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Central and Arctic Region

REVIEW OF HABITAT EVALUATION PROCEDURE (HEP) INPUT PARAMETERS AND MODEL RESULTS FOR THE MEADOWBANK GOLD MINE PROJECT

Context

The Agnico-Eagle Mines Ltd, Meadowbank Gold Mine is an open pit gold mine in the Kivalliq district of Nunavut, Canada, located 110 km north of Baker Lake. The mine property includes Goose, Portage and Vault deposits. Initial production began in 2010 from the Portage open pit and the mine life is estimated to extend from 2010–2018.

Under the Nunavut Land Claims Agreement and *Nunavut Project Planning and Assessment Act*, Project Certificates issued by the Nunavut Impact Review Board (NIRB) for mining projects in Nunavut must, upon closure and reclamation of the project, compensate or offset appropriately for the loss of fish and fish habitat.

To evaluate habitat losses and gains for the Meadowbank open-pit gold mine project and other mining projects in Nunavut and the Northwest Territories, Agnico Eagle Mines Ltd (AEM) in collaboration with Golder Associates Ltd, adapted a Habitat Evaluation Procedure (HEP) model.

As part of the Fisheries and Oceans Canada's (DFO) review and authorization, the Fisheries Protection Program (FPP) has requested Science to peer review the adapted HEP model input parameters and results for the Meadowbank No-Net-Loss and Fish Habitat Offsetting Plan. FPP asked if the Proponents' model input parameters are scientifically valid and a defensible approach to calculating loss and gain for projects. Science was also asked to calculate the appropriate offset ratio for any lost productivity due to the timing of losses and delayed offsets.

The request was submitted to Science in early February 2016 with advice requested by May 2016 as the Proponent has requested a *Fisheries Act* Authorization in June 2016. This Science Response results from the Science Response Process of April 2016 for the Review of Habitat Evaluation Procedure (HEP) input parameters and model results for the Meadowbank Gold Mine Project.

Background

The Habitat Evaluation Procedure (HEP) modelling approach is a tool used in environmental impact assessments to document and budget habitat losses and gains. The Habitat Evaluation Procedure and associated Habitat Suitability Index (HSI) modelling approaches were developed by the U.S. Fish and Wildlife Service (USFWS 1981) in the late 1970s and early 1980s. These approaches contributed significantly to the conceptual evolution of defensible methods (Minns 1997), the habitat suitability matrix (HSM) model approach (Minns et al. 2001), a software application, known as HAAT (Habitat Alteration Assessment Tool) in 2001, and recently the web-based software HEAT[1] (*Lake Habitat/Ecosystem Assessment Tool*). The HEP model developed by Agnico Eagle Mines Ltd (AEM) in collaboration with Golder Associates Ltd is based on the defensible methods and the HSM model approaches. AEM adapted HEP model

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[1] The *Lake Habitat/Ecosystem Assessment Tool* (HEAT) is an on-line software tool to quantify habitat suitability of a site, is an evolution of HAAT (Habitat Alteration Assessment Tool) also referred to as 'Defensible Methods for Assessing Fish Habitat' (Minns et al. 2001).

input parameters and results are included in the Meadowbank No-Net-Loss (AEM 2012) and Fish Habitat Offsetting Plan (AEM 2016).

The HSM model uses pooled matrices representing the aggregate habitat preferences of many fish species by life stage to ensure that the needs of all fishes occurring in an ecosystem or ecoregion are considered. The HSM model generates suitability values for specific combinations of depth, substrate, and cover that can be assigned to individual habitat patches.

Habitat Units (HU) are outputs of the HEP model and are estimated as the product of the quantity and quality of each habitat category. Habitat quality is assessed through use of habitat suitability indices (HSIs) for fish species occurring in the system. The HSI value (between 0 and 1) is derived from an evaluation of the ability of key habitat components to provide the species' requirements. The reliability of HEP and the significance of HUs are dependent on assigning well-defined and accurate HSIs to the species, habitat categories, additional cofactors, and weighting parameters under investigation.

Analysis and Response

Review of input parameters to the HEP model

The input parameters used by AEM in their HEP modelling for Phaser Lake are described in AEM (2012, 2016). It would be helpful to add information to report on the geographic location of the lake's center, the water level that was used to define the lake area, and the tertiary watershed, in which Phaser Lake is located. Water depth zones (< 2 m, 2–4 m, > 4 m) and substrate zones (fines, mixed, coarse) were evaluated to provide area (hectares) of each habitat type (Table 1). Definitions of the fine, mixed and coarse substrate class, in particular the ratio between fines and coarse substrate in mixed substrate class should be provided.

Table 1. Habitat types identified in the HEP model for Meadowbank Lakes (from AEM 2012, 2016)

Habitat type	Criteria	
	Depth zone	Substrate
1	< 2 m	Fines
2	< 2 m	Mixed
3	< 2 m	Coarse
4	2–4 m	Fines
5	2–4 m	Mixed
6	2–4 m	Coarse
7	> 4 m	Fines
8	> 4 m	Mixed
9	> 4 m	Coarse
10†		

† Habitat type 10 is assigned to non-backfilled pit areas independent of estimated depth or substrate characteristics. It is applied only to pit areas in offsetting calculations.

Fish surveys were undertaken in Vault and Phaser lakes in 2012 using gillnets (25 mm, 38 mm, 51 mm, 76 mm, 102 mm, and 126 mm stretch mesh panels). Both lakes contained Lake Trout (*Salvelinus namaycush*) and Round Whitefish (*Prosopium cylindraceum*). The two species were captured in similar proportions in Phaser Lake while a higher proportion of Lake Trout were caught in Vault Lake. A single Burbot (*Lota lota*) was captured in Phaser Lake. Net placement attempted to target Arctic Char (*Salvelinus alpinus*) although none were captured. The fish out of Vault Lake in 2013 resulted in the capture of about 100 Arctic Char. Arctic Grayling (*Thymallus articus*) and Cisco (*Coregonus artedi*) do not occur on the mine site (AEM 2012). Slimy Sculpin (*Cottus cognatus*) was rarely caught while Ninespine Stickleback (*Pungitius*

pungitius) was occasionally observed in project lakes. Neither Slimy Sculpin nor Ninespine Stickleback are susceptible to the survey gear. Life functions identified in the HEP modelling included spawning use, nursery use, foraging use, and overwintering use and these life functions are given equal weighting for the calculations.

1) Habitat suitability indices

The habitat suitability index (HSI) values used in the AEM HEP model represent the relative quality of each habitat type for each life function of each fish species present in the region. Habitat suitability for each life function was ranked as 0 (unsuitable), 0.25 (below average), 0.5 (average), 0.75 (above average) or 1 (optimal). The HSIs were the same as those used for the Meliadine Gold Project (AEM 2012). The AEM Meliadine property is located near the western shore of Hudson Bay in the Kivalliq region of Nunavut, about 25 kilometres north of the hamlet of Rankin Inlet and 290 kilometres southeast of the Meadowbank mine site. The Arctic Char general life history section of the Meliadine Final Environmental Impact Statement describes anadromous Arctic Char rather than the lake-resident life history form of Arctic Char found in the Meadowbank lakes.

Information on habitat use is not the same as habitat preference and habitat quality is not directly equivalent to incidental reports of life history functions associated with habitat variables. Detailed studies and a better understanding of the range of habitats, and availability of habitat types are needed to evaluate habitat quality. However, general habitat preferences used by AEM were reportedly based largely on Scott and Crossman (1979), McPhail and Lindsey (1970), and Richardson et al. (2001), yet, we had some difficulty reconstructing how the AEM HEP values were derived.

Richardson et al. (2001) summarizes lacustrine habitat requirement data for freshwater fishes occurring in the Northwest Territories and Nunavut. Habitat characteristics are identified for four distinct life stages:

i. spawning (eggs);
ii. young-of-the-year (YOY);
iii. juvenile; and
iv. adult.

Habitat requirements are reported on the basis of three physical habitat features:

i. *Water Depth* (0–1, 1–2, 2–5, 5–10, and >10 m);
ii. *Substrate* (**fines:** clay, muck/detritus, silt, sand; **coarse:** gravel, cobble, rubble, boulder); and
iii. *Vegetative cover* (submergent vegetation, emergent vegetation, overhead cover [e.g., riparian cover, undercut banks, surface woody debris], *in situ* [e.g., submerged woody debris]).

Cover is defined as any feature within the aquatic environment that may be used by fish for protection from predators, competitors, and adverse environmental conditions. The degree of association between a given species and these habitat features is tabulated using a rating system of *nil* (species is not associated), *low* (species is infrequently associated), *medium* (species is frequently associated) or *high* (species is nearly always associated).

To analyze if the HSIs assigned to each species, life stage, and habitat type in the HEP model are appropriate, we extracted the habitat category ratings assembled by Richardson et al. (2001) for the four life stages of the six fish species reported to be occurring in Phaser Lake area (Arctic Char; Lake Trout; Round Whitefish; Burbot; Slimy Sculpin; Ninespine Stickleback) along with the two additional species found in the general area (Arctic Grayling, Cisco). These ratings are assigned independently for each habitat category within each habitat class (*Water Depth, Substrate*) on a scale of *nil*, *low*, *medium* or *high* preference (*nil* is the default). *Vegetative cover* and woody debris were ignored since only *Water Depth* and *Substrate* were considered in the HEP model under evaluation.

To conduct the analysis, the following steps were undertaken:

1. *Lake Habitat/Ecosystem Assessment Tool* (HEAT) ratings data were used to derive a proxy suitability matrix for the Phaser Lake fish species by life stage.
2. The *nil, low, medium* and *high* ratings were converted on a linear scale to 0, 0.333, 0.667, and 1.000, respectively.
3. The mean habitat suitabilities were computed by species and life stage combination for fines (clay, muck/detritus, silt, sand), coarse (bedrock, boulder, rubble, cobble, gravel), and mixed. Depth zones used were 0–2 m (combined 0–1 m, 1–2 m), 2–4 m (approximated by 2–5 m), and 4–10 m (approximated by 5–10 m).
4. As no information was provided in the 2016 Fish Habitat Offsetting Plan, it was assumed that the HEP model for mixed substrate was set as a 50:50 mix between fines and coarse substrate, by species and life stage.
5. By species and life stage, we then multiplied the three substrate indices by the three depth indices to obtain nine habitat suitabilities as proxies for those presented in the HEP model.
6. We then normalized the habitat suitabilities across habitats within each species-life stage combination by dividing them by the maximum value within the category (i.e., ranging from 0 to 1).
7. Subsequently, we extracted the species by life stage (spawning, YOY, juvenile, adult) by habitat suitabilities from the spreadsheet provided in the 2016 Fish Habitat Offsetting Plan.
8. We then compared the values in the two matrices in R (R Core Team, 2013), conducting four comparisons:
    a. **Species means**: We computed mean species suitabilities by habitat in the HEP model and the HEAT model, subsequently paired the suitabilities and plotted one against the other (Figure 1, the dotted 1:1 line is for reference only).
    b. **Spawning**: We extracted the spawning values from the HEP model and the species values from the HEAT model assuming they would be comparable (Figure 2).
    c. **Nursery/YOY**: We extracted the *Nursery* values from the HEP model and the *YOY* values from HEAT and assumed they would be comparable (Figure 3).
    d. **Foraging/(juvenile + adult)/2**: We extracted the *Foraging* values from the HEP model, the *Juvenile and Adult* values from HEAT and took a mean, and assumed the HEP Foraging and HEAT (juvenile + adult)/2 values would be comparable (Figure 4).

Results of the four comparisons

While the species mean plot shows a weak agreement between the HEP species mean suitabilities and the HEAT species mean suitabilities across the nine habitat types under the assumption of equal weights for life stages (Figure 1), there is no agreement within the life stage specific plots (Figures 2–4). In particular, the spawning plot shows the lowest agreement (Figure

2). The Foraging [(juvenile + adult)/2] displays a wider range of values from the HEP model while the HEAT model only generated values >0.5 (Figure 4).

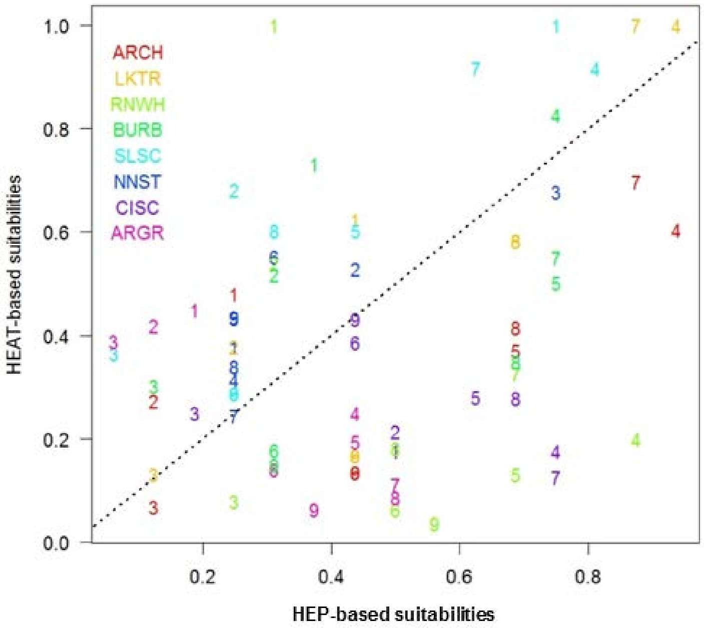

Figure 1. Comparison of the HEP species mean suitabilities versus the HEAT species mean suitabilities across the nine habitat types (# in plot) assuming equal weights for life stages (HEP: spawning + nursery + adult + overwintering; HEAT: spawning + YOY + juvenile + adult). Colours present different fish species.

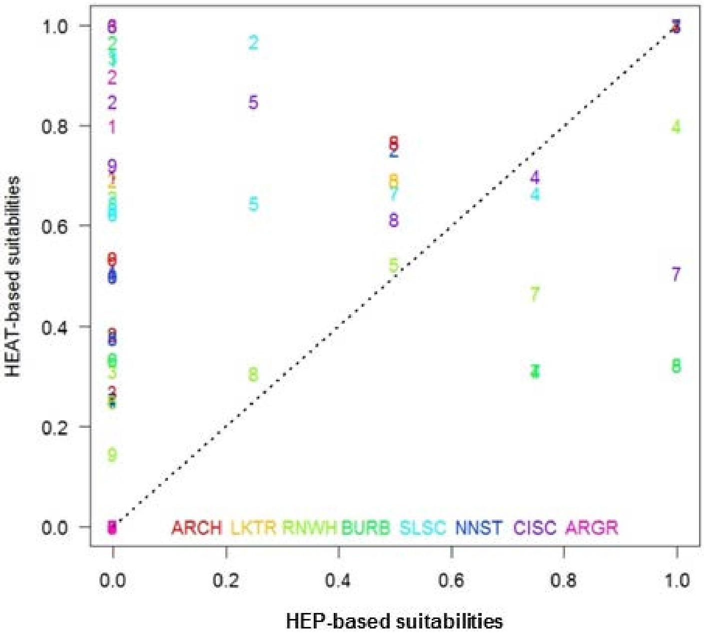

Figure 2. Comparison of HEP spawning suitabilities versus HEAT spawning suitabilities across the nine habitat types (# in plot). Colours are for different fish species.

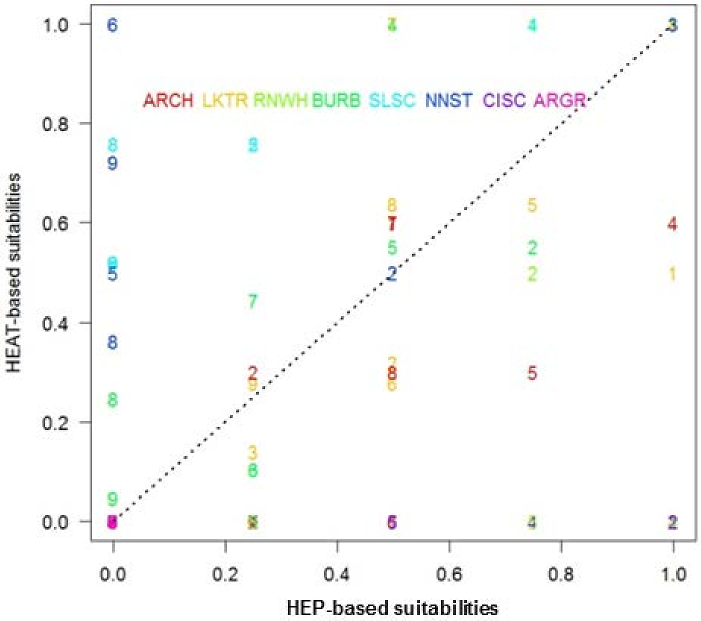

Figure 3. Comparison of the HEP nursery suitabilities versus HEAT YOY suitabilities across the nine habitat types (# in plot). Colours are for different fish species.

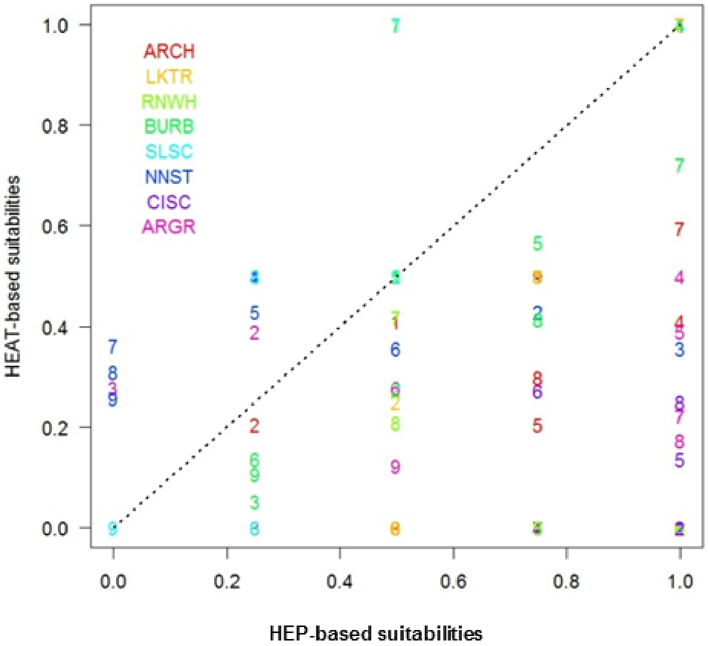

Figure 4. Comparison of the HEP foraging suitabilities versus HEAT (juvenile + adult/2) suitabilities across the nine habitat types (# in plot). Colours are for different species.

Discussion

While we can understand how the HEAT values were obtained using the suitabilities for northern population from Richard et al. (2001), we were unable to reconstruct the HEP values using the scoring provided in Richardson et al. (2001).

We compared AEM HSIs with the information presented in Richardson et al. (2001). In general, habitat that was identified by Richardson et al. (2001) as being low was often scored by AEM as being unsuitable (i.e., zero) underestimating the quality of this habitat.

Spawning

Over winter, the 0–2 m depth water in the Meadowbank area of Nunavut freezes to the bottom, making this habitat unsuitable for fall/winter spawners and as a result AEM scored this habitat as unsuitable rather than using the information in Richardson et al. (2001).

Arctic Char and Lake Trout were given the same scores. The 2–4 m and >4 m depth zones were scored the same, which seems consistent with the literature. Coarse substrate was identified by AEM as optimal spawning habitat, fine substrate as unsuitable, and mixed substrate as average. This may overestimate the quality of coarse substrates and underestimate the quality of fine substrates for spawning.

Round Whitefish HSIs were optimal for spawning over coarse substrate in 2–4 m, above average over coarse substrate in >4 m depth, average in mixed substrate in 2–4 m, below average in mixed substrate in 4 m depth, and unsuitable in fine substrate. This may overestimate the quality of >4 m depths and underestimate the quality of fine substrates for spawning.

Burbot spawning was considered optimal in mixed substrates from both 2–4 m and >4 m depths and above average at both depths over coarse substrate. All other habitat types were considered unsuitable. The quality of >4 m depths may be overestimated and quality of fine substrates may be underestimated.

Slimy Sculpin and Ninespine Stickleback, spring/summer spawners, make use of the 0–2 m depth zones for spawning. For Slimy Sculpin the quality of spawning habitat seems to be overestimated in the 2–4 m and >4 m depth zones and quality of fine substrates may be underestimated for all depths. Ninespine Stickleback spawning habitat seems to be underestimated in the 2–4 m depth zones for all substrates and for coarse substrates in <2 m depths.

Arctic Grayling are spring spawners. The AEM HSIs for spawning identify all habitats as being unsuitable. The 0–2 m depths should be accessible and optimal for spawning and coarse substrates should be higher quality than mixed and fines (Larocque et al. 2014).

Cisco spawning habitat qualities seem to be underestimated in the 2–4 m compared to the >4 m depth zone. Richardson et al. (2001) would indicate that the various substrate categories should be scored more evenly.

Nursery

Young Arctic Char are most often found in nearshore shallow water areas using coarse substrates as cover similar to young Lake Trout (Richardson et al. 2001). Young Round Whitefish are described as being in depths of 1.5–4.5 m with rock, sand, and gravel substrates (Richardson et al. 2001). Young Slimy Sculpin are found in shallow (0.5–1.5 m depths) with gravel and sand substrates (Richardson et al. 2001). The HSI scores may overestimate the deeper water habitat quality for the life function of these species and for Slimy Sculpin the fine substrates appear to be underestimated.

Foraging

For all species, HSIs for foraging do not follow the information summarized by Richardson et al. (2001) for juvenile and adult categories. It is not clear what was used to evaluate foraging habitat quality.

Overwintering

Richardson et al. (2001) provides limited information on overwintering habitat and this information is not included specifically in the species matrices. During winter, the 0–2 m depth water in the Meadowbank lakes will freeze making this habitat unsuitable for overwintering; therefore, HSIs were assigned as zero for overwintering habitat in this zone. HSIs for overwintering were rated the same for all species and substrate characteristics. This doesn't consider complexity of substrate, which may be an important structural element in winter for small fishes (i.e., juveniles of all species, Slimy Sculpin, and Ninespine Stickleback).

Recommendation

The plan does not lay out the rationale for the HSI scoring nor does the earlier Meliadine plan that it was based on. The proponent could use the species habitat suitability matrices entirely based on Richardson et al. (2001) providing the rationale for any justifiable changes (e.g., based on more recent information), clearly laying these out, and referencing them. It should be possible to review the HSIs and reproduce model outcomes. The information provided in the report is insufficient to be able to do this.

2) Habitat types

Instead of the typical nine habitat types, which are based on various combinations of substrate and depth, the HEP model for Phaser Lake has a 10th habitat type added. Habitat types 1–9 are applied to natural habitat for various combinations of substrate type and depth zone. However, a 10th habitat type was included in the HEP model by AEM to recognize the likely reduced habitat quality in deep pit areas that will likely function as nutrient sinks. It was proposed that in cases where pits are planned to be backfilled to depths occurring naturally in surrounding lakes, habitat types 1–9 will be applied for the pit area. Habitat type 10 was applied to all non-backfilled pit areas, independent of depth and substrate characteristics although substrate in pits was assumed to be coarse.

Results from a water quality model presented in the No-Net-Loss Plan indicated full mixing of the Phaser Pits. The validity of these model results is not under evaluation in this Science Response. AEM acknowledges that "although the water quality model indicated full mixing of the Phaser Pits, a chemocline may develop" and while the mixolimnion[2] may provide suitable pelagic fish habitat, the value of this habitat was assumed to be zero in the HEP model in recognition of the unknown value of pit areas within the lakes as fish habitat. However, AEM kept the habitat type 10 in the model to obtain credit in the case that habitat monitoring after re-flooding reveals that water quality is acceptable and fish are using the pit habitat type. Keeping this habitat category in the event that the habitat is suitable seems reasonable.

3) Model adjustment or tweaking factors

For each mine-site feature (e.g., pits, pit cap, basin, dikes, roads) where losses or gains are expected to occur, HUs are calculated by multiplying the area of each habitat type in that feature by the sum of the HSIs allotted to each life function of each fish species. In addition, the

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[2] The top layer in a meromictic lake is called mixolimnion. It is defined by a chemocline from the bottom layer, which is known as the monimolimnion. The waters in the monimolimnion circulate little and are generally hypoxic and saltier than the rest of the lake.

HUs can be multiplied by several other factors, e.g., species weight, life stage weight, access factor, and habitat co-factor, to tweak the model.

Species weighting factors

Depending on fishery or habitat objectives for an area, fish species can be given different weights in a HEP model.

A variety of schemes can be considered when developing species weights, for example:

1. Species presence/absence is given equal weights.
2. Biomass or catch-per-unit-effort (CPUE) contribution, which would require that the species abundances are fully assessed. This approach would be problematic for smaller fish species, such as Slimy Sculpin and Ninespine Stickleback that are poorly sampled in the Phaser Lake studies.
3. Production contribution, which would require that both species abundances and Production:Biomass (P:B) ratios are determined (Randall and Minns 2000). The biomass problem continues whilst it is well known that P:B ratios are higher in smaller, shorter-lived species. The combined effect of Biomass and Production will tend toward the presence-absence case and argues for equal weights.
4. Ecosystem contribution, where smaller species are often prey for larger species and the trophic pyramid suggests that lower trophic levels are necessarily more abundant/productive and hence smaller species should have higher weights than larger ones. Further the production of lower trophic level species provides the basis for higher trophic level productivity.
5. Fisheries contribution, which is poorly known regionally and almost completely unknown locally.
6. Cultural contribution, where some species are considered important to indigenous peoples.

When fishery or other management objectives are included as weights, the rationale should be clearly laid out and the evaluation should be done in consultation with DFO FPP.

Currently, species weights for Phaser Lake are based on relative biomass and a fishery value. Biomass weights for the Phaser Lake offsetting assessment are based on the proportional biomass in the fishout of the adjacent Vault Lake. Slimy Sculpin and Ninespine Stickleback, which were not susceptible to the fish-out gear, were assumed to be present and assigned 1% of the total biomass.

Fishery values were assigned based on annual creel surveys from 2007–2013 for Inuit and non-Inuit residents of Baker Lake (see 2013 Meadowbank Annual Report, Appendix G13, 2013 Hamlet of Baker Lake Harvest Study – Creel Results). The survey included Arctic Char, Arctic Grayling, Lake Trout, and Lake Whitefish (*Coregonus clupeaformis*). For the HEP model, Lake Whitefish was used as a proxy for Round Whitefish. The results of the Creel survey emphasized the importance of Lake Trout over the other three fish species surveyed for the local Aboriginal/recreational fishery by Baker Lake residents. Catch-based weighting schemes may understate the contribution of smaller species to overall, and commercial, recreational, and Aboriginal (CRA) fishery productivity, which are less vulnerable to the sampling gears used.

As a result, we recommend using equal weights for all species that occur in the lake rather than either weighting by relative biomass or fishery value (or the combination of both). We also recommend to not include Arctic Grayling and Cisco in the HEP model as they do not occur on the mine site.

Life stage weighting factors

The life stage weights can be set independently of the species weights and apply equally to species on the assumption that all life stages are important to all species if viable populations are to be sustained. The default option assumes that all life stages are equally important.

The Proponent has chosen to use life functions (spawning, nursery, foraging, overwintering) in developing their HEP model rather than using life stages (spawning, YOY, juvenile, adult). However, relevant information on the relationship between life functions and habitat characteristics from the literature for arctic areas is limited.

There are various opinions and limited definitive evidence to guide the choice of weights (Minns et al. 2001). Cumberland (2005) had weighted life stages (spawning/nursery 4, rearing 2, foraging 3, and overwintering 1) in their HEP model. The current AEM HEP model uses equal weighting as we would recommend.

Access factors

The access factor represents the accessibility of the area to each species (or their estimated presence/absence). The access factor is 1 for any species present in the habitat area and 0 for any species not present. Each species receives an access factor in both the loss and gain calculations. The access factor can be used when fish assemblages are expected to change in the offsetting scenario. The opening of access to a habitat area for a species that did not have access pre-construction, results consequently in an increase of HUs. Accordingly, the loss of access results in a loss of HUs. These gains or losses may be complete (affect all species, e.g., conversion to a tailings storage facility) or partial (only some species are affected).

In the No-Net-Loss Plan, the Proponent indicated that their presence or absence of a species in loss calculations is based on surveys in the affected habitat area, whereas presence or absence in the offsetting scenario is anticipated (to be confirmed after access is altered as part of compensation/offsetting monitoring). However, they have only applied this to Arctic Char. Slimy Sculpin and Ninespine Stickleback have not been collected in Phaser Lake but are assumed to occur there. Arctic Char were found in Vault Lake and would be expected to occur in Phaser Lake as well. We would therefore recommend that Arctic Char be assigned a 1 in the “Access Factor losses”.

Habitat co-factors

A habitat co-factor can be used to describe changes in hydrological, thermal or chemical water quality in the HUs that will occur as a result of project impacts or offsetting. The habitat co-factor is an appropriate weighting to apply when degradation is expected to occur or remediation of non-pristine lakes is proposed as offsetting. AEM assumed no change in habitat quality pre- and post-mining and consequently the weightings were set to 1 for both loss and gain calculations. This is in contrast to AEM’s predictions of elevated levels of various substances (e.g., copper, ammonia, iron, cadmium, zinc) in the lake water after mine closure – a condition, which is likely to persist for several years, if not indefinitely. AEM should account for this habitat degradation using habitat co-factor in HEP model. If monitoring would prove that the water quality is once again suitable, the adjustment can be invoked.

4) Net change accounting

In the net change accounts presented by AEM for Phaser Lake, unequal species weights while equal life stage weights are used. Based on our comparison of HEAT and HEP results, an alternate net change analysis was developed using the areas by habitat type given by AEM for losses and gains, the HEAT habitat suitability matrix developed from Richardson et al. (2001) for four life stages (spawning, YOY, juvenile, adult) but not for overwintering for which there is

Table 2. The HEP net change result using unequal species weights, equal life stage weights, and AEM's habitat suitability matrix is compared with the HEAT net change result using equal species weights, equal life stage weights, and the habitat suitability matrix derived from Richardson et al. (2001). The effect of adding the unmapped habitat type 3 area is included.

AEM Total unequal species weights – Phaser Lake						HEAT Total equal species weights – Phaser Lake					
Habitat Type	Losses (Hectares)	Gains (Hectares)	Comp Suitability	HU Losses	HU Gains	Habitat Type	Losses (Hectares)	Gains (Hectares)	Comp Suitability	HU Losses	HU Gains
1	0.86	0.00	0.159	0.13	0.00	1	0.86	0.00	0.282	0.17	0.00
2	5.44	2.57	0.260	1.37	0.65	2	5.44	2.57	0.444	1.80	0.85
3	13.96	13.77	0.395	5.32	5.25	3	13.96	13.77	0.605	6.52	6.43
4	1.03	0.00	0.451	0.44	0.00	4	1.03	0.00	0.238	0.16	0.00
5	1.72	1.49	0.685	1.11	0.96	5	1.72	1.49	0.387	0.48	0.42
6	1.21	1.83	0.916	1.05	1.57	6	1.21	1.83	0.536	0.49	0.74
7	0.52	0.00	0.466	0.23	0.00	7	0.52	0.00	0.212	0.07	0.00
8	0.20	0.71	0.637	0.12	0.43	8	0.20	0.71	0.354	0.05	0.18
9	0.11	6.83	0.823	0.09	5.27	9	0.11	6.83	0.496	0.04	2.59
10	0.00	1.79	0.000	0.00	0.00	10	0.00	1.79	0.000	0.00	0.00
Total	25.06	29.00		9.85	14.13	Total	25.06	29.00		9.79	11.22
Unmapped 3	2.23	2.23	0.395	0.88	0.88	Unmapped 3	2.23	2.23	0.605	1.35	1.35
New Total	**27.29**	**31.23**		**10.73**	**15.01**	**New Total**	**27.29**	**31.23**		**11.14**	**12.57**

no published habitat requirements database. For the HEAT analysis, equal species and life stage weights were applied. We use the baseline habitat type areas (ha) and HUs given in Table 3-1 in AEM (2016) and not the values in Table 4-2 that are used in the “total by feature – summary” spreadsheets as “Pre-” values, at the end of that report.

Results

The results from the HEP and HEAT analyses are shown side by side (Table 2). The results are similar. The difference between losses and gains is relatively smaller in the HEAT calculations than in the HEP calculations. The effect of the unmapped habitat type 3 area is added in for both accountings to show how it can be accommodated. The composite suitability values by habitat type differ between the two analyses for the following two reasons:

1. the AEM species by life stage ratings differed; and
2. the species weighting schemes differ.

The nominal net gain is smaller in the HEAT analysis. This will likely have an impact if time-lag effects are added to the accounting scheme.

Recommendations

1. Habitat suitability maps would be useful to illustrate and review changes.
2. The report indicates some area omitted in mapping. This area should be added.
3. The summary HUs tables do not provide sufficient detail particularly when trying to combine losses and offsets into a net sum. There should be a net sum table with subdivision of habitat type areas to delineate losses, restored areas, and newly created areas (e.g., loss, unchanged, offset, modified areas).

Neglected unmapped areas

There was a portion of the Phaser Lake basin, which was unmapped and hence the area was ignored in subsequent calculations. However, the area, 2.23 hectares, should be included since the report indicates that is consists entirely of coarse substrate in water 2 m or less in depth. Adding this area to the nominal net change calculation does not affect the result, as the area is assumed to be the same before and after. However, if time-lag effects are considered, the net loss on the baseline scenario with the refilled lake recovering by year 10 increases to -1.08 from -0.78 (see Section 5 below on time lag calculations).

5) Time lag, viz. offset ratio, calculation

AEM’s offset plan currently does not take into account the timing of habitat losses and offsets and does not consider how quickly the ecosystem may regenerate. There is little discussion on the post-mining environmental conditions in Vault-Phaser Lake and how they might reduce the expected HUs. In order to evaluate the potential loss in fisheries productivity due to the time lag in habitat offsetting, we calculated the offset ratio after Minns (2006), which has to be greater than one, considering a potential time lag of more than 20 years.

Once a set of baseline scenarios for pre- versus post-development are set, we can run calculations on the effects of time lags given some estimates of the time the losses occur before offsets occur and how long it might take offset areas to become fully operational.

Before the changes to the *Fisheries Act* in 2012, net change calculations have been performed assuming that losses and gains/offsets occur instantaneously. However, in reality this is seldom the case. Losses normally occur before offsets are applied. Further, the losses typically occur over a very short time frame, whilst the benefits of offsets may take a longer time to be realized. Simple methods for inserting time-lag adjustments into net change calculations have been developed (Minns 2006). Recently computer code using the R language has been developed to facilitate such calculations using continuous integrals in support of the expanding development of HEAT at DFO-Burlington. This software allows a user to set up a simple Excel spreadsheet describing the basic results at the patch level for pre- and post-development scenarios along with expected time-lines for each patch.

The summary information provided by AEM in the Phaser Lake Offsetting Plan allows a simple assessment of the effects of time-lags. The report indicates that Phaser Lake will be drained quickly within one year and then should be refilled after mineral extraction after five years. This can be implemented by assuming that all losses occur during year 1, from 0 to 1. Then after five years, the refilling of the expanded lake basin can be treated as implementation of a set of offsets. Since the refilled lake will not be fully functional immediately, it is worth examining alternate scenarios wherein it takes 5, 10 or 15 years for full functionality to be restored. Overall a 20-year time-frame is used to assess the net changes.

Results

The results indicate modest increases in offsets are required to account for time-lag effects (Figure 5). The baseline instantaneous net change shows a balance of +4.27 HUs. When time-lags are applied over a 20-year reference time-frame, the net change showed average per annum losses of -0.78, -2.55, and -4.32 HUs times for the refilled lake to return to full function for 5, 10, and 15 years, respectively, starting in year 5. These negative balances can be compensated with modest increases in the offset plan, especially if they are implemented early on (Figure 5b).

Recommendations

1. Time-lag effects should be included in determining the overall offset requirements.
2. The unmapped areas should be brought into the net change calculations.
3. Any extra offset areas outside of the Phaser Lake basin should be implemented alongside the refilling plan for Phaser Lake.

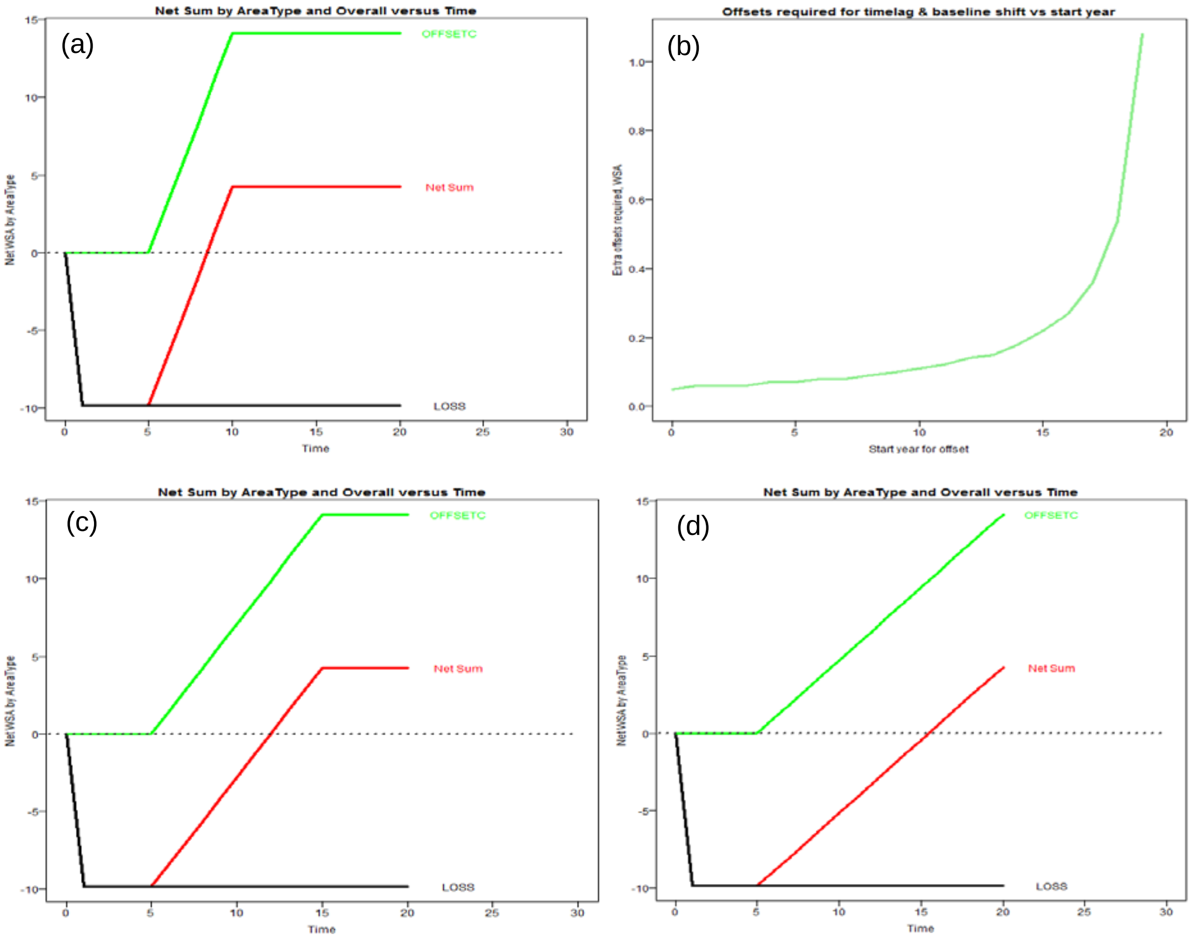

Figure 5. Losses, offsets, and net change over a 20-year reference time-frame. (a) Net Sum by area type when offsets begin in year 5 and are functional in year 10. (b) The amount of extra offsets required for scenario (a) to compensate for the time-lag (light green) versus the starting year for the extras. (c) Time results when offsets begin in year 5 and are functional in year 15. (d) Time results when offsets begin in year 5 and are function in year 20.

Conclusions

Fisheries Protection Program (FPP) requested Science to peer review the adapted HEP model input parameters and results for the Meadowbank No-Net-Loss and Fish Habitat Offsetting Plan to determine if the Proponents’ model input parameters are scientifically valid and a defensible approach to calculating loss and gain for the project. Science was also asked to calculate the appropriate offset ratio for any lost productivity due to the timing of losses and delayed offsets.

There was insufficient information in the report to reconstruct the HSIs used by AEM based solely on the references cited. The Proponent chose to use life functions associated with key habitat types (spawning, nursery, foraging, overwintering) in their HEP model rather than using life stages (spawning, YOY, juvenile, adult). No detailed explanation on the HSIs scoring was provided to be able to evaluate their validity.

Physical characteristics of the ten habitat types are reasonable.

The proponent used species weights based on biomass and fishery weights. We would, however, recommend using equal weights for all species that occur in the lake rather than either weighting by relative biomass or fishery value (or the combination of both). Arctic Grayling and Cisco would not be included in the modelling.

The current AEM HEP model uses equal life function weighting as we would recommend.

Arctic Char were found in Vault Lake and would be expected to occur in Phaser Lake as well. We would, therefore, recommend that Arctic Char be assigned a 1 in the “Access Factor losses”.

The habitat co-factor approach has not been used at this point. Considering the predicted water quality degradation, AEM should account for this habitat degradation using habitat co-factor in HEP model. If monitoring would prove that the water quality is once again suitable, the adjustment can be invoked.

Maps would better illustrate the net change accounting achieved. Omitted areas can be addressed by scaling the mapped areas. The summary HUs tables do not provide sufficient detail particularly when trying to combine losses and offsets into a net sum. There should be a net sum table with subdivision of habitat type areas to delineate losses, restored areas, and newly created areas.

Time-lag effects should be added to determine the overall offset requirements. The time lag is meant to offset lost productivity from the start of the fishout to the point when the lake is returned to a fully functional ecosystem. Depending on the length of the time period in which productivity is lost, it may not be possible to offset within the same lake and other off-site offset options have to be determined.

The unmapped areas should be included into the net change calculations. Any extra offset areas should be implemented alongside the refilling plan for Phaser Lake to minimize the areas required for manipulation.

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(Approved July 12, 2016)

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Appendix

Table A1. Copy of a sample data page from Richardson et al. (2001) as an illustration. This page identifies lacustrine habitat requirements for (freshwater resident normal) Arctic Char.

Habitat Features:	Ratings[1]				Sources[2]			
Categories[3]	S	Y	J	A	S	Y	J	A
Depth:								
0-1 meters	L	L	L	H	26,28,29	25,26,27,29,30	13,27	5,6,8,18,24,26,27
1-2 meters	M	L	L	H	15,26,28,29,31	27	13,27	5,6,8,18,24,26,27
2-5 meters	H	L	L	H	2,10,11,15,19,28,31	27	13,27	5,6,8,9,18,20,24,26,27
5-10 meters	H	L	H	H	10,19	27	3,27	5,6,8,9,18,20,24,26,27
10+ meters	M	H	H	H	10,23,24	18,25	3	5,6,8,9,12,18,20,24,26
Substrate:								
Bedrock			L				32	
Boulder		H	H	H		13,27	13,24,26,27,32	20,26,27
Rubble	L	H	H	H	28	13,15,27	13,24,26,27,32	20,26,27
Cobble	H	H	H	H	2,10,22,28	13,15,27	13,24,26,27,32	25,26
Gravel	H				2,10,15,16,17,19,22,23,31			
Sand								
Silt	L				11,28			
Muck (detritus)	L				28			
Clay	L				10,19			
Pelagic	L	L	H	H	1,25	25	1,13,18	1,4,1,12,14,18,20,21,24,30
Cover:								
None								
Submergents	L		H		2,7,11		3,24	
Emergents			H				3,24	
Overhead								
In Situ		H	H			13	13,24	
Trees & Brush								

[1] Ratings are Nil (default), Low, Medium or High.
[2] Sources are numbered and references starting on page 128 of this report.
[3] Categories are S-spawning, Y-young-of-the-year, J-juveniles, and A-adults

Comments and observations:
Juveniles are most often found in the benthic areas of lakes at depths > 5 m avoiding littoral and shallow benthic habitats which are often occupied by large conspecifics and potential predators (Johnson 1980; Klemetsen et al. 1989; Bjoru and Sandlund 1995; 4,18,24).
Similar to young-of-the-year juveniles seek cover amongst boulder, rubble and cobble substrates as well as in vegetation (3,13,24).
Adults make seasonal habitat shifts to pelagic habitats in the summer to feed on abundant zooplankton (1,4,6,12,14,18,20,21,24,30).

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