainties, sensitivities, accuracy, and precision measures. As such, there is a need to build user knowledge in what assumptions were used when transferring data from the literature review to the base suitabilities, as well as the confidence level in how this data was gathered and reviewed. Users should also understand the level or precision required for area/ patch data such as the level of detail required to run an effective scenario. Another limitation is the amount of effort required to collect data for its continued acceptance and use which should be minimized to avoid any assumptions having to be made by the proponent. The minimum requirements for running a HEAT scenario are spatial knowledge of the area which includes depth ranges, substrate types, and vegetative/woody debris cover distributions.

The speaker continued to discuss precautions that must be taken in the use of HEAT for analysis. The Tool currently defines depth categories as 0–1, 1–2, 2–5, 5–10, and 10+. However, it is unclear how to establish a reference point for this information, for example whether high water mark, low water mark, season of use, functional water level, or an 80th percentile should be used as a default or other scenarios. Currently a depth of 0 is defined as the 80th percentile of long term water levels in the Great Lake for which the HEAT scenario will be run. In such a case, any elevation above this would not be considered. An example of an issue with depth selection is that the proponents can manipulate this value in order for the results to yield gains if no direction is given.

Substrate was another factor that required some clarification or additional documentation for its proper use. Substrate categories are bedrock, boulder, rubble, cobble, gravel, sand, silt, clay, and hardpan. Users wanted more clarification on how to qualify organics or “muck”. It was suggested that perhaps an understanding of how the substrate categories were generated in the base suitability tables would be beneficial in understanding how to classify substrates. Clarification or use of substrate requires a protocol that addresses the following items:

1. how to determine the substrate % for organics/ detritus material;
2. how was the separation of fines determined for base table associations; and,
3. how to address veneers of fine substrates that create habitat in open areas where the surficial geology may be different.

It was also noted that substrate inputs are highly sensitive in the model, meaning that outputs can change significantly with minor changes in substrate type or percentages. It was noted that it may be useful to simplify the categories by size as coarse, medium, or fine. A detailed review of fish habitat substrate preferences should be redone with these factors in mind. Because HEAT is designed as a state comparison, it does not capture how substrate might be changing or shifting and should be considered in its further review. Furthermore, obtaining soil samples and quantifying them into such fine classes through soil analysis is difficult and expensive. A standard soil-testing procedure and methodology should be established to standardize the approach as well as the input needs based on collected data.

Cover categories include submergent, emergent, and no cover. This creates some confusion for inclusion of other types of cover such as coarse woody debris, and man-made structures such as cribs, sea walls, or docks. Direction is needed as some of these examples were covered in older documentation and may need to be validated with new information.

The speaker then presented a case study: the Brant Inn Node. This project included an infill and the offset creation of a wetland. The HEAT scenario resulted in an overall gain, however, when examining the details it was noted that there were losses in some areas and gains in others. It is important to examine the details when examining a scenario as important life stages or species may experience detrimental losses even when there is an overall gain for the fish community or vice versa. It is important to note that the standard HEAT advice states that there should be no net loss in the results, but does not define whether losses in other vital subareas (i.e., specific guilds, life stages) should be flagged. Advice on consistent interpretation of the results should be supplied.

The speaker reiterated the potentially confounding effect of substrate changes by giving a case example. The case she described presented a scenario in which the pre-condition substrate was composed of 100% sand and the post-condition contained 100% cobble. Although it was predicted that this would yield a gain by habitat practitioners, a loss occurred for all species except for cold water species (i.e., spawning habitat for coldwater species). Thus, a literature review is needed to support FPP biologists on which types of substrates can be used for offsetting and under which circumstances. It must also be verified whether the values of the substrate within the model are correct and if the value of sand is being overvalued because it is ubiquitous and has a potential spurious correlation with fish distributions. This over-valuing of sand could be due to correlation rather than causation, since many fish live or pass through these areas; however, this does not mean that fish are actually dependent on sand for survival, growth or reproduction.

There was some discussion from participants regarding the efficacy of cobble as an offsetting measure. Some argued that cobble should not be accepted as an offset as it degrades to sand overtime if it is in depositional areas and it may shift and move. Further examination of this issue should be thoroughly undertaken. The speaker noted that it is important to highlight that if the combination of sand/silt/clay is changed, it results in substantially different outcomes and this should at least be flagged within the model. Minor changes in composition make significant impacts on weighted suitable area results and are particularly noticeable by guild. Future work should be done to provide FPP with guidance on substrate use, possibly through a sensitivity analysis. HEAT should possibly contain some standardized compositions for set substrate classes such as glacial tills (for example a set composition for biogeographic regions or eco-classes in Ontario).

The speaker then presented on how the habitat variable fetch was applied through a QAF and how it can also affect model results. The case she examined was one where there was no change in substrate, but one location had high fetch and the second location had low fetch. The prediction was that the low fetch will be used more by more fish. However, the model results did not show this distinctly. Thus, FPP would like to have a set of assumptions and standards outlined for using the quality adjustment factor properly.

There was a discussion by the group about the uncertainty within the model. There was consensus that simulations need to be conducted to test scenarios and sensitivities within the model. It was noted that the homogeneity of the site may affect model results where greater habitat differences would have a greater impact. This means that there is a limit to how many of the classes can contain information within one single patch. For example, if one patch contains all possible substrate types; the model has more difficulty producing reliable values if patches are not distinct from each other where each patch is of a homogenous habitat classification. It was suggested that a possible solution may be to put a flag or warning into the system or within the guidance document to identify that there is a limit to the size of the patch, or spatial resolution. It was further suggested that the model be validated through using real data and monitoring sites that have been assessed with HEAT-type approaches through time to best advise on substrate compositions to be used for fines and fish-habitat associations.

The Current and Future Direction HEAT

Presenter: Susan Doka

The presenter discussed important inclusions and updates that were currently being made to HEAT as well as its proposed future development.

Currently base tables containing fish species distribution information by tertiary watershed (originally from N.E. Mandrak, DFO, unpublished data [1996]) are being updated to include more recent information as well as new data on juvenile life stages and their thermal preferences and tolerances. In future, base tables will be expanded to include all Canadian fishes which will be particularly important for its national application. Information on SAR or rare species designations will also need to be added or updated as their status changes. A review of any additions or changes to base tables will need to be done so it is vetted by experts at each phase. It will be important to investigate how fish behave differently in different areas and eco-regions, for example Lake Trout in the High Arctic areas behave differently than those in the Great Lakes region. This process could be aided by the creation of “eco-regional” teams that would regulate and update their own section’s information but still report to a national steering committee for consistency.

Guidance on water levels will be another important inclusion to HEAT. Most Great Lakes scenarios have used the 80th percentile or low water datum as a reference for calculating depths. The goal in the future is to capture a range of water depths in HEAT calculations. This is not trivial as the entire patch size will change with depth and differences in spawning and other suitabilities will change under different water level scenarios. Guidance for a reference water level to be used (average, high water mark, low water mark) will need to be included in the Tool. This currently can be done using HEAT by using site-specific information and running multiple scenarios of water levels for any given project. Clarification is also required on the period of record to use for the water level reference (e.g., some jurisdictions allow construction if an area has been dry for one year, but for the main Great Lakes DFO FPP advises using the 80th percentile of water levels from longer term records). There has been some discussion surrounding whether the Tool should have elevation values instead of depths within the model and depths are calculated on the fly with an approved set of water level to use. Using GIS capabilities to create digital elevation models (DEMs) for the Great Lakes and elsewhere would aid in this type of analysis.

The speaker also discussed the inclusion of temperature in HEAT as temperature is an important driver of fish behavior, vital rates, and productivity. A methodology for inclusion of temperature within HEAT has already been developed but still needs to be translated into programming language and beta tested before implementation. The established methodology will require users to provide an annual average temperature curve (pre and post if different) into the model. HEAT assigns species into spawning temperature ranges based on their seasonal temperature cues to classify fish into spawning guilds (early spring, late spring, summer, fall/ winter). Base data tables that include information on spawning temperature preferences, optimal growth rates, lethal temperatures, and other life stage temperature requirements will allow for analysis of seasonal thermal habitat supply and the success of species within different temperature signatures.

Nursery/YOY thermal guilds are based on a combination of spawning/adult classifications. Minns and Shuter (2013) have already developed a generalized Seasonal Temperature Model (STM) for inland lakes that predicts profiles from seasonal temperature relationships of warming, maximum temperature, and cooling. This forms the basis for predictive modelling for 3D thermal structure to then use in HEAT for habitat supply calculations. For each depth class in HEAT (0-10+ m range) a temperature value is assigned based on known thermal depth profile relationships and the use of an existing 3D statistical model which will complete the matrix of values required for input. This structure allows for the creation of thermal suitability windows based on YOY/adult growth start dates and using lower and upper temperature spawning limits and how these align within the derived temperature matrix. If the minimum amount of time to reach the next life stage is met for each thermal window calculation, then this is rated as a success (1) for that life stage. For example, using the equation: D = time needed for egg development = 186.23* exp(-0.197*T) (Teletchea 2009); if D is not met, then based on a site's thermal regime that patch would obtain a suitability of 0. The simple temperature model will use the minimum growth window required to overwinter as a goal for nursery suitabilities and will use seasonal models for adult growth and survival to scale suitabilities within each thermal guild between 0 and 1. Either a binary or suitability scalar can be applied on each patch based on these thermal windows. The result will be an annual representation of a state response (i.e., probability to support a life stage or guild) based on a project's location and its thermal regime.

The speaker next outlined how converting area into productivity could involve using some common currency such as adult equivalents or other standard production measures (such as number of adults/area; conversion to egg/nursery/juvenile densities). For example, a primary production scalar, a total fish production scalar, or a potential yield scalar (fisheries biomass) applied by habitat type could be used to convert habitat units to productivity or production units if that is the desired metric.

One application of habitat to production conversion would be a landscape accounting approach using WSAs scaled by ongoing productivity indices (OPIs) which recognizes that different eco-classes or largescale habitat types have differing base or maximum levels of productivity. Examples of different eco-classes include river mouths or estuaries, wetlands, embayments, open coast or high energy environments, etc. This methodology is being used to inform restoration activities using a landscape approach, where projects must be evaluated through cumulative assessment in HEAT and conversions are based on these larger spatial differences.

Another potential application of a HEAT type of approach extends to landscape scale modelling and areal inputs into population models. One example includes the ranking of simulated nearshore nursery habitat supplies across Lake Ontario shoreline units using guild-based habitat supply models and habitat-based population models to estimate the relative contribution of the areas to guild dynamics. This particular application of the HEAT-type methods required modified species lists, different group assignments by life stage, and new customized guilds which were based on spawning temperatures and vegetation associations instead of the standard adult thermal and piscivore guilds used as defaults. The customization was necessary for the question asked and is seen as new functionality that may be needed depending on regulatory need.

Other HAAT modules were developed in the past but were not ported to the current HEAT online tool based on user prioritizations (i.e., top priority recodes were completed first). These modules should be re-incorporated through time and include a River HEAT version, time lag discount functions, and an uncertainty module. River HEAT (Minns 2010) can be used to examine project impacts in streams/rivers and like Lake HEAT can be used to provide productivity surrogate output through HSIs and WSAs but requires slightly different inputs (e.g., flow information). River HEAT still requires some development before it can be re-established as a module or a standalone Tool. Its main use would be in situations where a project may impact both riverine and lake habitats, but on a smaller scale (i.e., not large dam projects that affect whole ecosystem change). Secondly, the time lags module calculated discounts to habitat supply based on expected delays (e.g., years) between project impacts and offset measures. Finally, the uncertainty module explored the implications of uncertain knowledge regarding habitat associations of fishes and the impact on evaluation outcomes (i.e., HAAT output).

A compilation slide of the next steps and future directions for HEAT included:

- base table information review and systematic updates;
- a review for its national application and regional data needs;
- incorporation of other habitat variables such as:
    - instruction on water level references;
    - inclusion of temperature;
    - possible inclusion of dissolved oxygen and turbidity;
- productivity conversions of habitat supply and links to population modelling;
- output links to population models;
- examples of HEAT approaches in landscape ecology and management;
- habitat banking and accounting frameworks for cumulative impact assessment;
- reincorporation of time lag and uncertainty modules;
- programming of a River HEAT version; and,
- continued technical updates and production of training materials.

There was some discussion regarding the use of the tertiary watershed lists and whether proponents using HEAT should be able to customize their own lists because this introduces bias and could change the output of the model. Currently the practice is to use the whole lake list for each Great Lake as these are all the species that can potentially use that space. Limiting the number of fish also introduces a higher sensitivity in the model to those specific fish and their habitat uses. The aggregated fish community output is important as it is the main concept of the Tool. This highlights the potential issues with using short fish lists, although this becomes complicated since in species poor areas it is accurate. If users are to employ this function in a standardized way, the unequal weighting of life stages will need further guidance. Both of these factors could be explored through a sensitivity analysis. Similarly, there is currently no written guidance on how to treat “valuable areas” or “critical habitat” in project evaluations; for example those that support SAR species. HEAT did not originally aim to evaluate individual species, rather it is a community-based tool and should only be used to assess scenarios at the guild level as the lowest level until further guidance is given on species-specific approaches.

A discussion evolved around how HEAT could be modified to be used more specifically by FPP given the changes to the Program and Fisheries Act. This would include some nomenclature changes (e.g., “compensation” will be changed to “offset”), but more significantly, modified area that are improvements within a project may need further guidance from policy regarding their designation with the mitigation hierarchy. Offsetting may have to be equal to the gross amount of residual serious harm and not the intrinsic positive impacts of modifications within the development project. It was proposed that this could currently be accomplished by running two scenarios:

1. a set of scenarios using only the proposed development site; and,
2. a set of scenarios using only the offsetting component and then comparing the two.

It should be noted that much of this information is already available in the base output tables.

REFERENCES CITED

Bradford, M.J., Smokorowski, K.E, Clarke, K.D., Keatley, B.E., and Wong, M.C. 2016. Equivalency metrics for the determination of offset requirements for the Fisheries Protection Program. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/046. vi + 32 p.

Coker, G.A, Portt, C.B., and Minns, C.K. 2001. Morphological and Ecological Characteristics of Canadian Freshwater Fishes. Can. MS Rpt. Fish. Aquat. Sci. 2554: iv + 89 p.

DFO. 1986. The Department of Fisheries and Oceans Policy for the Management of Fish Habitat. Fisheries and Oceans Canada, Ottawa, ON. iii + 28 p.

DFO. 2013. Science Advice to Support Development of a Fisheries Protection Policy for Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/063.

Hayes, D., Jones, M., Lester, N., Chu, C., Doka, S., Netto, J., Stockwell, J., Thompson, B., Minns, C.K., Shuter, B., Collins, N. 2009. Linking fish population dynamics to habitat conditions: insights from the application of a process-oriented approach to several Great Lakes species. Rev. Fish Biol. Fish. 19: 295–312.

MacNeil, J.E., Murphy, S., Ming, D., and Minns, C. K. 2008. Analysis of infilling projects affecting fish habitat in the Great Lakes (1997-2001). Can. Manuscr. Rep. Fish. Aquat. Sci. 2840: vi + 194 p.

Minns, C.K. 1995. Approaches to assessing and managing cumulative ecosystem change, with the Bay of Quinte as a case study. J. Aquat. Ecosys. Health. 4: 1-24.

Minns, C.K. 1997. Quantifying “no net loss” of productivity of fish habitats. Can. J. Fish. Aquat. Sci. 54(10): 2463–2473.

Minns, C.K. 2001. Science for freshwater fish and habitat management in Canada: current status. Aquat. Ecosys. Health and Manag. 4(4): 423–436.

Minns, C.K. 2006. Compensation ratios needed to offset timing effects of losses and gains and achieve no net loss of productive capacity of fish habitat. Can. J. Fish. Aquat. Sci. 63(5): 1172–1182.

Minns, C.K. 2010. Ontario stream fishes habitat associations and derivation of a simple habitat assessment model. Can. Manuscr. Rep. Fish. Aquat. Sci. 2909: vi + 31 p.

Minns, C.K., and Nairn, R.B. 1999. Defensible Methods: applications of a procedure for assessing developments affecting littoral fish habitat on the lower Great Lakes. *In* Aquatic Restoration in Canada. Edited by T.P. Murphy and M. Munawar. Backhuys Publishers, The Netherlands. pp.15–35.

Minns, C.K., and Moore, J.E. 2003. Assessment of net change of productive capacity of fish habitats: the role of uncertainty and complexity in decision making. Can. J. Fish. Aquat. Sci. 60: 100–116.

Minns, C.K., and Shuter, B.J. 2013. A semi-mechanistic seasonal temperature-profile model (STM) for the period of stratification in dimictic lakes. Can. J. Fish. Aquat. Sci. 70(2): 169–181.

Teletchea, F. 2009. Molecular identification methods of fish species: reassessment and possible applications. Rev. Fish Biol. Fish. 19: 265–293.

APPENDIX 1. TERMS OF REFERENCE

Habitat Ecosystem Assessment Tool (HEAT) Software Development and Evaluation

Regional Peer Review – Central and Arctic Region

January 27-29, 2016
Burlington, Ontario

Chairpersons: Gavin Christie and Sophie Foster

Context

The *Fisheries Act* was amended in 2012 to include new provisions for fisheries protection which came into force in 2013. The amended Act focuses on managing threats to the sustainability and ongoing productivity of fisheries and contains a prohibition against serious harm to fish that are part of or support a commercial, recreational or Aboriginal fishery. Serious harm to fish is defined in the Act as the death of fish, or the permanent alteration to, or destruction of, fish habitat. If serious harm to fish or fish habitat cannot be avoided, proponents of projects may apply for authorizations. The Fisheries Protection Program (FPP) aims to support its project review and decision-making processes with the development of quantitative metrics and tools that can be coupled with decision criteria to assist FPP staff when determining the magnitude of impact and in evaluating offset plans.

The Habitat Ecosystem Assessment Tool (HEAT) evaluates proposed development projects or any change (e.g., a stressor) and its effects on fish habitat quality and supply in lakes. The Tool has primarily been applied in the Great Lakes region but some elements of the tool are set for broader application. Similar approaches have been used beyond the Great Lakes, on a case-by-case basis. Currently the tool translates combinations of physical variables into fish habitat quality and quantity by life stage and fish guild groupings. Estimates of potential relative changes in fisheries productivity are currently provided through net habitat supply calculations. As we continue the refinement of Lake HEAT we require input from current and potential users to review its current form and requirements for its expansion and improvement, if needed.

This review process and elements of the tool may complement current FPP initiatives to gather additional habitat information for Canadian fisheries and other impact and offset advice. Recently, habitat offset metrics including habitat supply and fish or fisheries productivity were evaluated (Bradford et al. 2015) building on previous science advice (Clarke and Bradford 2014). As part of the process, we will evaluate proposed methods and metrics for the conversion of habitat supply to measures of fisheries productivity as a derived offset metric.

Participants will review the science and documents behind HEAT and proposed upgrades for the purposes of providing feedback to the FPP at DFO on its use and applicability primarily in the Great Lakes but also for its expansion in the Central and Arctic Region, and possibly beyond.

Objectives

The objective of this meeting is to evaluate elements of HEAT to help in the evaluation of proposed development projects and their potential risks to fishes and their supporting habitat. Background documents will be circulated providing information about the tool and its use. More specifically, the review objectives are to address:

- A review of offsetting methods in HEAT and their scientific basis.

- How the Tools' features can be used most effectively and consistently to better inform current management decisions. (Case studies and a user package will be provided for the session).
- Whether updates or improvements to the Tool are needed to enhance outputs for users, and if so, what these are.
- An examination of the applicability of the HEAT approach within a broader context. How could the tool be applied spatially within a landscape context or be used nationally? (e.g., extending the approach to other ecoregions across Canada, incorporation of productivity metrics, potential use in habitat banking or cumulative impact assessments).

The following working papers will be provided in early January for your review:

- HEAT User Guidance Document
- HEAT Survey and Meeting Report
- HEAT Background Document

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document(s)

Participation

- Fisheries and Oceans Canada (DFO) (Ecosystems and Oceans Science, and Ecosystems and Fisheries Management sectors)
- Toronto and Region Conservation Authority (TRCA)
- Ontario Power Generation (OPG)
- Other invited experts (e.g., academics, expert users)

References

Bradford, M.J., Koops, M.A., and Randall, R.G. 2015. Science advice on a decision framework for managing residual impacts to fish and fish habitat. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/112. v + 31 p.

Clarke, K.D., and Bradford, M.J. 2014. A Review of Equivalency in Offsetting Policies. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/109. v + 18 p.

APPENDIX 2. LIST OF MEETING PARTICIPANTS

Name	Organization/Affiliation
Sophie Foster (Co-Chair)	DFO – Science, National Capital Region
Gavin Christie (Co-Chair)	DFO – Science, Central and Arctic Region
Susan Doka (Rapporteur)	DFO – Science, Central and Arctic Region
Eva Enders	DFO – Science, Central and Arctic Region
Sommer Abdel-Fattah (Rapporteur)	DFO – Science, Central and Arctic Region
Marten Koops	DFO – Science, Central and Arctic Region
Neil Mochnacz	DFO – Science, Central and Arctic Region
Robert Randall	DFO – Science, Central and Arctic Region
Denis Chabot	DFO – Science, Quebec Region
Keith Clarke	DFO – Science, Newfoundland and Labrador Region
Dan Selbie	DFO – Science, Pacific Region
Andrea Doherty	DFO – Fisheries Protection Program, Central and Arctic Region
Sara Eddy	DFO – Fisheries Protection Program, Central and Arctic Region
Alywn Rose	DFO – Fisheries Protection Program, Central and Arctic Region
Guy Robichaud	DFO – Fisheries Protection Program, Gulf Region
Ken Minns	Emeritus DFO – Science, Central and Arctic Region
Cindy Chu	Ontario Ministry of Natural Resources and Forests
Dak Dekerckhove	Ontario Ministry of Natural Resources and Forests
Thomas Sciscione	Toronto Region Conservation Authority
Jane Tymoshuk	External Consultant

APPENDIX 3. MEETING AGENDA

Canadian Science Advisory Secretariat (CSAS)
Regional Science Advisory Workshop

AGENDA - Science Review of the Habitat / Ecosystem Assessment Tool (HEAT)

Waterfront Hotel, Burlington, ON
January 27-29, 2016

Chairpersons: Gavin Christie / Sophie Foster

DAY 1	**WEDNESDAY, JANUARY 27TH**
9:00–10:00	Introduction to CSAS advisory process (Chair)
	-Introduction of participants
	-Review Terms of Reference
	-Overview of goals and objectives of meeting
	-Background to HEAT
10:00 – 10:30	Overview of the Fisheries Protection Program: (Alwyn Rose)
	-Changes to Fisheries Act
	-Applications for Authorization under Paragraph 35(2)(b) of the Fisheries Act Regulations, the Fisheries Protection Policy, and the Proponent’s Guide to Offsetting
	-Benefits and challenges of how HEAT is currently used by the Program
10:00–10:30	Presentation: History and Science Behind HEAT (Charles K. Minns)
10:30–10:45	Break
10:45–11:15	Presentation: Science in Context (Susan Doka)
11:15–12:00	Discussion: History and Science of Tool
12:00–1:00	Lunch Break
1:00–1:30	Presentation: User Survey and Previous Meeting Proceedings (Jane Tymoshuk)
	-Discussion: HEAT functionality and user feedback
1:30–2:15	Active Demo Online Example of HEAT (Sommer Abdel-Fattah)
2:15–2:30	Break
2:30–4:30	Discussion cont’d: HEAT Science and Feedback

	Begin Drafting Science Advisory Report (SAR)
DAY 2	**THURSDAY, JANUARY 28TH**
8:30–9:30	Re-cap of day 1 (Chair)
9:30–10:30	Presentation- Calculations of Suitability Indices (Charles K. Minns)
10:30–10:45	Break
10:45–12:00	Presentation: Case Studies (Andrea Doherty)
	Discussion: Case studies and standards for application
12:00–1:00	Lunch Break
1:00–1:30	Presentation: New Elements for HEAT (Susan Doka)
1:30–2:30	Discussion: re new elements / functionality
2:30–2:45	Break
2:45–4:30	Identification of key themes for the SAR
	-Continue drafting Science Advisory Report
	DAY 3 FRIDAY, JANUARY 29TH
8:30–10:30	Re-cap of day 2 (Chair)
	-Continue drafting SAR
10:30	Break
10:45–12:00	Drafting Science Advisory Report
	-Wrap Up / Next Steps
	Workshop Ends