Cumulative Environmental Management Association
Suite 214, 9914 Morrison Street
Fort McMurray, AB T9H 4A4
Phone: 780-799-3947
Facsimile: 780-714-3081
E-Mail: info@cemaonline.ca
Website: www.cemaonline.ca

CUMULATIVE ENVIRONMENTAL MANAGEMENT ASSOCIATION (CEMA)

Report Disclaimer

This report was commissioned by the Cumulative Environmental Management Association (CEMA).

This report has been completed in accordance with the Working Group's terms of reference. The Working Group has closed this project and considers this report final.

The Working Group does not fully endorse all of the contents of this report, nor does the report necessarily represent the views or opinions of CEMA or the CEMA Members.

The conclusions and recommendations contained within this report are those of the consultant, and have neither been accepted nor rejected by the Working Group.

Until such time as CEMA issues correspondence confirming acceptance, rejection, or non-consensus regarding the conclusions and recommendations contained in this report, they should be regarded as information only.

For more information please contact CEMA at 780-799-3947.

Office de la propriété intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An Agency of Industry Canada

2010-0034
#274

Certificate of Registration of

Copyright

Certificat d'enregistrement du

Droit d'auteur

This Certificate of Registration is issued pursuant to sections 49 and 53 of the Copyright Act. The copyright in the work described below was registered on the date of registration as follows:

Ce certificat d'enregistrement est émis conformément aux articles 49 et 53 de la Loi sur le droit d'auteur. Le droit d'auteur sur l'oeuvre décrite ci-dessous, a été enregistré à la date d'enregistrement comme suit :

Date of Registration - Date d'enregistrement :	**September 14, 2011**
Registration No. - Numéro d'enregistrement :	**1089854**
First Publication - Première publication :	**Unpublished**
Title - Titre :	**Synthesis of Habitat Models Used in the Oil Sands Region**
Category - Catégorie :	**Literary**
Owner(s) - Titulaire(s) :	**Cumulative Environmental Management Association** **#214 - 9914 Morrison Street** **Fort McMurray, Alberta** **Canada, T9H 4A4**
Author(s) - Auteur(s) :	**Judy Muir** **Virgil Hawkes** **Krysia Tuttle** **Tony Mochizuki**

Canada

(CIPO 00200)
03-11

OPIC CIPO

Date of Issuance of Certificate - Date d'émission du certificat : **September 14, 2011**

Registrar of Copyright
Copyright office

Registraire des droits d'auteur
Bureau du droit d'auteur

CEMA Contract No. 2010-0034 EA3259

Synthesis of Habitat Models used in the Oil Sands Region




Final Report

Prepared for

Cumulative Environmental Management Association
The Reclamation Working Group (RWG)
Suite 214, Morrison Building
9914 Morrison Street
Fort McMurray, AB T9H 4A4

Prepared by

Judy E. Muir, M.Sc., R.P.Bio.
Virgil C. Hawkes, M.Sc., R.P.Bio.,
Krysia N. Tuttle, M.Sc.
and
Tony Mochizuki, B.Sc.

Contact
Virgil C. Hawkes, M.Sc., RP.Bio.
vhawkes@lgl.com

15 August 2011

LGL LIMITED
environmental research associates

Suggested Citation:

Muir, J.E, V.C. Hawkes, K.N. Tuttle, and T. Mochizuki. 2011. Synthesis of Habitat Models used in the Oil Sands Region. LGL Report EA3259. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for the Cumulative Environmental Management Association (CEMA) – The Reclamation Working Group (RWG), Fort McMurray, AB. 30 pp + Appendices.

Cover photos:

From left to right: North American Beaver (*Castor canadensis*), American Black Bear (*Ursus americanus*) © Judy E. Muir, Canadian Toad (*Bufo hemiophrys*), and Moose (*Alces americanus*).

EXECUTIVE SUMMARY

Identifying the locations of high quality habitat for a species of interest is an essential step when assessing potential impacts of industrial activity on a species or developing management plans to mitigate possible impacts. Models that link habitat quality to the potential occurrence of a species are frequently used as a tool to identify important habitat locations and limiting habitat features in a region. Species habitat models include easily measured predictive environmental variables that are assumed to influence, or be highly correlated with variables that influence, the potential density of species through direct or indirect effects on life requisites. Models can be used to assess both habitat capability (the highest potential value of a habitat for a species, regardless of the current habitat condition), suitability (the ability of the habitat in its current condition to provide the life requisites of a species) and effectiveness (the suitability of habitat after accounting for the effects of anthropogenic disturbance and landscape context, e.g., a small or isolated habitat relative to the species' needs).

Species habitat models are frequently used in the Athabasca Oil Sands Region (AOSR) to assess potential impacts to species of interest when preparing environmental impact assessments (EIAs) and to address Environmental Protection and Enhancement Act (EPEA) approval conditions. In particular, EPEA approval issued since 2007 requires Mine Reclamation Plans and Mine Closure Plans to provide fish and wildlife habitat for key indicator species (KIRs) consistent with pre-disturbance capabilities that have been defined by validated habitat modelling or other habitat assessment tools. The Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Reign (AENV 2010) provides guidance for wildlife habitat reclamation and summarizes, in part, the application of species habitat models to that process. However, use of species habitat models in assessment of impacts and ability to restore habitat to pre-disturbance condition assumes that these models provide accurate predictions of habitat suitability across the landscape. This assumption is questionable because studies show that species habitat models have varying degrees of accuracy (Van der Lee 2006) and it has been estimated that models may only explain or predict up to half of the variation in species density or abundance (Morrison et al. 2006). An improperly validated model could over- or under-estimate the amount of pre-disturbance habitat (i.e., habitat units) available to a species. Under-estimating the amount of available habitat means that a closure plan will not effectively address the impacts to a species, while an over-estimation may put too much emphasis on the creation of habitat for that species at the detriment to other species.

Errors and uncertainties in species habitat model predictions can arise from several sources, including limited knowledge of species habitat relationships and/or data needed to develop models (Boyce et al. 2002, Morrison et al. 2006). Variability, bias and uncertainty about the true values of model parameters and inaccuracies of spatial depiction of mapped polygons also have the potential to substantially affect model predictions (EPA 1998, Roloff and Kernohan 1999). Consequently, testing the accuracy of species habitat model predictions and assessing the utility, reliability, and completeness of the model and its credibility through a model validation process is a crucial step to fully understand the caveats and limitations of any habitat models that are used in EIAs and closure planning (Morrison et al. 2006, Van der Lee et al. 2006, Tirpak et al. 2009). It is essential that managers understand model inaccuracies, limitations, uncertainties and variation around the predicted outputs because these factors limit the confidence and application of the model predictions. Managers can then make informed choices regarding the relative risk associated with using a model when making management decisions (Van der Lee et al. 2006, Morrison et al. 2006). It is also critical that model caveats and limitations are clearly stated in an EIA so that uncertainties related to the impacts predicted by species habitat models are understood.

This project assessed the current state of habitat models used in oil sands region EIA and closure planning to meet the following objectives:

1. Determine which habitat models are used in EIAs and closure planning, and how these models were used;
2. Determine what linkages exist between the habitat model predictions in the EIAs and closure plans;
3. Determine which habitat models have been validated, and of these, describe and evaluate the validation procedures that were used on each model with recommendations for improvement if needed; and
4. Recommend procedures to validate non-validated models.

These four objectives were addressed through the completion of four tasks:

1. Review and summarize EIA species habitat models used in the oil sands regions for Environmental Impact Assessments (EIAs) for oil sands project applications and for other projects such as wildlife habitat mapping.
2. Review and summarize how regional wildlife habitat mapping data, EIA habitat model data, and habitat models, are used to develop oil sands closure plans conducted by SEWG or for the Lower Athabasca Regional Plan (LARP)
3. Summarize the validation methods and status of existing validated models
4. Provide recommendations for validation procedures of non-validated models

The main activities that were performed to complete the above four tasks included collation of Oil Sands EIAs and Supplementary Information Requests (SIRs) that were submitted from 1990 onwards, review of all documented species habitat models in these EIAs, interviews with oil sands closure planners, and assessment of the validation that was performed for the EIA species habitat models. We summarized the characteristics of all documented species habitat models, determined how model outputs were incorporated into the closure plans, identified which habitat models were validated and evaluated the appropriateness of the validation methods that were used. We also developed an interactive database to store project and model characteristics that can be queried by species, model type, project name and proponent. We then made recommendations for improvement of species habitat model validation. Finally, in consultation with CEMA, we selected a North American Beaver (*Castor canadensis*) model as a test case for validation and developed a workplan to perform a comprehensive validation of this model.

We collated a total of 22 of the 25 EIAs requested by CEMA. A total of 228 species habitat models in the EIA documents were reviewed. The number of models in an EIA varied from 4 to 15, with a median of 12 models. The vast majority of these models (82.0%) were reused from previous EIAs, often with some degree of modification although this was frequently not clearly specified in the model documentation. Three types of species habitat models were mainly used. Habitat suitability index (HSI) models were used the majority of the time (74.1%), with resource selection functions (RSFs) and CAPSU models used 7.9% and 16.7% respectively. RSF models were solely used for Moose (*Alces americanus*), Canada Lynx (*Lynx canadensis*), Fisher (*Martes pennanti*), Barred Owl (*Strix varia*) and Black-throated Green Warbler (*Dendroica virens*) and were only included in three EIAs (Kirby In-situ, Christina Lake and Jackpine Mine Expansion).

The process used to develop reclamation plans in the AOSR was assessed through interviews with closure planners. Based on the information provided, two primary approaches to reclaiming land in the AOSR are used: 1) build it and they will come; and 2) build it and they will come (with modelling). Both approaches have a common objective: to create ecologically viable habitat for vegetation and wildlife; however, the latter considers the collection of data and the response of wildlife to the reclamation prescriptions to revise or adapt the approach to reclamation. In all cases closure planning does not stop as soon as the revegetation prescriptions have been applied. Reclaimed habitats are assessed for vegetation productivity and interventions or modifications to the reclamation prescription are applied as needed. To date no formal monitoring of wildlife use has occurred on reclaimed plots and there is a need to establish attainable goals for wildlife habitat reclamation. Benchmarks for wildlife habitat reclamation are also required and are apparently under development. Until these benchmarks are developed and until wildlife use on naturally regenerating stands of varying age (e.g., those affected by fire) is studied in the AOSR, it will not be possible to determine if the reclaimed lands are providing wildlife habitat that is similar to that provided by naturally regenerating stands.

We searched for model validation documentation within the main body of an EIA wildlife section and appendices dedicated to species habitat modelling. An entire EIA document was not searched when a model's validation was not documented in either of these two locations; we assumed a model was not validated in the absence of documented validation methods or results[1]. We did not accept previous validation for a reused model in the same study area because it was rarely clear if, or what, modifications were made to the model. Reused models from other study areas that were validated in other EIAs or in a published paper (e.g., the Black-throated Green Warbler RSF model in Boyce et al. 2002), but were not independently validated within an EIA were also considered to be unvalidated for this purpose of this report. Habitat selection patterns for many species can vary substantially across geographic areas and models are often only relevant to the specific location and time period for which they were developed. Thus a model's application to other geographic areas needs to be tested through appropriate validation methods. Although in most cases the reused (and validated) models were developed for the same large study area (i.e., the Athabasca Oil Sands Region), it is possible that variation in local conditions would affect model components and introduce errors in model predictions.

One hundred and one of the 228 models (44.3 %) had some validation documented in an EIA, with RSF models most likely to be validated (66.7 %) followed by HSI models (52.1 %). Only one of the CAPSU models was validated. Data gaps were the main reason given for performing limited or no model validation. Three main data gaps were identified: i) lack of species observations within the study area [e.g., American Black Bear (*Ursus americanus*)], ii) species observations were available, but had been made during a different season than that targeted by the species habitat model (e.g. fall surveys of waterfowl when models applied to nesting habitat suitability), and iii) species observations were available, but these observations did not sample all the seasons represented by the model [e.g., only breeding season data for an all-year Canadian Toad (*Bufo hemiophrys*] model).

There appeared to be an increasing trend of documented model validation with EIAs submitted from 2005 and later. An average of 54.8% of the models in these EIAs had some level of validation documented. Only 32.4% of the models were apparently validated in EIAs from 1996-2003 (no EIAs were reviewed for the year 2004). The percentage of validated models was similar for new models and reused models. When species/species groups were considered, Canada Lynx models were validated most often (75.0%). Other frequently modelled species/species groups (i.e., Fisher/Marten, Canadian Toad, Moose, Ruffed Grouse, Snowshoe Hare and Woodland Caribou) had 62.5 to 70.0% of their models validated. No Barred Owl, non-treed wetland/riparian birds or Black-throated Green Warbler models were validated.

Statistical methods were used in 48.5% of all validated models when HSI and RSF model types were pooled. Statistical methods were used in 42.0% of the validated HSI models and in all instances of validated RSF models. We found that the validated HSI models used various methods; however, there was no evidence of validating the model structure or calibrating the model as recommended in the reviewed literature, although the Aurora Mine EIA did refer to "fine-tuning" the models. Instead, most of the documented HSI model validation consisted of a portion of the recommended methods, i.e.,

[1] Note that this assessment of model validation was based on information provided in the wildlife sections and species habitat model appendices of the reviewed EIA. It is possible that validation steps were performed, but were either not documented or were documented in a different section of an EIA that was not reviewed.

testing species observations against model predictions. There was also no indication that an iterative validation process was carried out whereby model validation results were used to improve the model, which was then subjected to further validation until satisfactory results were achieved, or no more improvements could be made to the model given the limitations of current knowledge.

Requirements for proper design of a validation sampling study implies that habitat variables and species observations collected as part of other survey work are likely not appropriate for validation of an HSI model because those observations may not provide the correct type of samples, adequate sample size, stratification across the full range of predicted HSI values, or in the case of species observations, span sufficient time to adequately represent patterns in species habitat use. There was no evidence presented in the reviewed models for any design or implementation of specific studies to collect validation data for a model; data from baseline studies for the project and occasionally other projects in the area were used instead. This approach limited HSI model validation because of data gaps within these baseline data.

The RSFs presented in the reviewed EIAs modelled habitat suitability for Moose, Canada Lynx, Fisher, Barred Owl and Black-throated Green Warbler. Models for Moose, Canada Lynx, Fisher, Barred Owl were all of the “used/available” RSF form. Each of these models was validated using the methods recommended by Boyce et al. (2002), i.e., k-fold validation and use of the Spearman rank correlation to assess the relationship of area corrected frequencies of presence to bins of predicted RSF scores.

Our review of EIA species habitat models revealed that while RSF models tended to be appropriately validated, the HSI models were not. Only 52% percent of HSI models were validated and this validation didn’t appear to conduct all four steps recommended by standards documents (e.g., USFWS 1981, RIC 1999). Furthermore, descriptive comparisons of species observations in habitat suitability classes used in several cases of HSI model validation didn’t correct for the available area of the suitability classes, and so may have misinterpreted the validation results.

We suggest the following recommendations to improve both understanding of the model development done for species habitat models in Oil Sands EIAs and the validation of these models.

1) Provide complete documentation of model history, assumptions, limitations, all model variables and rationale for inclusion, and details of model structure.
2) Provide complete documentation of all model validation steps that were performed. This includes details of methods used, specifics of test data (e.g., where obtained, for what season(s) and year(s), sample size), clear description of test variables used and how these were calculated, and detailed documentation of results with statistical outputs (e.g., p-values) as appropriate.
3) Use appropriate statistical techniques to validate HSI models. Use test variables such as area corrected species’ usage in habitat suitability classes, relative densities (e.g., pellet group densities/ha) or Manly’s standardized selection ratio.
4) Follow the four steps recommended in section 3.2.2 to validate HSI models.
5) Specifically design a field program to collect appropriate habitat and species data to validate HSI models. Sample over multiple years. Target the most sensitive assumptions in the model for validation. See Appendix C. Model Validation for a description of a model validation workplan.
6) Use the results of model validation to improve the models.
7) Fully document the caveats, uncertainties and limitations of using model predictions when estimating impacts to a modelled species or predicting potential for habitat restoration.
8) Design a field study to test a selected model’s generality, i.e., applicability, within different lease areas of the AOSR. Species habitat models were frequently reused in different EIAs, typically without a thorough validation of the model. As discussed in this report, scientific literature cautions against using a model in different geographic areas without appropriate validation. However, it is possible that ecological conditions across the different lease areas within the AOSR are similar

enough for a species' important life requisites to support reuse of an appropriately validated model for that species with some limited additional validation. If so, then the process of model validation could be streamlined for reused models in the AOSR, thus reducing costs of EIA and closure plan development. Note that generality must be tested for each particular species model; a field study for a selected model will demonstrate a methodology for testing model generality in some selected lease areas and provide valuable insights into the model validation that may be required to support model reuse.

9) Provide the CEMA habitat model synthesis database as a resource to consultants developing EIAs and maintain the database as a "living document" by allowing these consultants to update the database with their project/model details.

Discussion to prioritize models for validation and to select a test model as a case study to demonstrate recommended model validation methods was held with the Wildlife Task Group of CEMA Reclamation Working Group during the 29 March 2011 meeting with LGL Limited. This model validation test case aims to provide detailed documented methods and an example of model validation for professionals developing species habitat models in the AOSR. It was agreed to select a North American Beaver HSI model as the test species for the following reasons:

1. An HSI model was the preferred model type for this validation exercise because this study found that while HSI models were commonly used in EIAs, they were generally not well validated;
2. A beaver model was selected because of this species' importance to First Nations and Métis;
3. Although operators are actively managing beavers and excluding them from their leases and reclamation plots, the 'allowable' use of habitat by key indicator resources (KIRs) is not a consideration during the EIA process and the assessment of predicted impacts to wildlife, nor does it form part of the closure plan. The emphasis (in the closure plan) is on habitat availability, i.e., restoration of pre-disturbance habitat that was impacted by the AOSR operation. Thus having a properly validated beaver habitat model and using these model predictions in the closure planning will provide assurance to regulators that impacted beaver habitat is made available on a reclaimed landscape (regardless if beavers are able to use those habitats or not); and
4. A properly validated beaver model will provide a more accurate assessment of the extent and location of beaver habitat in the AOSR lease area that was used for this test case because the validation process will be used to improve the model. In addition, the uncertainties of the model predictions will be more clearly understood. These results will provide crucial information to closure planners considering immediate and post-reclamation management of reclaimed plots based on the known distribution of beaver habitat relative to those reclaimed plots. For example, this information will assist in the selection of reclamation plot locations and better inform managers interested in keeping beavers out of reclaimed plots (to improve the survivorship and vigor of the vegetation);

We evaluated the 16 beaver HSI models in the reviewed EIAs and recommended using either the Kirby or Jackpine version for the test case because this model was used with minor modifications in the majority of EIAs that were reviewed for this project. A workplan was then developed to validate the selected model. The objective of the workplan is to clearly describe the steps needed to implement a thorough validation of the model. We have broken the workplan down into tasks to be completed in sequence. The initial task consists of preparatory work that identifies the study area and collates all necessary data to run the model. Subsequent tasks mirror the four recommended validation steps described in the report. Using this approach, a selected beaver model will be validated through a process of internal model review and calibration, external expert review, field studies to collect habitat data to validate the SI relationships, field studies to assess the distribution of beavers in the selected project area(s) to correlate areas of high, moderate, low, or nil suitability to actual beaver presence.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
LIST OF TABLES viii
LIST OF FIGURES ix
LIST OF APPENDICES x
1 Introduction 1
2 Project Objectives and Tasks 3
3 Species Habitat Model Background 4
3.1 Habitat Capability and Suitability (CAPSU) models 4
3.2 Habitat Suitability Index (HSI) Models 4
3.2.1 Background 4
3.2.2 HSI Model Validation 6
3.3 Resource Selection Function (RSF) Models 8
4 Task 1: Review and summarize habitat models used in the oil sands region for Environmental Impact Assessments (EIAs) for oil sands project applications and for other projects such as wildlife habitat mapping 9
4.1 Methods 9
4.1.1 EIA document acquisition 9
4.1.2 Database design and structure 9
4.1.3 EIA document review and data entry 10
4.2 Results 11
4.2.1 EIA document acquisition 11
4.2.2 Database design and structure 13
4.2.3 EIA document review and data entry 14
5 Task 2: Review and summarize how regional wildlife habitat mapping data, EIA habitat model data and habitat models are used to develop oil sands closure plans conducted by SEWG or for the Lower Athabasca Regional Plan (LARP) 16
5.1 Methods 16
5.2 Results 16
6 Task 3: Summarize the validation method and status of existing validated models 17
6.1 Methods 17
6.2 Results 19
7 Task 4: Provide recommendations for validation procedures of non-validated models 23
7.1 HSI Model Validation 23
7.2 RSF Model Validation 25
8 Conclusions and Recommendations 25
9 Acknowledgements 27
10 Literature Cited 28
11 Appendices 31

LIST OF TABLES

Table 1. The relationships between species group and species or species group models reviewed in the EIAs..11

Table 2. Environmental Impact Assessment documents requested for this project.. 12

Table 3. Number of models by species group across the 21 EIAs that were reviewed..................15

Table 4. Classes of validation methods used in EIA species habitat models. 18

Table 5. Mapping of a model's performance based on the validation results..............................19

LIST OF FIGURES

Figure 1. Suitability index (SI) relationships used in the CNRL Horizon American Black Bear (*Ursus americanus*) HSI model (from CNRL 2002) ... 5

Figure 2. Wildlife habitat models database tables and relationships. ... 10

Figure 3. Number of models across the 21 EIAs that were reviewed for species/species groups that were combined. ... 15

Figure 4. Percentage of each model type that had some validation documented in an EIA. ... 20

Figure 5. Percentage of models that were validated by year. EIA documents from 1996 to 2008 were reviewed; however, there were no EIA documents for the years 1997, 1999 and 2004.. ... 20

Figure 6. Percentage of validated models by model history... ... 21

Figure 7. Percentage of validated models for species/combined species groups across the reviewed EIAs.. ... 21

Figure 8. The percentage of each validation method class used for each validated model type (CAPSU, HSI and RSF models) is shown. ... 22

Figure 9. Ranking for validated model's predictive ability based on the model validation results. 22

LIST OF APPENDICES

Appendix A. Database User Guide. 31

Appendix B. Database Data Dictionary. 53

Appendix C. Test Case for Validation 54

1 Introduction

Identifying the locations of high quality habitat for a species of interest is an essential step when assessing potential impacts of industrial activity on a species or developing management plans to mitigate possible impacts. No species is distributed uniformly throughout its range. Instead, individuals live in particular areas, or habitats, that provide the resources (e.g., food, water, nesting/denning sites and cover) and environmental conditions (e.g., climate, elevation, topography and soil) needed to survive and reproduce (Baydack et al. 1999, Fernandez-Juricic and Jokimaki 2001, Johnson and O'Neil 2001). Habitat quality for a species varies throughout its range because it is affected by the amount and quality of resources important to that species, and on other factors such as the presence of conspecifics, interspecific competitors and predators (Morrison et al. 2006).

Direct approaches to identify high quality habitat include measurement of density, population productivity indices such as nesting success or population growth rate (Suryan and Irons 2001, Hansen and Rotella 2002) and field studies to locate sites associated with species-specific resource requirements, such as food, cover types or nesting sites (Raphael and Marcot 1986, Johnson and O'Neil 2001). However density can be a misleading index of habitat quality (Van Horne 1983) and it is often difficult to obtain productivity or resource specific data for many species, particularly at regional scales where inventory data are frequently meagre or absent (Fleishman et al. 2001).

As an alternative, models that link habitat quality to the potential occurrence of a species are frequently used as a tool to identify important habitat locations and limiting habitat features in a region. Species habitat models include easily measured predictive environmental variables that are assumed to influence, or be highly correlated with variables that influence, the potential density of species through direct or indirect effects on life requisites (Van Horne and Wiens 1991). These models can be used to assess wildlife-habitat relations and to predict species' sensitivity to perturbations, thus providing valuable tools in developing land use plans and mitigating effects of human activities on wildlife species (Van Horne and Wiens 1991). The probability of a species' presence throughout the study area is modelled as a function of large-scale environmental variables, such as topography and climate, and/or finer scale variables such as vegetation inventory, ecosystem classification and forest stand structure. Models can be used to assess both habitat capability (the highest potential value of a habitat for a species, regardless of the current habitat condition) and suitability (the ability of the habitat in its current condition to provide the life requisites of a species) (Mahon and Reid 2004). Species habitat models may be further extended to estimate habitat effectiveness, i.e., the suitability of habitat after accounting for the effects of anthropogenic disturbance and landscape context (e.g., a small or isolated habitat relative to the species' needs) (RISC 1999; Hamilton and Austin 2004). Habitat model outputs can be calculated in a Geographic Information System (GIS) that contains habitat polygons and layers of the model's predictor variables within each polygon to predict the likelihood of the species' occurrence across the entire region of interest (Pearce and Ferrier 2001). Habitat maps are then produced that depict the distribution of the habitat capability/suitability categories on the landscape being studied for each species of interest (RISC 1999).

Habitat models are frequently used in the Athabasca Oil Sands Region (AOSR) to assess potential impacts to species of interest when preparing environmental impact assessments (EIAs) and to address Environmental Protection and Enhancement Act (EPEA) approval conditions. In particular, EPEA approval issued since 2007 requires Mine Reclamation Plans and Mine Closure Plans to provide fish and wildlife habitat for key indicator species (KIRs) consistent with pre-disturbance capabilities that have been defined by validated habitat modelling or other habitat assessment tools. The Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Reign (AENV 2010) provides guidance for wildlife habitat reclamation and summarizes, in part, the application of wildlife habitat models to that process. However, use of species habitat models in assessment of impacts and ability to restore habitat to pre-disturbance condition assumes that these models provide accurate predictions of habitat suitability across the landscape. This assumption is questionable however, because studies show that species habitat models have varying degrees of accuracy (e.g., Van der Lee 2006) and it has been estimated that models may only explain or predict up to one half of the variation in species density or abundance (Morrison et al. 2006). An improperly validated model could over- or under-estimate the amount of pre-disturbance habitat (i.e., habitat units) available to a species. Under-estimating the amount of available habitat means that a closure plan will not effectively address the impacts to a species, while an over-estimation may put too much emphasis on the creation of habitat for that species at the detriment to other species.

Errors and uncertainties in species habitat model predictions can arise from several sources. Species habitat models are typically developed with limited knowledge and/or data (Morrison et al. 2006). For example, knowledge regarding species habitat relationships is often incomplete and may not apply to the particular area or time of interest due to ecological and behavioural variation of the target organisms (Boyce et al. 2002). Data used to develop the mathematical relationships between habitat variables and habitat quality/species' occurrences are often scarce, which can lead to errors in statistical models. Variability, bias and uncertainty about the true values of model parameters and inaccuracies of spatial depiction of mapped polygons also have the potential to substantially affect model predictions (EPA 1998, Roloff and Kernohan 1999). Sensitivity analysis is a method used to examine the behaviour of a model by measuring the variation in outputs resulting from changes to model inputs (Suter 2007). It is a valuable technique to identify which parameters most affect model results and hence need to be measured most accurately, and to assess the variability of a model's predictions (McCarthy et al. 1995; Brandon et al. 2007).

Testing the accuracy of species habitat model predictions through a model validation process is a crucial step to fully understand the caveats and limitations of any habitat models that are used in EIAs and closure planning because these factors limit the confidence and usage of the model predictions (Van der Lee et al. 2006, Tirpak et al. 2009). Morrison et al. (2006) recommend that model validation be routinely preformed to assess the appropriateness of objectives and structure of the model; the utility, reliability, accuracy and completeness of the model, and its credibility. It is essential that managers understand model inaccuracies, limitations, uncertainties and variation around the predicted outputs, and use these factors to make informed choices about when to use a model and the relative risk associated with using that model (Van der Lee et al. 2006, Morrison et al. 2006). It is also critical that model caveats and limitations are clearly stated in an EIA so that uncertainties in the impacts predicted by species habitat models are understood. Consequently data gaps, possible errors in the available data, and the variability, uncertainties, assumptions and limitations of the data and analyses used in habitat models need to be clearly identified through a model validation process and summarized within the EIA and closure plan documents. The results of the model validation process can be used to refine and improve the model, to further understand/justify the model's applicability to the EIA and closure planning, and to clearly describe the limitations and uncertainties of model predictions when presenting the assessment of project impacts for a modelled species or the potential to reclaim habitat for that species.

2 Project Objectives and Tasks

This project assessed the current state of habitat models used in oil sands region EIA and closure planning to meet the following objectives:

1. Determine which habitat models are used in EIAs and closure planning, and how these models were used;
2. Determine what linkages exist between the habitat model predictions in the EIAs and closure plans;
3. Determine which habitat models have been validated, and of these, describe and evaluate the validation procedures that were used on each model with recommendations for improvement if needed; and
4. Recommend procedures to validate non-validated models.

These four objectives were addressed through the completion of four tasks:

1. Review and summarize EIA species habitat models used in the oil sands regions for Environmental Impact Assessments (EIAs) for oil sands project applications and for other projects such as wildlife habitat mapping.
2. Review and summarize how regional wildlife habitat mapping data, EIA habitat model data, and habitat models, are used to develop oil sands closure plans conducted by SEWG or for the Lower Athabasca Regional Plan (LARP)
3. Summarize the validation methods and status of existing validated models
4. Provide recommendations for validation procedures of non-validated models

The main activities that were performed to complete the above four tasks included collation of Oil Sands EIAs and Supplementary Information Requests (SIRs) that were submitted from 1990 onwards, a review of all documented species habitat models in these EIAs, interviews with oil sands closure planners, and an assessment of the methods used to validate the species habitat models used in each EIA. We summarized the characteristics of all documented species habitat models, determined how model outputs were incorporated into the closure plans, identified which habitat models were validated and evaluated the appropriateness of the validation methods that were used. We also developed an interactive MS Access database to store project and model characteristics that can be queried by species, model type, project name and proponent. We then made recommendations for improvement of species habitat model validation. Finally, in consultation with CEMA, we selected a North American Beaver (*Castor canadensis*) model as a test case for validation and developed a workplan to perform a comprehensive validation of this model.

This report first provides background information for the three types[2] of species habitat models that were used in the reviewed EIAs to assist the reader in understanding the characteristics of each model's structure and the methods used to develop the model. The recommended validation methods for each model type are also presented. The methods and results for the first three tasks are then summarized, following by a detailed discussion of the model validation results and recommendations for improvement under Task 4. The workplan for the beaver model validation is then documented and provided in an appendix.

[2] Three models not of the HSI, RSF or CAPSU types were assigned a model type of "other". A brief description of these models is provided in the results section of Task 1.

3 Species Habitat Model Background

Habitat models can be developed using expert opinion that may also be supported by empirical data, or can be statistically derived. The choice of model is usually determined by the availability and quality of data, and the available resources and time to construct it. Three types of habitat models that were used in the reviewed EIAs (in increasing order of complexity in data and modelling requirements) include wildlife habitat capability/suitability ratings and mapping (CAPSU), habitat suitability index (HSI) models and resource selection functions (RSF). These three types of models are described (briefly) below to provide context with respect to the application and subsequent validation requirements of each model type.

3.1 Habitat Capability and Suitability (CAPSU) models

CAPSU models and their associated maps are planning tools for land management decision making. Habitat capability and/or suitability (CAPSU) ratings indicate the value of a habitat to support a particular wildlife species, usually in its current and optimal condition.

Expert opinion is used (usually in conjunction with field data) to assign a numerical or categorical rating of capability/suitability (e.g., very high or 1, high or 2, moderately-high or 3, moderate or 4, low or 5, or nil or 6) to each habitat type (or map polygon) for each species of interest. The end product is the development of a ratings matrix (i.e., a table listing the habitat polygons, their attributes, and the capability /suitability rating) and a series of maps depicting the distribution of high to nil-value habitat (based on a colour scheme, e.g., red for very high and no colour for nil) for each season considered. These maps and the associated area of each category of habitat can be used to assess the location of important patches of habitat or, in the case of an environmental impact assessment, to determine the potential level of impact to high quality wildlife habitat resulting from activities related to a given development.

A wildlife habitat capability/suitability mapping project should include the development of a species model, which describes the natural history of the species being considered. The information in the species model can be used to identify important habitat attributes, limiting habitat features, or known effects of development on the species in question. While the species model should be developed using the peer-reviewed and grey-literature, the ratings developed for a given project area are generally based on expert opinion and should be project-specific. Validation methods for CAPSU models and maps include comparisons of species observations with predicted habitat suitability as described below in section 3.2.2 under HSI model validation.

3.2 Habitat Suitability Index (HSI) Models

3.2.1 Background

HSI models evaluate the ability of key habitat components to supply the life requisites (biological elements such as food and cover, and factors specific to reproductive success) that directly affect a species' presence and abundance (USFWS 198, RISC 1999). This popular modelling approach provides a simple model structure with easy to understand equations that represent the major environmental factors believed to affect the distribution and abundance of a species (Morrison et al. 2006). Hence HSI models can be thought of as hypotheses of species habitat relationships (Morrison et al. 2006). Models aim to be biologically valid and operationally robust, and are developed based on a set of assumptions regarding a species' life history, biology and habitat requirements that are typically derived from expert opinion and literature review (USFWS 1980, RISC 1999).

HSI models consist of four primary components: 1) assumptions; 2) input habitat variables; 3) variable relationships; and 4) model output (Roloff and Kernohan 1999). Unlike RSF models that are statistically based (see section 3.3 below), HSI modellers subjectively apply the model assumptions to develop the model's equations that consist of suitability index (SI) relationships that are combined into a linear HSI equation. The SI relationships may be categorical or mathematical; each relationship links a measurable structural, compositional or spatial habitat feature (e.g., herbaceous canopy cover, tree height) to species habitat suitability for a particular life requisite (Roloff and Kernohan 1999). The SI scale ranges from 0 = "not suitable" to 1 = "maximum suitability" (Figure 1). An algorithm is then developed that systematically combines the range of values for each SI (using equations) into the final HSI equation that generates a single HSI score between 0 to 1 for each habitat unit or polygon being assessed. Some HSI models include an intermediate step of first combining some or all of the SI relationships into life requisite (e.g., food, cover) equations, which are then combined into the HSI equation (Roloff and Kernohan 1999). Examples of HSI equations used to model the distribution of American Black Bear habitat for Canadian Natural Resources Ltd's (CNRL) Horizon Project are shown below.

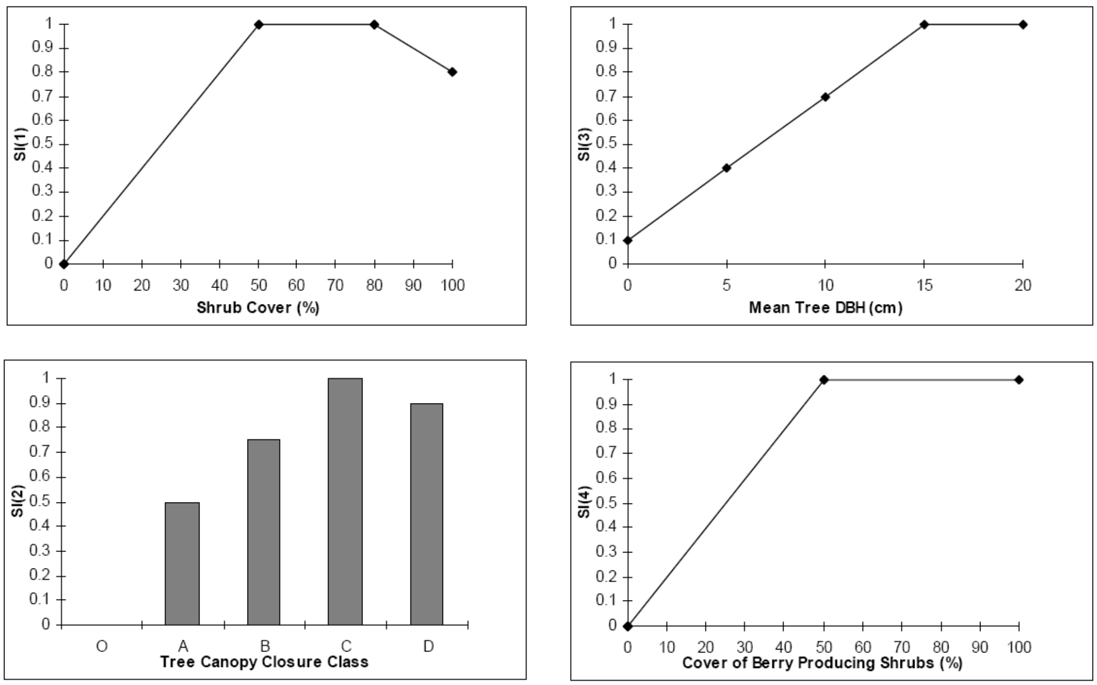


Figure 1. **Suitability index (SI) relationships used in the CNRL Horizon American Black Bear (*Ursus americanus*) HSI model (from CNRL 2002).**

The cover HSI equation used in the EIA for CNRL's Horizon Project assumes that 60% of the cover index is determined from shrub cover (SI(1) in Figure 1) and 40% is determined from tree cover (a combination of SI(2) and SI(3) in Figure 1). The following weighted average was used:

HSI Cover = {0.6 x [SI(1)]} + {[0.4 x [SI(2)] x [SI(3)]}

The HSI food was directly related to SI(4).

HSI Food = SI(4)

The overall HSI equation for bear habitat was determined by weighting the value of food at 70% and cover at 30% in a weighted average as follows:

HSI Overall = [(0.7 x HSI Food) + (0.3 x HSI Cover)] x DC

The term 'DC' is a disturbance coefficient that is added to the model to indicate that the suitability of black bear habitat will be directly affected by infrastructure (roads, utility corridors, facilities and developments) associated with the Horizon Project. A site with no cover could be considered suitable habitat for black bears if food is available and vice versa, but it cannot have optimum conditions unless both food and cover are high. The overall HSI is then reduced by the disturbance coefficient within zones of influence of developments (CNRL 2002).

The shape of the SI relationships (Figure 1) and structure of the final HSI equation can vary with season and geographic location; consequently the application of an HSI model is limited to the season(s) and area for which it was developed. It may be necessary to develop a suite of HSI models to predict habitat suitability over multiple seasons and/or different geographic regions.

HSI models are widely used because they do not require species occurrence data for their construction and they are considered to be a valuable tool in conservation planning, land use planning and mitigating effects of human activities on wildlife species (Van Horne and Wiens 1991, Doswald et al. 2007). They are relatively easy to develop (Roloff and Kernohan 1999) and document a repeatable assessment procedure for evaluating habitat suitability based on a few easily calculated environmental variables (Morrison et al. 2006). However, HSI models have received considerable criticism because of their potential bias due to the use of professional judgement when developing the model and inadequate knowledge about species habitat requirements can introduce errors in SI and HSI equations (Brooks 1997). In addition, models are rarely tested with independent data (Roloff & Kernohan 1999).

3.2.2 HSI Model Validation

Validation of HSI models should first evaluate the internal structure of a model to ensure that it is logically and operationally sound, followed by an assessment of whether the model makes sufficiently accurate predictions (Van Horne and Wiens 1991). The subjective nature of HSI model development means that the statistical validation methods used with RSF models to assess variable selection and model fit do not apply to HSI models and alternate methods must be used to validate the model structure. However, as described below, statistical methods can still be used to validate model predictions against species data in the study area. The USFWS (1981) recommended four main steps to validate HSI models. Steps 1 to 3 correspond to the internal model structure validation, and step 4 tests the model predictions. These steps are presented in the following sections, with specific methods documented for the completion of each step.

3.2.2.1 Step 1: Author review

The model documentation should be reviewed to ensure that all model assumptions and limitations are clearly and correctly stated. The model components and relationships should also be assessed to check that appropriate habitat variables were used, and that the mathematics and graphs for the SI and HSI relationships are consistent with the assumed habitat relationships for the species. Validation of SI relationships is particularly important because HSI equations combine individual SI functions in complex ways and any errors in SI functions or in assumptions underlying the SI functions will be compounded in the calculated HSI values (Van Horne and Wiens 1991). Van Horne and Wiens (1991) recommend that sensitivity testing be done on each SI relationship, particularly when thresholds are used, because model predictions are likely to be strongly affected by small differences in threshold levels.

The form of the HSI equation can greatly influence the expected mean of HSI values produced by a given model. Errors in defining the HSI equation can produce a surface of predicted HSI values that is not flat or symmetrical. This can be tested in step 2, Model Calibration. There are also assumptions regarding possible compensatory relations among variables when defining the HSI equation (Van Horne and Wiens 1991). Thus it is important to also conduct sensitivity tests for the HSI equation that include exploring the influence of various weighting functions in final HSI equation by systematically varying these functions, as well as varying input values for specific parameters (Van Horne and Wiens 1991).

3.2.2.2 Step 2: Model calibration

Model calibration is performed by applying the model to a sample data set and calculating HSI values for each habitat polygon. The HSI outputs are then inspected to assess i) how well the HSI predictions reflect known habitat suitability, i.e., do areas predicted to be high suitability habitat match up with a biologist's professional knowledge of the area, and ii) that a reasonable spread of predicted HSI values from 0 to 1 is produced. Uncalibrated HSI models often generate scores in the middle range of 0.3-0.7 which doesn't allow for useful discrimination of habitat quality among sites (Brooks 1997).

The model is calibrated by modifying the SI relationships and HSI equation as needed based on expert opinion, with HSI predictions regenerated and inspected. This is an iterative process that continues until professional judgement determines that either acceptable HSI score output is achieved, or that knowledge gaps prevent further adjustment of the model.

3.2.2.3 Step 3: External review of model

This step aims to increase the reliability of the model by having an independent expert review the model documentation and results of the model calibration. How well the model represents current ecological knowledge about the species should be evaluated by the reviewer (Morrison et al. 2006). The expert should identify any questionable parts of the model so that the model can be improved.

3.2.2.4 Step 4: Test with field data

Validation of the model with empirical data enables the modeller to assess the model's performance and refine the model as needed. The model's predictive power across the entire range of habitat quality should be evaluated to ensure that the model is robust and to assess the accuracy of model predictions across all HSI values (Roloff and Kernohan 1999). Note that limitations in knowledge regarding species habitat relationships and availability of appropriate and accurately measured habitat variables may constrain the modeller's ability to improve the model performance. In this case, the modeller needs to clearly document the caveats and limitations in regards to using the model predictions for the purpose of a project's assessment of impact to the modelled species or when using the model in a reclamation plan.

Two types of field data (habitat variables and species observations) are used in this step of model validation. Measurements of model habitat variables over a continuous gradient of habitat conditions across the distribution of HSI scores should be sampled to empirically test the SI relationships. Each habitat variable measurement can then be compared to the predicted value of that habitat variable for its associated habitat suitability level in the modelled SI relationship.

Species measurements of habitat suitability such as relative abundance or reproductive success are compared to predicted habitat suitability levels with the expectation that species measurements are positively related to habitat selection, i.e., preferred habitat types (those used more often than expected based on their availability) should have higher HSI scores compared to avoided habitats (used less than expected; Storch 2002). Testing techniques range from subjective comparisons (e.g., relative rankings) to statistical analyses (e.g., t-tests, correlation and regression, chi-square, non-parametric methods and Manly's standardized selection ratio [Manly et al. 2002]). Statistical methods are preferred, and modellers need to consider statistical power, assumptions and correct interpretation of these methods (Roloff and Kernohan 1999). Most studies use relative abundance or density as indicators of population response to habitat quality. Surrogates for fitness can be used instead (reproductive rate, fecundity, survival and mortality) but density dependent effects need to be considered (Roloff and Kernohan 1999). Roloff and Kernohan (1999) recommend using a combination of relative abundance and fitness indicators because animal response variables can differ in sensitivity to habitat quality. Van Horne and Wiens (1991) recommended that the sensitivity testing performed as part of step 1, author review, is used to guide decisions about which aspects of the model should be targeted for field tests and how field work should be designed.

The duration over which population data are collected is also an important consideration when designing the field validation study (Roloff and Kernohan 1999). Natural variability in population density and distribution confound the ability to demonstrate habitat quality and population index relationships. Demographic changes resulting from shifts in numerous environmental variables and extreme events (e.g., drought, insect outbreaks) confound the model validation process. Roloff and Kernohan (1999) recommend that the duration of data collection corresponds with the breeding cycle, with a minimum of 3 years for species with annual cycles and a longer data collection period otherwise. The influence of natural population cycles in species such as snowshoe hare and in their primary predators (e.g., lynx) also need to be considered when interpreting model validation data.

3.3 Resource Selection Function (RSF) Models

RSF models provide a relative estimate of the probability an organism will use a site based on a statistical analysis of the association between its presence in a landscape and selected habitat attributes (Boyce and McDonald 1999, Manly et al. 2002). RSFs compare habitat selection among sample locations "used" by a species to either sample locations where the species was not detected and are assumed to be "unused", or to those that may be "available" to the species throughout its range (Manly et al. 2002).

Resource selection functions are most commonly fitted using a logistic regression form of a generalized linear model (Boyce et al. 2002). Consequently, the structure (i.e., model parameters and model fit) of RSF models can be evaluated using standard statistical procedures such as the Akaike Information Criteria (AIC) to select the model that best balances the number of model parameters and deviance explained, and by examination of model residuals to assess the model fit (Boyce et al. 2002). The predictive ability of an RSF model is typically evaluated by how reliably the model predicts the location of organisms on a landscape (Boyce et al. 2002). Because RSFs are developed based on species observations, which typically are of low numbers, the method of k-fold model validation that uses a single set of species observations to both develop and test RSF models has been recommended by Boyce et al. (2002). K-fold validation is conducted by dividing the data set into K partitions. Each of the partitions is held back in turn to be used as the test data, with the remainder of the data set (i.e., the other K–1 partitions) used to develop the model. The model outputs predict the probability of occurrence for the test data which can then be statistically assessed (Fielding and Bell 1997, Pearce and Ferrier 2000). This process is repeated K times, i.e., for all combinations of partitions.

The methods used to assess a model's predictive ability depend on the class of RSF that was modelled. Predictions from "used/unused" models can be evaluated using standard procedures that have been developed for logistic regression, such as confusion matrices, Kappa statistics and Receiver Operating Characteristic (ROC) curves (Boyce et al. 2002). These methods are all based on the concept of "classification" of predicted values from the model. These predicted values are probabilities of use for an area, and consequently can range from 0 to 1. The modeller specifies a threshold level, i.e., a probability value, above which predicted values in an area map to the expected "presence" of a species. Predicted values below this value represent expected "absence" of a species. Species observations are then overlaid on the predicted probabilities for the area and statistically compared to the classification. Of the three methods described above, ROC curves are recommended because they test the full range of threshold probability cut-off levels (Boyce et al. 2002). The measure of classification accuracy is the area under the ROC curve (AUC) with AUC values over 0.9 indicating very good discrimination, 0.7 to 0.9 reasonable and values less than 0.7 indicating poor discrimination (Pearce and Ferrier 2000).

Predictions from "used/available" RSFs models are more difficult to evaluate. It isn't possible to use the same statistical methods as for "used-unused" models because available sites may also include "used" sites. Boyce et al (2002) recommends using the K-fold validation approach described above, and assessing model predictive ability by calculating the Spearman-rank correlation between ranks of binned RSF scores (i.e., RSF outputs from the "training set" are assigned into a number of bins) and ranks of area-adjusted frequencies for the "test set". A strong positive correlation of adjusted frequencies with RSF scores, i.e., increasing numbers of area-adjusted use locations fall into higher predicted RSF score bins, indicates good model predictive ability.

4 Task 1: Review and summarize habitat models used in the oil sands region for Environmental Impact Assessments (EIAs) for oil sands project applications and for other projects such as wildlife habitat mapping

4.1 Methods

4.1.1 EIA document acquisition

The Environmental Impact Assessments (EIAs) and Supplementary Information Requests (SIRs) to be reviewed for this project were specified by CEMA (Gillian Donald, pers. comm.) and consisted of 26 recent (1990 and later) EIAs for the Athabasca Oil Sands Region. EIA information and supplementary documents were obtained during November 2010 to February 2011 either by 1) online downloads; 2) requested by phone and email to the company directly; or 3) scanned from hard copies located at Alberta Environment library in Fort McMurray. Online downloads were made from several company websites, the provincial Government of Alberta Environment Assessment website (http://environment.alberta.ca/01495.html), and the federal Canadian Environmental Assessment Registry (http://www.ceaa-acee.gc.ca/050/index-eng.cfm).

EIA document requests and acquisitions were tracked in an excel spreadsheet and information was subsequently entered into the MS Access database. Key information recorded included: **project** name, date and type (e.g., oil sands mine, in-situ, etc.); **company** name, contact person and contact information; **date** of document request; **status** of EIA (e.g., requested, pending, in-hand); and **form** of document (e.g., hard copy, cd, pdf).

The PDFs of all received EIA documents were organized into a filing system on the LGL internal document server. Documents were organized into folders by company (e.g., Suncor), project name (e.g., Voyageur Project), and into additional subfolders by volume as needed.

4.1.2 Database design and structure

A preliminary set of database attributes was provided to CEMA for review in January 2011. This preliminary list was later revised to a smaller list of attributes that comprise the final database (Appendix B). Attributes from all reviewed EIAs were entered into a searchable Microsoft Access (v2003) database that was designed by LGL Limited. The database consists of seven main tables (Figure 2) that captured information for each EIA project (e.g., company and contact), project details (e.g., geographic location, lease, type of facility), EIA document information (e.g., submission date), the species modelled for each EIA and the rationale for inclusion, natural history and conservation status for each species modelled across all EIAs, model summaries (e.g., model type, species, location of the model specification in the EIA), and model validation (e.g., model validation status, method used, results and location of the validation documentation in the EIA). All data fields were entered into the database through direct entry into the tables. Interactive searchable forms were developed to allow users to query the database according to species, model type, EIA project and proponent name.

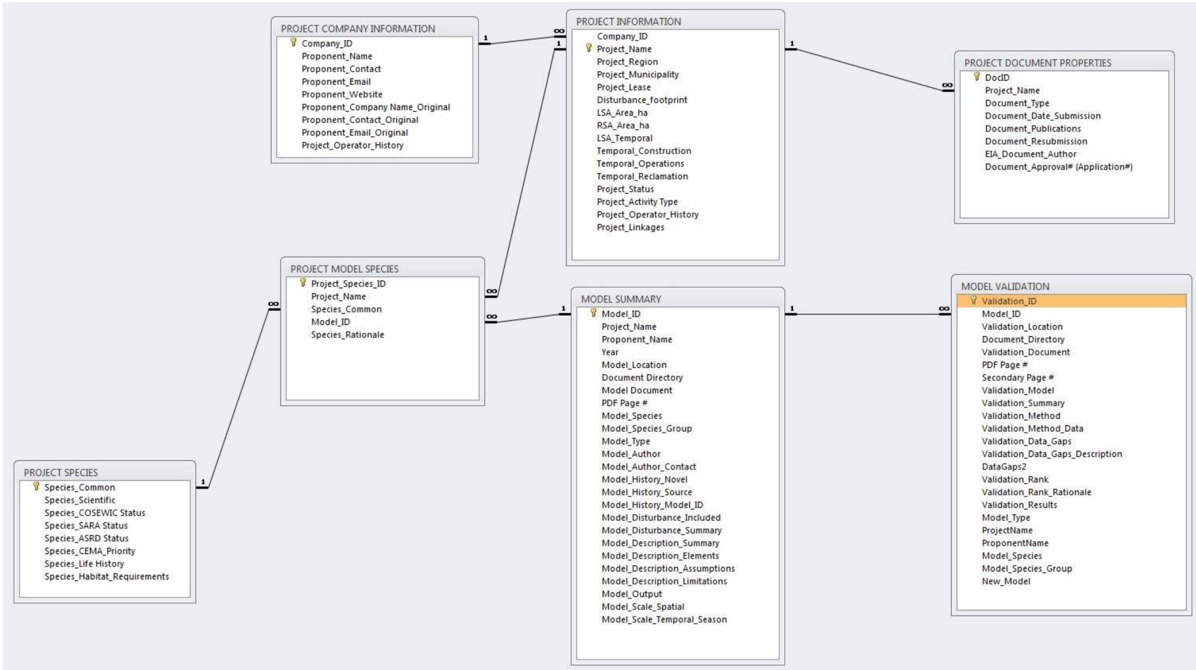


Figure 2. **Wildlife habitat models database tables and relationships.**

4.1.3 EIA document review and data entry

We reviewed each EIA to identify the locations of the closure plan and species habitat model documentation. We searched for model documentation within the main body of the wildlife section of an EIA and within appendices dedicated to species habitat modelling. We did not search an entire EIA document in cases where a species habitat model was not documented in either of these two locations. There were some instances when an EIA's KIR was apparently not modelled. In some cases this was explained in the EIA; however, there were times when no explanation could be found and the rationale as to why certain KIRs were modelled was not always clear. For these reasons, we did not put empty records for species without any documented models into the Model_Summary table. Consequently, the Model_Summary and Model_Validation tables contain records only for the species models that were found in the EIAs. The available closure plans and model documentation were then reviewed. Project and model database attributes were directly entered into the appropriate database tables.

To improve consistency in the database, one individual assessed and entered all project level attributes, while a second individual reviewed and assessed the models. Model summary attributes were filled in as much as possible; however, gaps in documentation occasionally precluded the entry of certain data. Incomplete model documentation was indicated with "Not clearly specified" in the relevant attribute field. In cases where database attributes were irrelevant (e.g., details of model disturbance coefficients when disturbance was not included in the model), attributes were assigned values of "NA".

Some database attributes (e.g., the proponent name, company details and species selected for modelling) rarely required subjective interpretation and were simply entered into the database. Model details, however, needed to be subjectivity summarized when entering data into the database. For example, model details were briefly presented, and only the model assumptions and limitations deemed most important by the reviewer were documented in the database. When the model history could not be clearly discerned, but the EIA text suggested that the model had been reused from a previous EIA, the "Model_History_Novel" attribute was set to "No?". Models having "No?" values were considered to be reused models when calculating the percentage of species habitat models that had been reused from previous EIAs.

As requested by CEMA during a project review meeting on 29 March 2011, we grouped similar species/species groups that were modelled in the EIAs into generic groups for the purpose of reporting summary results by species. In addition, species or species groups that were modelled in less than five EIAs were combined with other related species/species groups if possible (Table 1).

Table 1. The relationships between species group (used for reporting purposes) and species or species group models reviewed in the EIAs.

Species Group	EIA Model Species/Species Group
Waterfowl	Waterfowl
	Ducks and Geese
	Dabbling Ducks
	Ducks (Dabbling and Diving)
Semi-aquatic furbearers	Semi-aquatic furbearers
	North American Beaver
	Common Muskrat (*Ondatra zibethicus*)
	North American River Otter (*Lontra canadensis*)
Fisher/Marten	Fisher/Marten
	Fisher (*Martes pennanti*)
	Marten (*Martes americanus*)
	Terrestrial furbearers[1]
Mixed-wood Forest Bird Community	Mixed-wood Forest Bird Community
	Terrestrial birds[2]
	Western Tanager (*Piranga ludoviciana*)
	Bay-breasted Warbler (*Dendroica castanea*)
Red-backed Vole	Red-backed vole (*Myodes gapperi*)
	Small mammal community[3]
Old-growth forest bird community	Old-growth forest bird community
	Northern Goshawk[4] (*Accipiter gentilis*)
	Cape May Warbler (*Dendroica tigrina*)
	Pileated Woodpecker (*Dryocopus pileatus*)
Non-treed Wetland and Riparian Bird Community	Non-treed Wetland and Riparian Bird Community[5]
	Yellow Rail (*Coturnicops noveboracensis*)

[1]Terrestrial furbearers included marten, fisher, wolverine and lynx (Suncor Steepbank EIA 1996); [2]Terrestrial birds included all songbirds and Ruffed Grouse (Suncor Steepbank EIA 1996); [3]Includes shrews, voles, mice, chipmunks and squirrels (Suncor Firebag EIA 2000); [4] Models were for breeding season habitat that requires old mixedwood; [5] Includes Chipping Sparrow, Palm Warbler, Ruby-crowned Kinglet, Hermit Thrush, Yellow-rumped Warbler and Swainson's Thrush (Suncor Firebag EIA 2000).

The populated database was then used to calculate descriptive statistics and produce figures describing model characteristics and validation. Note that models in the Voyageur Upgrader and North Steepbank Extension projects were the same because the EIA was shared for these two projects. Consequently, these projects were considered a single EIA for the purpose of reporting all model summary and validation results. Only a single instance of each duplicated Voyageur species model was used to produce the summaries and figures shown below, and the number of EIAs presented in these results was reduced by one.

4.2 Results

4.2.1 EIA document acquisition

We collated a total of 22 of the 25 EIAs requested by CEMA (Table 2). The Voyageur Upgrader and North Steepbank Extension projects shared a common EIA (volumes 2-6) with separate project applications submitted (volume 1). We were unable to obtain three EIAs by the end of February 2011. These three EIAs were not available for the following reasons: 1), there was no response from the company to our requests; 2) the project was terminated (e.g., Solv-Ex Corporation); or 3) the price to acquire the document (e.g., scanning and printing the document from the Alberta Library Archives) was prohibitive.

Table 2. **Environmental Impact Assessment documents requested for the CEMA habitat model synthesis project.** The project name, current company managing the project, date the EIA was submitted and the status of LGL's success in obtaining the EIA are shown. Three EIAs could not be obtained: these are indicated in bold. The media type of the obtained EIA is shown for reviewed EIAs. Two EIA documents (Aurora Mine and Mildred Lake Upgrader Expansion) were scanned into PDFs.

Project Name	Company Name	Date of EIA Submission	Source for EIA	Reviewed by LGL?
Foster Creek In-Situ Phase II	Alberta Energy Co.	28-Dec-01	CD sent from Cenovus	Yes
Kirby In-situ Oil Sands Project	Canadian Natural Resources Limited	18-Sep-07	CD sent from CNRL	Yes
Horizon Oil Sands Mine	Canadian Natural Resources Limited	28-Jun-02	CD sent from CNRL	Yes
Surmont In-situ	**ConocoPhillips Canada Resources Corp**	**21-Mar-01**	**Not available**	**No**
Jackfish 2 In-situ	Devon ARL Corporation	29-Sep-06	CD	Yes
Sunrise In-situ	**Husky Oil Operations Limited**	**1-Sep-04**	**Not available**	**No**
Kearl Oil Sands Mine Project	ESSO Imperial Oil Resources Ventures Limited	12-Jul-05	http://www.ceaa-acee.gc.ca/050/document-eng.cfm?document=18778	Yes
Christina Lake Regional In-situ (Phase III)	MEG Energy Corp.	29-Jul-05	CD sent from MEG Energy http://www.megenergy.com/christinalake.html	Yes
Long Lake South In-situ (Phase II)	OPTI Canada Inc.	19-Dec-06	CD sent from OPTI	Yes
MacKay River SAGD Expansion Project	Petro-Canada Oil and Gas	8-Nov-05	CD sent from Suncor	Yes
Meadow Creek In-situ Project	Petro-Canada Oil and Gas	4-Dec-01	CD sent from Suncor	Yes
Jackpine Mine Expansion Project	Shell Canada Limited	20-Dec-07	http://www.ceaa-acee.gc.ca/050/document-eng.cfm?document=46924	Yes
Muskeg River Mine Expansion Project	Shell Canada Limited	28-Apr-05	http://www.ceaa-acee.gc.ca/050/document-eng.cfm?document=16923	Yes
Oil Sands Co-Production	**Solv-Ex Corporation**	**21-Jul-95**	**Not available**	**No**
Firebag In-situ Oil Sands Project	Suncor Energy Inc.	10-May-00	CD sent from Suncor	Yes
South Tailings Pond Project	Suncor Energy Inc.	19-Dec-03	CD sent from Suncor	Yes
Voyageur Project - Voyageur Upgrader	Suncor Energy Inc.	14-Mar-05	CD sent from Suncor	Yes
Voyageur Project - North Steepbank Extension	Suncor Energy Inc.	14-Mar-05	CD sent from Suncor	Yes
Steepbank Oil Sands Mine	Suncor Energy Inc.	30-Apr-96	CD sent from Suncor	Yes
Project Millennium	Suncor Energy Inc.	21-Apr-98	CD sent from Suncor	Yes
South West Sand Storage Conversion Project	Syncrude Canada Ltd.	17-Nov-08	CD	Yes
Aurora Mine	Syncrude Canada Ltd.	24-Jun-96	Scanned from Alberta Environment Library	Yes
Mildred Lake Upgrader Expansion	Syncrude Canada Ltd.	16-Jul-98	Scanned from Alberta Environment Library	Yes
Joslyn North Mine	Total E&P Joslyn Limited	6-Feb-06	http://www.total-ep-canada.com/upstream/regulatory.asp	Yes
Fort Hills Oil Sands Project	TrueNorth Energy L.P.	25-Jun-01	CD sent from Suncor	Yes

4.2.2 Database design and structure

The CEMA habitat model synthesis database has been submitted with this report as a stand alone Microsoft Access file. The structure of the relational dataset is shown in Figure 2, above.

4.2.2.1 Database Instructions

This database is a form-based system that allows a user to review details of species habitat models that have been used in the Oil Sands region from 1990 onwards. Command buttons in the lower right hand side of each form are used to navigate from one form to another. Project and proponent information can also be selected for display. The species habitat models in the database can be searched by species, model type, project and proponent. Detailed information about the model specifications and validation, if performed, can then be displayed. In addition, links to the actual project EIA PDF document for a model's specification and validation are provided when available. A visual representation of a model's history can also be displayed; a table showing the projects and/or citations used for a model going backwards in time is shown.

Instructions to set up and use the database are provided in Appendix A. This setup and user guide information may also be accessed from the opening form of the database.

4.2.2.2 Database Structure

The database structure is hierarchical; users can assess information by navigating through linked tables by clicking on primary or secondary headings to access information on specific projects, species, model types or proponents. Primary headings indicate major search categories (e.g., Model Types, Project Name, Species, Proponent) and secondary headings provide the specific information associated with each project (e.g., project details, species data, etc.). Each secondary heading is comprised of a table with an exhaustive list of data fields applicable to the category and attempts to capture all relevant aspects of each reviewed species habitat model.

The following sections describe the primary and secondary headings (i.e., tables) that comprise the Access database. Detailed information defining the fields nested within each table is located in Appendix A.

PROJECT COMPANY INFORMATION – This table includes all relevant information pertaining to the proponents and/or operators of the project. In several cases the original proponent for the project is not the same as the current operator (due to mergers and take-overs); therefore operator name, contact info (company contact name and email) and website are included for both the original proponent and the current operator. This information may be useful when a user is interested in contacting a company for additional project-related information.

PROJECT INFORMATION - This table includes all relevant information pertaining to the project including the project name and type of activity (oil sands mine, in-situ, upgrader, etc.), linkages between it and other projects (e.g., Jackfish 1, 2, 3 In-situ), location (region of Alberta, municipality, oil sands lease name/number), spatial information (disturbance footprint, local study area hectares [LSA], regional study area hectares [RSA]), and temporal information (length of project, time frames for construction, operation and closure). This general information provides context and background for the project.

PROJECT DOCUMENT PROPERTIES - This table includes details about the EIA or SIR document, including document author, date of submission (or resubmission), and approval numbers (when available).

PROJECT SPECIES - This table includes all relevant information pertaining to the species as it applies to provincial and federal status. This general information on species provides context and background for the modelling summary and validation tables.

PROJECT MODEL SPECIES - This table includes all relevant information pertaining to the species that were modelled for each of the projects including common and scientific name (or name of group if there was more than one species included in the model) and the rationale for its inclusion. This general information on species provides context and background for the modelling summary and validation tables.

MODEL SUMMARY – This table includes details for each species model that was documented in the reviewed EIAs. These details include the model history, the model type, a brief summary of the model and its assumptions, details of the model components and the season to which the model applies.

MODEL VALIDATION – This table presents the details of a model's validation when applicable. The validation method, data used and results are provided.

4.2.3 EIA document review and data entry

A total of 228 species habitat models in the EIA documents were reviewed. The number of models in an EIA varied from 4 to 15, with a median of 12 models. The vast majority of these models (82.0%) were reused from previous EIAs, often with some degree of modification although this was frequently not clearly specified in the model documentation.

Three types of species habitat models were mainly used. Habitat suitability index (HSI) models were used the majority of the time (74.1%), with resource selection functions (RSFs) and CAPSU models used 7.9% and 16.7% respectively. RSF models were solely used for Moose (*Alces americanus*), Canada Lynx (*Lynx canadensis*), Fisher (*Martes pennanti*), Barred Owl (*Strix varia*) and Black-throated Green Warbler (*Dendroica virens*) and were only included in three EIAs (Kirby In-situ, Christina Lake and Jackpine Mine Expansion).

Three models not of the HSI, RSF or CAPSU types were assigned a model type of "other". The Meadow Creek EIA used TWINSPAN (two way indicator species analysis) in two models to identify groups of bird species that corresponded to vegetation types for each of old growth and mixed-wood forest birds. How the results of the TWINSPAN analyses were subsequently used to model habitat suitability was not clearly specified. The Mildred Lake EIA indicated that a habitat analysis was performed for woodland caribou, but did not provide clear details about the model.

Thirty six species/species groups were modelled in the EIAs (Table 3), i.e., before the species groupings in Table 1 were applied. Moose was the only species to be modelled in all 21 EIAs. American Black Bear (*Ursus americanus*), Canadian Toad (*Bufo hemiophrys*), North American Beaver, Fisher, Canada Lynx and Snowshoe Hare (*Lepus americanus*) were included in at least 50% of the EIAs. Several species such as Yellow Rail, Northern Goshawk and Bay-breasted Warbler were included only in one or two EIAS.

Table 3. Number of models by species/species group across the 21 EIAs that were reviewed.

Species	# EIA models	Species	# EIA models
Moose	21	Pileated Woodpecker	5
American Black Bear	19	Cape May Warbler	4
Canada Lynx	16	Waterfowl	3
Canadian Toad	16	Dabbling Ducks	2
North American Beaver	16	Fisher/Marten	2
Fisher	15	Western Tanager	2
Snowshoe Hare	14	Yellow Rail	2
Red-backed Vole	10	Bay-breasted Warbler	1
Mixed-wood Forest Bird Community	9	Ducks (Dabbling and Diving Ducks)	1
Old Growth Forest Bird Community	9	Fisher/Small Mammal Community	1
Ruffed Grouse	9	Marten	1
Woodland Caribou	8	Non-treed Wetland/Riparian Bird Community	1
Great Gray Owl	7	Northern Goshawk	1
Barred Owl	6	North American River Otter	1
Black-throated Green Warbler	6	Semi-aquatic furbearers	1
Boreal Owl	6	Small Mammal Community	1
Ducks and Geese	5	Terrestrial birds	1
Common Muskrat	5	Terrestrial furbearers	1

Combining species/species groups based on Table 1 resulted in 18 different groupings (Figure 3). Semi-aquatic furbearers (North American Beaver, Common Muskrat and North American River Otter) were most frequently modelled, and in some cases, models for more than one of these species was included in an EIA (e.g., Suncor South Tailings Pond modelled all three species). Waterfowl, old growth and mixed-wood forest bird communities, and red-backed vole were now modelled in at least half of the EIAs.

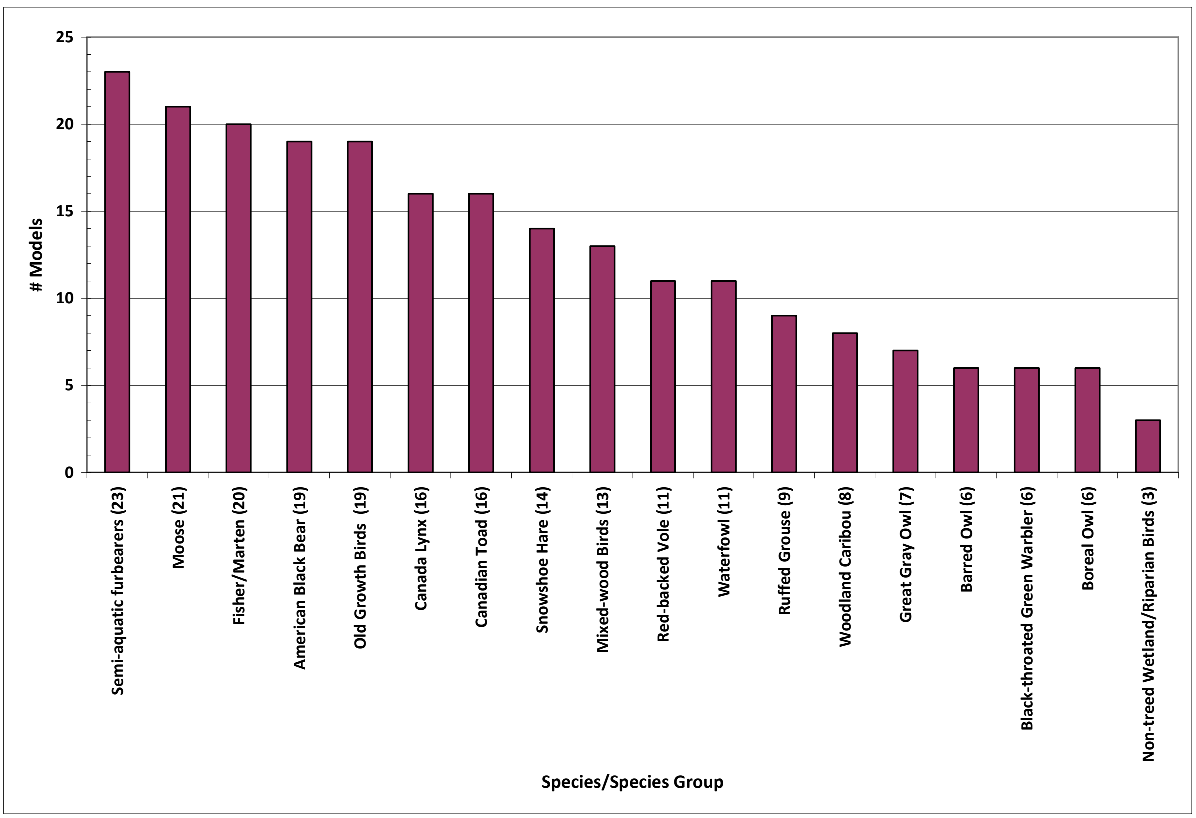


Figure 3. Number of models across the 21 EIAs that were reviewed for species/species groups that were combined. The number of models in each species/species group is shown in parentheses. Species and species groups were combined based on similarity in taxa (e.g., waterfowl and dabbling ducks) or habitat use (e.g., Western Tanager and mixed-wood forest bird community). Refer to Table 1 for more details as to which species and species groups were combined.

5 Task 2: Review and summarize how regional wildlife habitat mapping data, EIA habitat model data and habitat models are used to develop oil sands closure plans conducted by SEWG or for the Lower Athabasca Regional Plan (LARP)

This task required an assessment of how model outputs were transformed into the recommendations of the EIAs and then into the recommendations for closure plans. In other words, we needed to determine if the impacts to wildlife habitat predicted by the models and incorporated into the EIA were considered during the development of the reclamation / closure plans. Most of the EIAs that were reviewed contained closure plan and restoration documentation to some degree. The scope and detail of closure plans varied greatly between projects. Several appeared to be incomplete or composed without links to the wildlife modelling exercises.

5.1 Methods

To fulfil objectives 1 and 2 (see Section 2, page 3) we requested input from closure planners on the reclamation process for each operator in the AOSR. A questionnaire was developed that asked specific questions regarding the links between the predicted impacts to wildlife habitat included in the EIAs (or SIRs) and the closure planning process. There was some concern during a review of the first draft of the questionnaire with CEMA that the questions were too specific and might constrain the conversation with the closure planners, and thus not inform us adequately of the closure planning process used by each planner. Consequently, we elected to provide each closure planner with a list of categories of questions rather than constrain the discussion to a predetermined set of questions. These questions were open-ended and included the following general categories:

1. **Company and project information:** these questions were asked to ensure that information related to the closure planning process can be related to the EIAs and SIRs that have been reviewed and entered into the MS Access database;
2. **Closure Planning Process:** The purpose of these questions was to understand how the closure plans are developed and what the processes involved are;
3. **Spatial and Temporal Considerations:** These questions were asked to understand the temporal and spatial scales of the closure process (e.g., when will the closure process start and how large of an area will be affected?);
4. **Linkage Between Models and Closure Planning:** we wanted to know if any aspects of the species habitat models used to develop the EIA were used in the closure planning process; and
5. **Status of Reclamation Activities:** Have any reclamation activities occurred that are related to the closure process? If so, what has been done?

These five categories formed the basis of the interview to understand how each closure planner considered the output of the species habitat models used in the EIA process when developing a reclamation plan. The information provided was assessed relative to the five categories of questions and to objectives 1 and 2, and then summarized.

5.2 Results

Two closure planners were interviewed: one from Canadian Natural Resources Limited and one from Shell. The response provided by the two planners was later confirmed to be representative of the approach used by closure planners for most (if not all) operators working in the AOSR. The approach to closure planning can be characterized in one of two ways: 1) build it and they will come, and 2) build it and they will come (with modelling).

Using the "build it and they will come" approach, closure planners assess the landforms present in the reclamation area to develop a reclamation strategy. The development of the strategy includes an assessment of the capacity of available landforms in the reclamation area to support ecoystems or ecosite types. This information is then used to develop the site-specific reclamation prescriptions that will be applied to the area. Closure planners using the "build it and they will come" approach assume that reclaimed habitats will support wildlife in the future – reclamation prescriptions are not explicitly linked to wildlife habitat creation or to address the impacts to wildlife and wildlife habitat identified in the EIA developed for a given project. In other words, the reclamation prescriptions applied to the reclaimed areas are not linked to wildlife use.

Using this approach, closure planners strive to create ecologically viable communities that will provide habitat for wildlife to different degrees during different stages of succession. However, the use of the reclaimed habitats by wildlife may or may not be directly monitored so it is not currently possible to say with quantifiable certainty that the reclamation process has mitigated for the impacts to wildlife and wildlife habitat identified in the EIAs. In general, closure planners acknowledge that although the plan is to reclaim 100% of habitat for all species affected, it is not possible to do so, especially for semi-aquatic or fully-aquatic species such as North American Beaver and Common Muskrat.

The "build and they will come (with models)" takes a similar approach to that described above. However, the use of EIAs to assess impacts to wildlife habitat units was identified as one of the primary steps in the development of a reclamation strategy. Some operators also indicated that wildlife use of reclaimed areas is indirectly monitored by wildlife specialists, but there is a plan to implement longer-term monitoring on reclaimed areas to determine levels of wildlife use. As with the "build it and they will come" approach, reclamation is based on the implementation of an executable closure plan.

Closure planners commented that the goal of returning the landscape to pre-disturbance capabilities may not be possible given the removal of a climax community and the reduction of wetland habitat types. Further, and perhaps more importantly, monitoring the response of wildlife to reclamation activities requires the development of reasonable (and attainable) targets for reclamation that are based on benchmarks that are apparently under development. Ideally, the response by wildlife to naturally disturbed habitats of varying age would be studied and compared to wildlife using reclaimed habitats to determine if the reclamation prescriptions are providing habitat that is comparable to that found in naturally regenerating stands (e.g., fire-affected areas).

6 Task 3: Summarize the validation method and status of existing validated models

6.1 Methods

We searched for model validation documentation within the main body of the wildlife section of an EIA and within appendices dedicated to species habitat modelling. We did not search an entire EIA document in cases where a species' model validation was not documented in either of these two locations; we assumed that a model was not validated in the absence of documented validation methods or results[3]. Models that were indicated as being validated in other EIAs (either by using field data or expert review) or had validation documented in a published paper (e.g., the 3 instances of the Black-throated Green Warbler RSF model in Boyce et al. 2002), but were not independently validated within an EIA were also considered to be unvalidated for this purpose of this report. While some models may be applicable at a regional scale because the species response to a single habitat feature is consistent across the region, e.g., Northern Spotted Owl (*Strix occidentalis caurina*) strongly select for

[3] Note that this assessment of model validation was based on information provided in the wildlife sections and species habitat model appendices of the reviewed EIA. It is possible that validation steps were performed, but either not documented or were documented in a different section of an EIA that was not reviewed.

old growth forest (Boyce et al. 2002), habitat selection patterns for many species can vary substantially across geographic areas and models are often only relevant to the specific location and time period for which they were developed (Morrison et al. 2006). Habitat selection can change seasonally and yearly due to changes in resources with time, and can vary spatially because a species' habitat selection may be influenced by the availability of a habitat or resource in the area (Boyce et al. 2002).

We assigned a validation status of "No" to all unvalidated models and set all other database validation attributes for the model to "NA". The validation status of a species habitat model was set to "Yes" if any evidence for independent validation of a model by the model developer was documented in the EIA. This evidence included a statement that the model was validated even if no details of the validation were provided, and/or presentation of validation methods and/or results. We then reviewed and summarized the documented validation methods and results for each model with a validation status of "Yes". A database field was set to "Not clearly specified" when there was insufficient information to determine an appropriate value.

We entered the validation method details (e.g., summary of what was done, data used), documented the data gaps and summarized validation results into the database. We assigned the validation methods into seven classes (Table 4) to simplify reporting of these results and to facilitate discussion under Task 4 (see section 7 below) regarding appropriateness of these classes of methods and specific recommendations to improve them. One class describes the methods used to validate a CAPSU model, five classes distinguished methods for validation of HSI models, and the seventh class applied to RSF used/available model forms. Note that "other" model types and the "used/available" RSF model for the Black-throated Green Warbler were not included in this table because none of these model types were considered to be validated for the purpose of this report.

Table 4. Classes of validation methods used in EIA species habitat models. A description of each validation class is provided. None of the "other", CAPSU or Black-throated Green Warbler used/unused RSF model types were validated.

Validation Class	Description of methods used
CAPSU - Field data (descriptive)	Descriptive comparison of how many species occurrence observations fell into each predicted suitability rating. Simple summary and statement regarding the correspondence between the number of observations and which suitability rating they fell into, if any.
HSI - Not clearly specified	EIA indicated that model predictions had been tested either by using independent species observations or population measures, or by professional judgement. However the methods used and results were not indicated for individual models.
HSI – Calculated model outputs	EIA indicated that models had been run and outputs inspected. It was unclear if the model outputs had been used to calibrate the model.
HSI- Expert opinion	Review of model by external experts
HSI - Field data (descriptive)	Descriptive comparison of how many species occurrence observations fell into each predicted suitability rating. Simple summary and statement regarding the correspondence between the number of observations and which suitability rating they fell into.
HSI - Field data (statistical)	Statistical assessment of relationship between index of species habitat use (e.g., #observations, pellet group densities) and predicted habitat suitability. Includes use of chi-squared tests, Pearson's and Spearman's rank correlation, regression and Manly's standardized selection ratio.
RSF - Used/Available statistical	Use of methods recommended by Boyce et al (2002), i.e., K-fold validation with use of Spearman-rank correlations to quantify strength of relationship between bins of test model predictions and area adjusted frequencies of occurrence (e.g., track counts) per bin

We also ranked a validated model's predictive ability by subjectively assigning a category of good, moderate, fair and poor in the database as shown in (Table 5) to assist in the reporting and subsequent discussion of these results. "Not clearly specified" was assigned to a rank if there was insufficient information about the validation results to determine a ranking.

Table 5. Mapping of a model's performance based on the validation results to a categorical rank. One or more of the listed criteria must be met to assign a given rank, otherwise "Not clearly specified" was assigned to the validated model's performance.

Validated Model Performance Rank	Validation results criteria in EIA
Good	Model predictions correlated well with species observations for all habitat suitability rankings Correlation statistic (if provided) is at least 0.7. Validation methods were appropriate. Modeller called model "acceptable".
Moderate	Model predictions matched with species observations for most habitat suitability rankings. Moderate correlation statistic (if provided) of 0.40 – 0.69. One of LSA/RSA scale is assessed as "good", then other as "moderate". "Acceptable" external expert review of model. "Good" rating downgraded to "Moderate" if observations/predictions correlation did not take area of habitat suitability classes into account.
Fair	Model predictions matched with species observations for some habitat suitability rankings. Absence of species observations is consistent with most area mapped as low or poor suitability. One of LSA/RSA scale is assessed as "good", then other as "poor". Only internal review and/or calibration of model. Moderate, but non-significant correlation between observations and habitat suitability. Moderate correlation between observations and habitat suitability but model developer expressed reservations due to few samples or difficulties in identifying observations to species (e.g., grouse tracks).
Poor	Model predictions did not match with species observations for most habitat suitability rankings.
Not clearly specified	Model developer did not sufficiently document model validation methods and results to allow a rank to be determined.

6.2 Results

One hundred and one of the 228 models (44.3 %) had some level of validation documented in an EIA, with RSF models most likely to be validated (66.7 %) followed by HSI models (52.1 %) (Figure 4). Only one of the CAPSU (2.6%) and none of the "other" model types were validated.

Data gaps were the main reason given for performing limited or no model validation. Three main data gaps were identified: i) a lack of species observations within the study area (e.g., American Black Bear), ii) species observations were available, but these observations had been made during a different season than that targeted by the species habitat model (e.g., fall surveys of waterfowl when models applied to nesting habitat suitability), and iii) species observations were available, but these observations did not sample all the seasons represented by the model (e.g., only breeding season data for an all-year Canadian Toad model).

There appeared to be an increasing trend of documented model validation with EIAs submitted from 2005 and later (Figure 5). An average of 54.8% of the models in these EIAs had some level of validation documented. Only 32.4% of the models were apparently validated in EIAs from 1996-2003 (no EIAs were reviewed for the year 2004).

The percentage of validated models was similar for new models and reused models (Figure 6). When species/species groups were considered, Canada lynx models were validated most often (75.0%) (Figure 7). Other frequently modelled species/species groups (i.e., fisher/marten, Canadian Toad, Moose, Ruffed Grouse, Snowshoe Hare and Woodland Caribou) had 62.5 to 70.0% of their models validated. No barred owl, non-treed wetland/riparian birds or Black-throated Green Warbler models were validated.

Statistical methods were used in 48.5% of all validated models when model types were pooled (Figure 8). Statistical methods were used in 42.0% of the validated HSI models. All instances of RSF model validation (i.e., the used/available model form) used the statistical methods recommended by Boyce et al. (2002). Only one of the 38 CAPSU models was validated; this validation was a descriptive comparison of field data with predicted habitat suitability ratings.

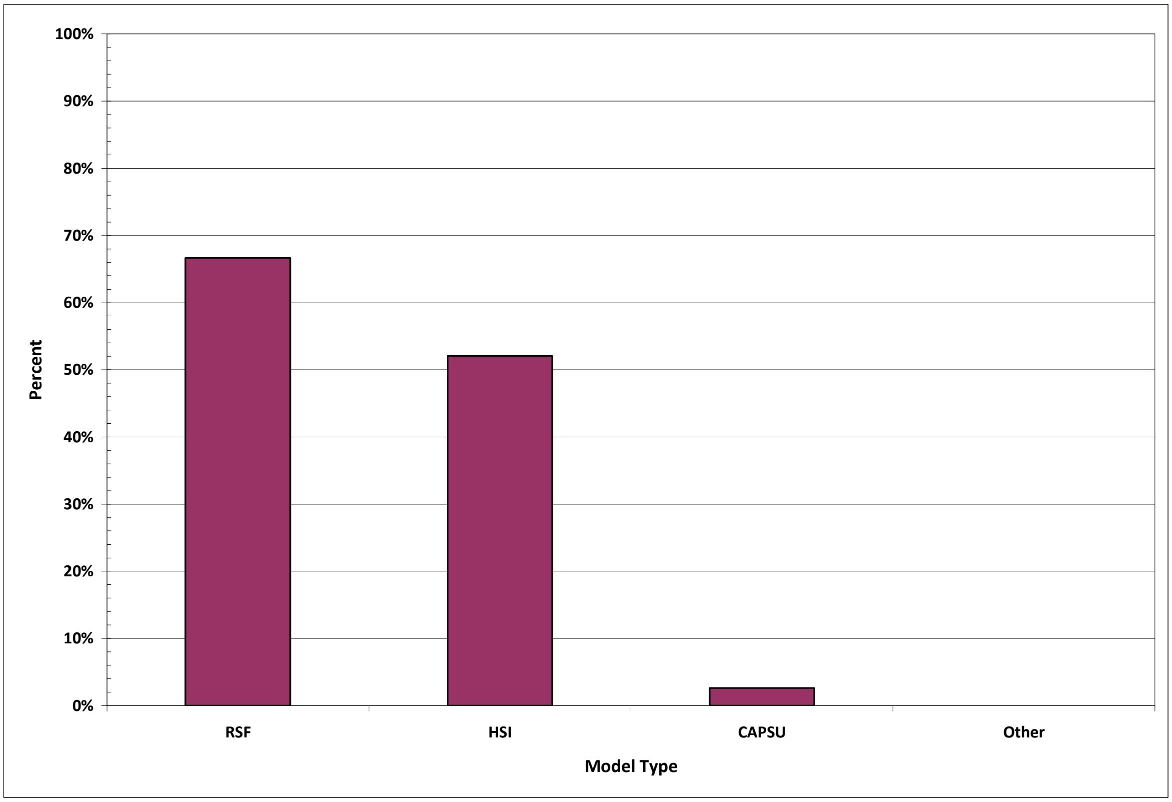


Figure 4. **Percentage of each model type that had some validation documented in an EIA.** No "Other" models were validated.

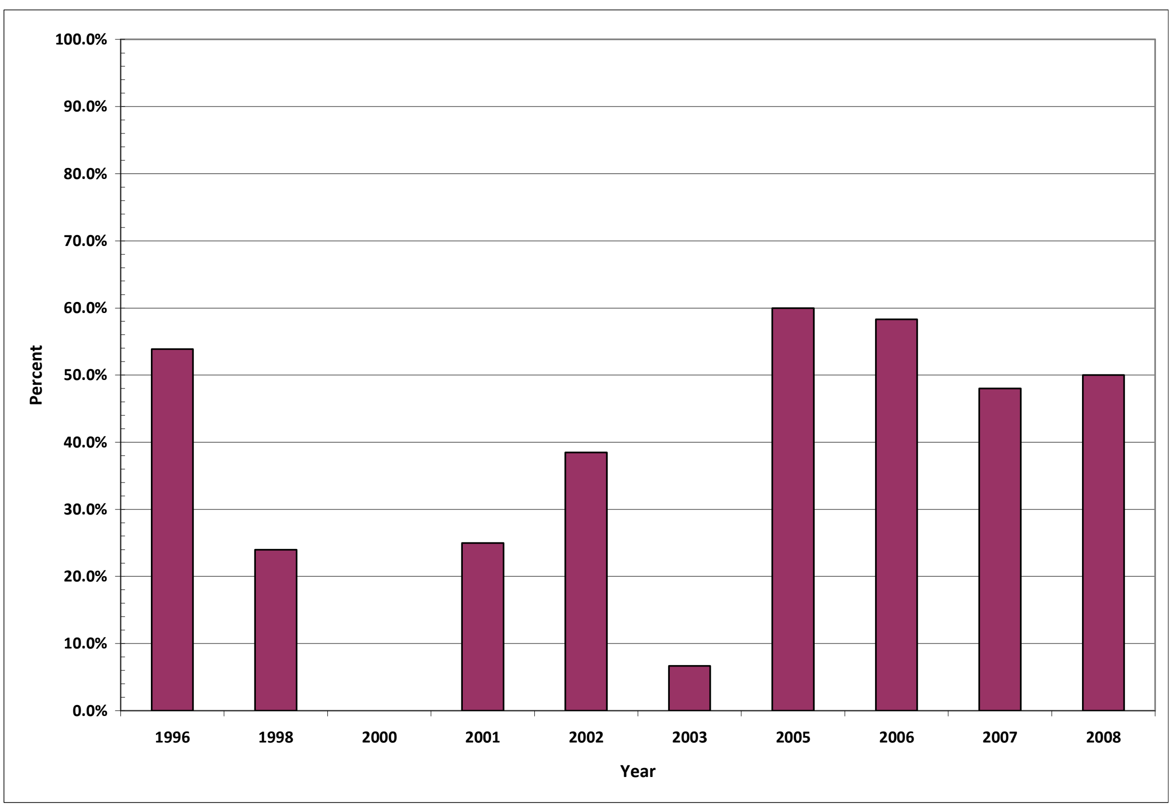


Figure 5. **Percentage of models that were validated by year.** EIA documents from 1996 to 2008 were reviewed; however, there were no EIA documents for the years 1997, 1999 and 2004. No EIA models from the year 2000 were validated.

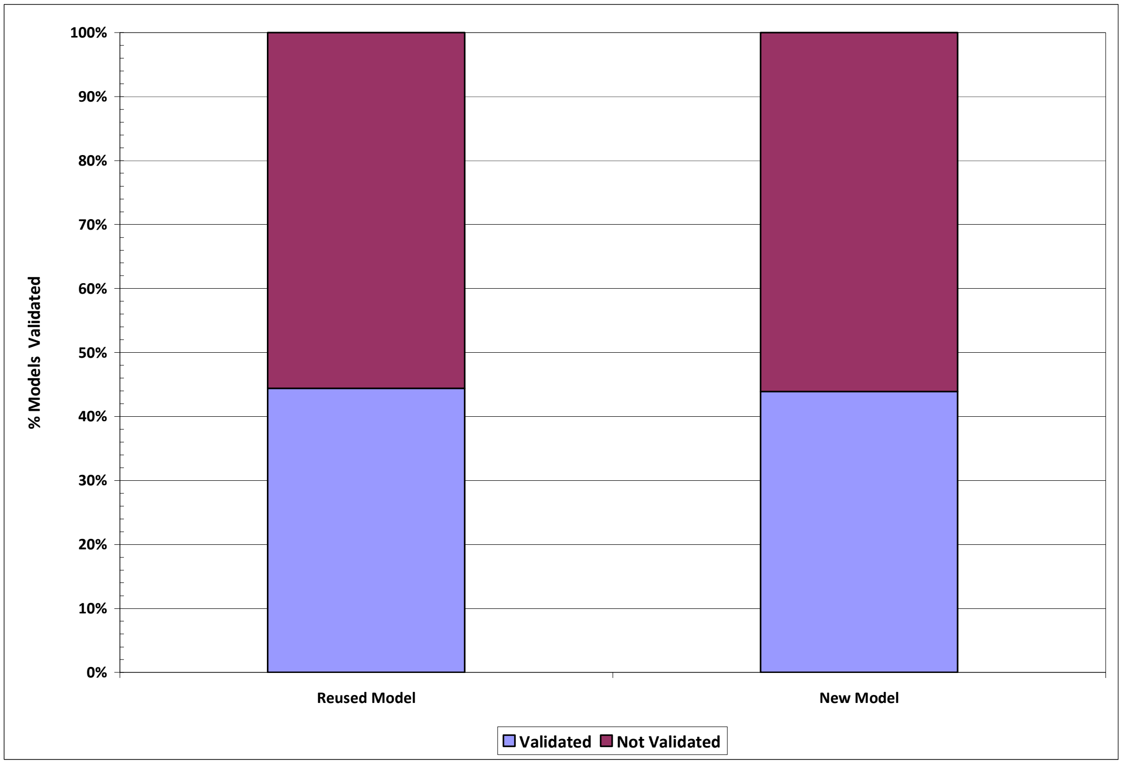


Figure 6. **Percentage of validated models by model history.** A "reused" model has been used in one or more other projects, and may have been modified for its current project. "Reused" models had values of "No" or "No?" in their model history attribute in the database.

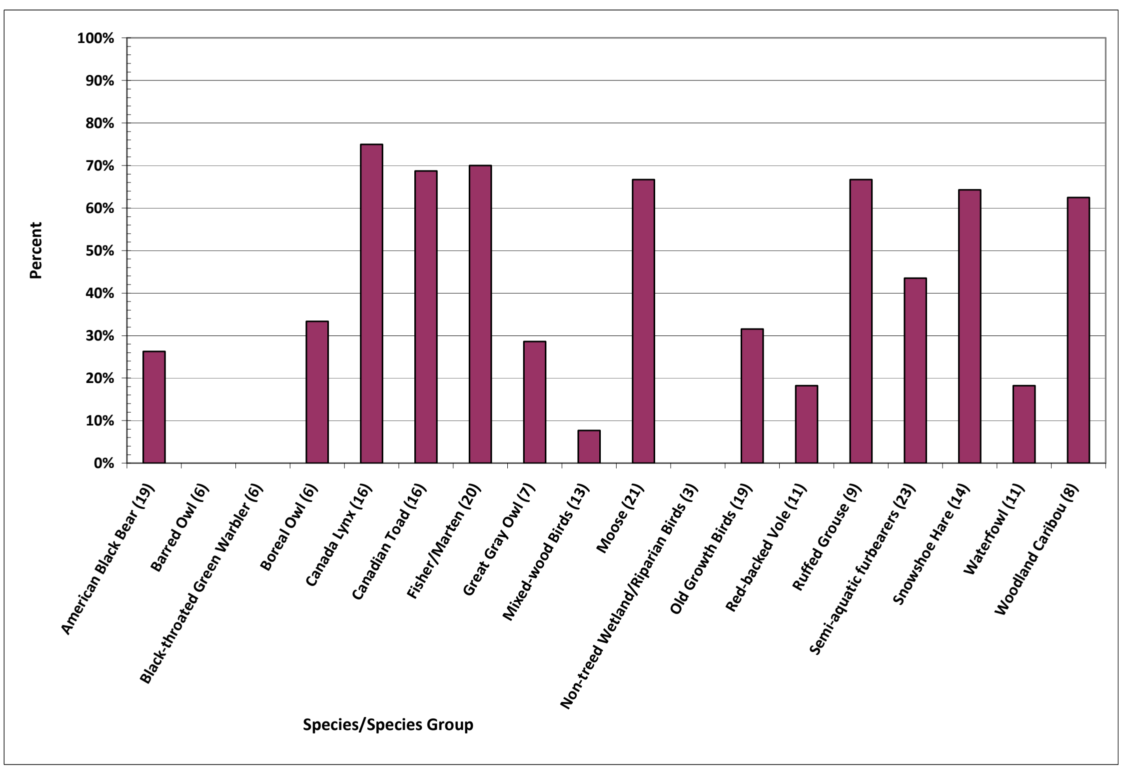


Figure 7. **Percentage of validated models for species/combined species groups across the reviewed EIAs.** The total number of models in each species/species group is shown in parentheses. Species groups were combined based on similarity in taxa (e.g., waterfowl and dabbling ducks) or habitat use (e.g., Western Tanager and mixed wood forest bird community) as described in section 6.1.

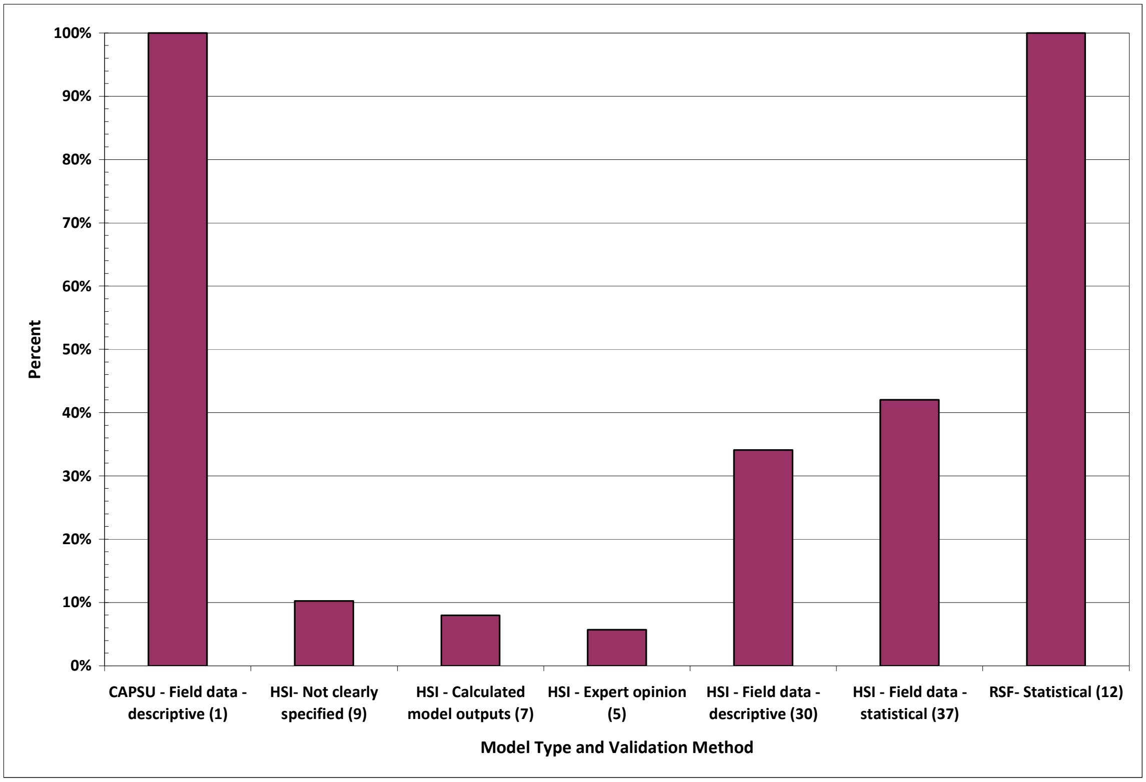


Figure 8. **The percentage of each validation method class for each validated model type (CAPSU, HSI and RSF models) is shown.** Percentages were calculated separately for each model type. The number of models validated by each model type/method class combination is shown in parentheses.

Approximately 80% of the validated models were assigned a validation confidence rank (Figure 9). Approximately 37% of the models were ranked as "good" or "moderate".

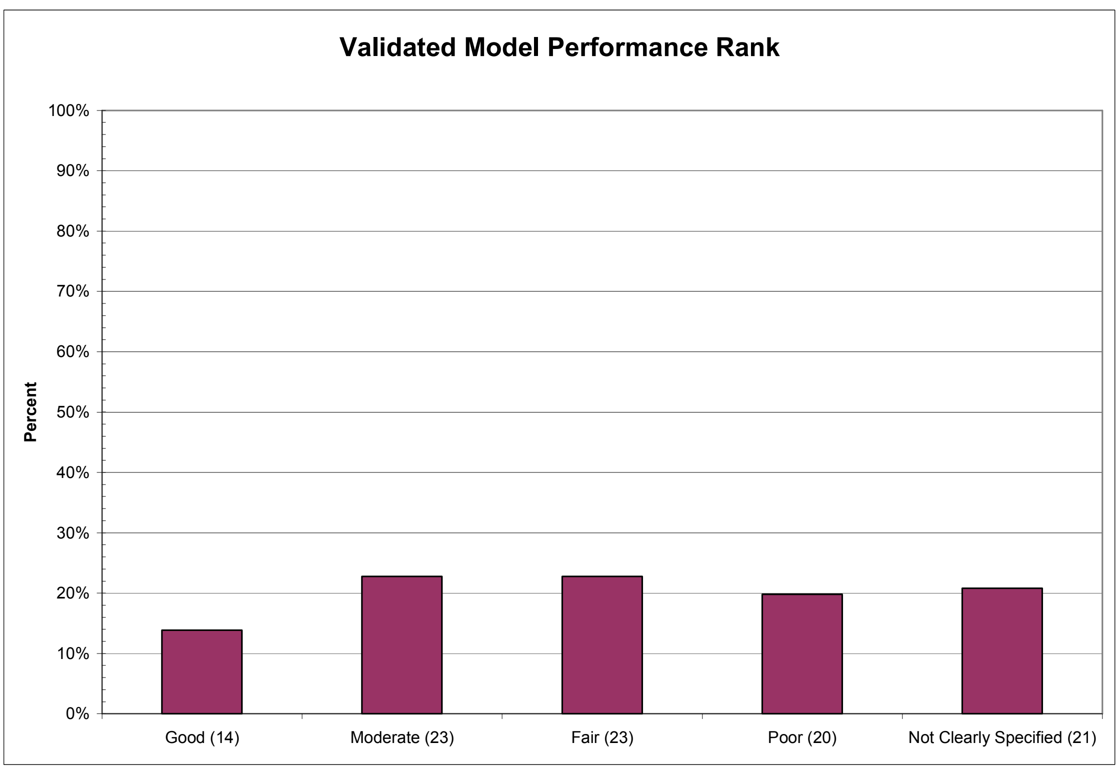


Figure 9. **Ranking for validated model's predictive ability based on the model validation results.**

7 Task 4: Provide recommendations for validation procedures of non-validated models

A model is a simplification of reality that is based on several assumptions. An essential component of model validation involves the identification of the most sensitive assumptions through sensitivity testing, and then targeting the most sensitive assumptions during other model validation steps. In order to do this, the model assumptions must be clearly stated (Van Horne and Wiens 1991).

Models also have limitations. A species habitat model is developed for a particular combination of geographic area, spatial scale, season(s), and selected life requisite(s). While ideally a model is sufficiently general to be applied to a wide range of situations without major modifications, there is a limit to a model's generality. This is because of differences in the ecology of a target species, region dependent changes in habitat responses, variations in individual ecological and behavioural responses to habitat variables, and the fact that different habitat variables may be relevant at different spatial scales (Van Horne and Wiens 1991, Storch 2002).

Because of the assumptions and limitations that are inherent in species habitat models, it is essential to validate all models used in Oil Sands project EIAs and closure plans to assess the accuracy of model predictions. This process then allows the limitations and level of uncertainty of these predictions to be considered when assessing impacts to species of interest by Oil Sands projects or predicting effects of reclamation programs on restoring suitable habitat for species.

Only 44.3% of the reviewed models provided documentation indicating the model had been validated as part of its development. As mentioned earlier, this figure may be biased low because the documentation may not have been located in the reviewed sections of the EIAs or simply not described in the EIA. The percentage of validated models was also reduced by our constraint that the validation needed to be performed in the project study area using the particular version of the model presented in an EIA. We did not accept previous validation for a reused model in the same study area because it was rarely clear if, or what, modifications were made to the model. We also did not consider validation of a re-used model that was developed outside a particular EIA's study area to constitute a reasonable validation of that model for the purpose of predicting impacts for a particular project. As discussed above, a model's application to other geographic areas is limited and needs to be tested through appropriate validation methods. Although in most cases these projects are in the same large study area (i.e., the Athabasca Oil Sands Region), it is possible that variation in local conditions affect modelled SI relationships and HSI equations, and in the case of RSF models, may alter which parameters were retained in the statistically fitted model and the values of their coefficients. Some other reused models were from more distant geographic locations. There were three USFWS HSI models that were used in the EIAs without being validated. In addition, three instances of the Boyce et al. (2002) Black-throated Green Warbler RSF model used in the EIAs referred to the validation performed in that paper, which was conducted at Calling Lake, Alberta, i.e., approximately 200 km southwest of Fort McMurray.

The following sections discuss the specific methods that were performed in the EIA species habitat model validation for the HSI and RSF model types. We evaluated the appropriateness of the validation methods used, the robustness of the validation and issues (e.g., data gaps) that limited model validation. We also compared the model validation that was done on the EIA models to the recommended methods that were presented in section 3 above and identified gaps in model validation. Recommendations were then made to improve future species habitat model validation.

7.1 HSI Model Validation

The majority (52.1%) of the reviewed HSI models were validated. These models used various methods in their validation, however there was no evidence of validating the model structure or calibrating the model as described in the recommended HSI validation steps 1 and 2 (section 3.2.2 above), although the

Aurora Mine EIA did refer to “fine-tuning” the models. Interestingly, the need to perform these steps was documented in the species habitat modelling sections of several EIAs. This suggests that the modellers were aware of these recommended methods, and it may be that this level of validation was carried out but not documented within the EIA. The recommended validation step 3, “external expert review “ was performed in only 5 of 94 validated models and appeared to be done in lieu of using field observations to test model predictions as opposed to the recommended approach of performing the expert review to improve the model before the field verification.

Most of the documented HSI model validation corresponded to step 4 “test with field data”, however only species observations were used in the validation. There was no evidence presented in the EIAs that sampled habitat variables had been validated against predicted SI relationships. There was also no indication that an iterative validation process was carried out whereby model validation results were used to improve the model, which was then subjected to further validation until satisfactory results were achieved, or no more improvements could be made to the model given the limitations of current knowledge.

As discussed in section 3.2.2, requirements for proper design of a validation sampling study implies that habitat variables and species observations collected as part of other survey work are likely not appropriate for validation of an HSI model because those observations may not provide the correct type of samples, adequate sample size, stratification across the full range of predicted HSI values, or in the case of species observations, span sufficient time to adequately represent patterns in species habitat use. There was no evidence presented in the reviewed models for any design or implementation of specific studies to collect validation data for a model; data from baseline studies for the project and occasionally other projects in the area were used instead. This approach limited the HSI model validation because of data gaps within these baseline data.

Thirty four percent of the validated HSI models rated model performance by descriptively assessing the proportion of species observations (e.g., track numbers or pellet groups) that occurred in each of the predicted habitat suitability classes. A model was considered to perform well if high percentages of species occurrences were found in the highest suitability classes. However, this approach does not take into account the amount of predicted area for each suitability class. Thus species habitat selection was not actually evaluated and validation results may have been misinterpreted. For example, if 90% of the study area was predicted by the model to be of the high suitability class, then 90% of the species observations would be expected to occur in this class due to chance alone. An occurrence level of 80%, although seemingly high and, according to this validation method, would be taken as indicating good model performance, actually shows avoidance of this habitat class and suggests the model is not performing well.

Thirty seven of the HSI models used statistical methods (Chi-squared tests, Pearson and Spearman rank correlations, regression and Manly’s standardized selection ratio) to compare species observations with HSI values. These methods aim to statistically assess if species observations are made more often than expected in high and moderate suitability habitat. Of these methods, only the Manly’s standardized selection ratio ensures that species’ habitat selection of suitability classes is being evaluated. Selection ratios represent the proportion of resource units used in relation to the proportion of resource units available (Mahon et al. 2007). The calculated selection ratio for each resource unit provides the relative probability that the resource unit (in the HSI model this is the class of habitat suitability) will be selected given that the organism has unrestricted access to all available resource units of that type (Manly et al. 2002). Manly’s standardized ratio simply adjusts the ratios across all resource units so that the ratios sum to 1 (Manly et al. 2002), which allows direct comparison among selection ratios for all resource units (Desbiez et al. 2009). Higher standardized selection ratios indicate stronger preference for a habitat suitability class. This preference can be statistically tested to detect if there are significant differences among the selection ratios for the suitability classes.

Chi-squared tests that compare number of actual observations to calculated expected observations do have the potential of taking area into account when calculating the expected values for each suitability class, but can potentially make the mistake of equally assigning expected numbers to the suitability classes. While the methods used to calculate these expected values were not fully documented in the model validations that used chi-squared tests, tables of expected and observed values used in the tests were often provided. These tables suggested that area was considered in the calculation of expected values (e.g., Horizon, Meadow Creek).

Appropriate use of correlations and regressions to assess habitat selection also require that area adjusted response variables are used (e.g., locations per area, % of sampled locations in each suitability class where species were detected) or an index of density (e.g., track/pellet group density). We confirmed that track and pellet group densities were used in correlation and regression tests for model validation and in some cases when the Spearman rank correlation was used. A few cases of model validation using the Spearman rank correlation indicated that relative abundance was used, but the actual test variable was not clearly indicated. The Spearman rank correlation has the advantage over Pearson correlation and standard regression methods of not assuming that the relationship between the variables is linear (Townend 2004). However the actual regression validation that was performed in the EIAs (e.g., Long Lake, MacKay River) used a statistical package that did allow for nonlinear relationships.

7.2 RSF Model Validation

The RSFs presented in the reviewed EIAs modelled habitat suitability for Moose, Canada Lynx, Fisher, Barred Owl and Black-throated Green Warbler. Models for Moose, Canada Lynx, Fisher and Barred Owl were all of the “used/available” RSF form. Each of these models was validated using the methods recommended by Boyce et al. (2002), i.e., k-fold validation and use of the Spearman rank correlation to assess the relationship of area corrected frequencies of presence to bins of predicted RSF scores.

The Black-throated Green Warbler (BTGW) RSF model used in 3 EIAs was taken from the Boyce et al. (2002) paper. This was a used/unused RSF and was validated in the Boyce et al. (2002) paper using ROC curves. The model performed well on the test data set (Calling Lake, Alberta) which represented boreal forest use in Calling Lake, Alberta. However this model was not tested using data from the local study areas in the 3 EIAs that used it.

8 Conclusions and Recommendations

Less than half of the 228 models reviewed had some level of validation documented in an EIA, with RSF models most likely to be validated followed by HSI models (Figure 4). Only one of the CAPSU models was validated. No “other” model types were validated. Data gaps were the main reason given for performing limited or no model validation including i) a lack of species observations within the study area; ii) species observations were available, but these observations had been made during a different season than that targeted by the species habitat model; and iii) species observations were available, but these observations did not sample all the seasons represented by the model. There appeared to be an increasing trend of documented model validation with EIAs submitted from 2005 and later (Figure 5). The percentage of validated models was similar for new models and reused models (Figure 6). When species/species groups were considered, Canada lynx models were validated most often (75.0%) (Figure 7). Other frequently modelled species/species groups (i.e., Fisher/Marten, Canadian Toad, Moose, Ruffed Grouse, Woodland Caribou and Snowshoe Hare) had 62.5 to 70.0% of their models validated. No Barred Owl, non-treed wetland/riparian birds or Black-throated Green Warbler models were validated.

Our review of EIA species habitat models revealed that while RSF models tended to be appropriately validated, the HSI models were not. Forty eight percent of HSI models were not validated at all. In addition, the validation that was performed did not appear to conduct all four steps recommended by standards documents (e.g., USFWS 1981, RIC 1999). Furthermore, the descriptive comparisons of species observations within habitat suitability classes that were used in several cases of HSI model validation did not take the available area of the suitability classes into account, and so may have misinterpreted the validation results. These findings led to the recommendation that an HSI model developed for North American Beaver be selected for model validation (see Appendix C).

Van Horne and Wiens (1991) comment that most HSI models have been constructed as working versions rather than final, definitive models, but HSI models are often published in a way that suggests they are final products rather than working quantitative summaries of available information. We suggest that this is indeed the case in the Alberta Oil Sands Region EIAs that were reviewed by this project. Due to limitations in time and funding, it is unlikely that species habitat models will be subjected to a full range of testing. In addition, species observations data and knowledge of habitat relationships are often limited for indicator species used in the EIAs because many of these species were selected due to their conservation status of threatened or higher. Consequently, it is inevitable that species habitat models used as a basis for EIA evaluations of species' habitat loss and in closure planning will contain errors and uncertainties in their predictions. For this reason, it is essential that the use of model predictions in EIAs clearly document the caveats and limitations of the models, and considers the implications of these factors when presenting and discussing impacts to species and potential for habitat reclamation.

We make the following recommendations to improve both the understanding of the model development done for species habitat models in Oil Sands EIAs and the validation of these models.

1) Provide complete documentation of model history, assumptions, limitations, all model variables and rationale for inclusion, and details of model structure.

2) Provide complete documentation of all model validation steps that were performed. This includes details of methods used, specifics of test data (e.g., where obtained, for what season(s) and year(s), sample size), clear description of test variables used and how these were calculated, and detailed documentation of results with statistical outputs (e.g., p-values) as appropriate.

3) Use appropriate statistical techniques to validate HSI models. Use test variables such as area corrected species' usage in habitat suitability classes, relative densities (e.g., pellet group densities/ha) or Manly's standardized selection ratio.

4) Follow the four steps recommended in section 3.2.2 to validate HSI models.

5) Specifically design a field program to collect appropriate habitat and species data to validate HSI models. Sample over multiple years. Target the most sensitive assumptions in the model for validation. See Appendix C. Model Validation for a description of a model validation workplan.

6) Use the results of model validation to improve the models.

7) Fully document the caveats, uncertainties and limitations of using model predictions when estimating impacts to a modelled species or when predicting potential for habitat restoration.

8) Design a field study to test a selected model's generality, i.e., applicability, within different lease areas of the AOSR. This study found that species habitat models are frequently reused in different EIAs, typically without a thorough validation of the model. As discussed in this report, scientific literature cautions against using a model in different geographic areas without appropriate validation. However, it is possible that ecological conditions across the different lease areas within the AOSR are similar enough for a species' important life requisites to support reuse of an appropriately validated model for that species with some limited additional validation. If so, then the process of model validation could be streamlined for reused models in the AOSR, thus reducing costs of EIA and closure plan development. Note that generality must be tested for each particular species model; a field study for a selected model will demonstrate

a methodology for testing model generality in some selected lease areas and provide valuable insights into the model validation that may be required to support model reuse.

9) Provide the CEMA habitat model synthesis database as a resource to consultants developing EIAs and maintain the database as a "living document" by allowing these consultants to update the database with their project/model details.

9 Acknowledgements

This project was administered by Kyle Harrietha of the Cumulative Environmental Management Association with technical support provided by Dr. Gillian Donald. We appreciate the input of the CEMA members to previous versions of aspects of this report and on the database. We extend our appreciation to the operators in the AOSR that provided EIA documentation. Cole Thomson of the Energy Resources Conservation Board provided assistance with the acquisition of several EIAs. Steve Tuttle of Canadian Natural Resources Ltd. and Dr. Vivienne Wilson of Shell Canada were interviewed regarding the closure and reclamation process associated with their respective companies.

10 Literature Cited

Alberta Environment. 2010. Guidelines to reclamation of forest vegetation in the Athabasca Oil Sans Region, 2nd edition. Prepared by the Terrestrial Subgroup of the Reclamation Working Group of the Cumulative Environmental Management Association, Fort McMurray, AB. December 2009.

Banfield, A.W. 1981. The Mammals of Canada. Revised edition. University of Toronto Press, Toronto, Ont.

Baydack, R.K., H. Campa, and J.B. Haufler. 1999. Practical approaches to the conservation of biological diversity. Washington, DC. Island Press.

Boyce, M. S. and L. L. McDonald. 1999. Relating populations to habitats using resource selection functions. Trends in Ecology and Evolution 14(7):268-272.

Boyce, M. S., Vernier, P. R., Nielsen, S. E. and F. K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157(2-3):281-300.

Brandon, J.R., J.M. Breiwick, A. E. Punt and P. R. Wade. 2007. Constructing a coherent joint prior while respecting biological realism: application to marine mammal assessment stocks. ICES J. Mar. Sci. 64: 1085-1100.

Brooks, R.P. 1997. Improving habitat suitability index models. Wildlife Society Bulletin 25(1): 163-167

CNRL 2002. Canadian Natural Resources Limited Horizon Oil Sands Mine EIA Appendix II.

Desbiez, A.L.J., R.E. Bodmer and S.A. Santos. 2009. Wildlife habitat selection and sustainable resources management in a Neotropical wetland. International Journal of Biodiversity and Conservation 1(1):11-20.

Doswald, N., F. Zimmermann and U. Breitenmoser. 2007. Testing expert groups for a habitat suitability model for the lynx in the Swiss Alps. Wildlife Biology 13(4): 430-446.

EPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F.

Fernández-Juricic, E. & J. Jokimäki. 2001. A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. Biodiversity and Conservation, 10:2023-2043

Fielding, A. H. and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental conservation 24(1):38-49.

Fleishman, E., R.B. Blair, and D.D. Murphy. 2001. Empirical validation of a method for umbrella species selection. Ecological Applications 11:1489–1501.

Fuller, T.K. and J.A. Markl. 1987. Beaver, *Castor canadensis*, colony density in the Bearsville study area, northcentral Minnesota. Can. Field-Nat. 101(4):597-598.

Hamilton, A.N., and M.A. Austin. 2004. Estimating Grizzly Bear (Ursus *arctos*) Population Size in British Columbia Using an Expert-Based Approach. B.C. Ministry of Water, Land and Air Protection, Victoria, BC.

Hansen, A.J. and J.J. Rotella. 2002. Biophysical factors, land use, and species viability in and around nature reserves. Conservation Biology, 16: 1112–1122.

Johnson, D.H. and T.A. O'Neil. 2001. Wildlife-Habitat Relationships in Oregon and Washington. Oregon State University Press: Corvallis, Oregon.

Mahon, C.L., K. Martin and J.D. Steventon. 2007. Habitat attributes and chestnut-backed chickadee nest site selection in uncut and partial-cut forests. Canadian Journal of Forest Research 37: 1272-1285.

Mahon, T. and D. Reid. 2004. Predictive habitat mapping with Grizzly Bear Habitat Suitability ratings for the Kispiox and Cranberry Timber Supply Areas Draft Report.

Manly, B.F.J., McDonald, L.L., Thomas, D.L., McDonald, T.L. and W.P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. 2nd Edition. Kluwer Academic Publishers. Dordrecht.

McCarthy, M. A., M. A. Burgman and S. Ferson. 1995. Sensitivity analysis for models of population viability. Biological Conservation 73: 93-100.

Morrison, M. L., B. G. Marcot and R.W. Mannan. 2006. Wildlife-Habitat Relationships: concepts and applications 3rd edition. Island Press. Washington D.C.

Novak, M. 1987. Beaver. Pages 283-312 *In*: M. Novak, J.A. Baker, M.E. Obbard and B. Malloch (eds). Wild Furbearer Management and Conservation in North America. Ontario Ministry of Natural Resources, Toronto, Ont.

Pearce J. and Ferrier S. 2001. The practical value of modelling relative abundance of species for regional conservation planning. Biological Conservation 98: 33–43.

Potvin, F., L. Breton, C. Pilon and M. Macquart. 1992. Impact of an experimental wolf reduction on beaver in Papineau-Labelle Reserve, Quebec. Can. J. Zool. 70:180-183.

Raphael, M. G. and B. G. Marcot. 1986. Validation of a wildlife-habitat-relationships model: vertebrates in a Douglas-fir sere. pp 129-138 in: Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Verner, J., Morrison, M.L. and C.J. Ralph editors. The University of Wisconsin Press. London. England.

RISC. 1999. British Columbia Wildlife Habitat Rating Standards Version 2.0 Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee.

RISC. Resource Inventory Standards Committee. 1996. Addenda to Terrestrial Ecosystems Mapping Standards. Draft. Prepared by the Ecosystem Working Group of Resource Inventory Standards Committee.

Roloff, G.J. and B.J. Kernohan. 1999. Evaluating reliability of habitat suitability index models. Wildlife Society Bulletin 27(4): 973-985.

Storch, I. 2002. On spatial resolution in habitat models: Can small-scale forest structure explain Capercaillie numbers. - Conservation Ecology 6 (1): 6. Available at: http://www.consecol.org/vol6/iss1/art6

Suryan, R.M. and D. B. Irons. 2001. Colony and population dynamics of black-legged kittiwakes in a heterogeneous environment. The Auk 118(3):636-649.

Suter, G.W. II. 2007. Ecological Risk Assessment. Second Edition. CRC Press, Taylor & Francis Group.

Tirpak, J.M., Jones-Farrand, D.T., Thompson, F. R. III, Twedt, D.J., Baxter, C.K., Fitzgerald, J.A. and W.B. Uihlein III. 2009. Assessing ecoregional-scale habitat suitability index models for priority landbirds. The Journal of Wildlife Management 73(8): 1307-1315.

Townend, J. 2004. Practical statistics for environmental and biological scientists. John Wiley & Sons Ltd. Chichester, England.

Ursus Ecosystem Management Ltd. 2003. Regional habitat evaluation and mapping for key wildlife species in the Athabasca Oil Sands Region. Prepared for the Cumulative Environmental Management Association. (CEMA), Wildlife and Fish Working Group. August 2003.

USFWS 1980. Habitat Evaluation Procedures (HEP) (102 ESM). Division of Ecological Services U.S. Fish and Wildlife Service. Department of the Interior. Washington, D.C.

USFWS 1981. Standards for the development of habitat suitability index models (103 ESM). Division of Ecological Services U.S. Fish and Wildlife Service. Department of the Interior. Washington, D.C.

Van der Lee, G.E.M., Van der Molen, D.T., Van den Boogaard, H.F.P. and J. Van der Lis. 2006. Uncertainty analysis of a spatial habitat suitability model and implications for ecological management of water bodies. Landscape Ecology 21: 1019-1032.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. The Journal of Wildlife Management, Vol. 47, No. 4. (Oct., 1983), pp. 893-901.

Van Horne, B. and J.A. Wiens. 1991. Forest bird habitat suitability models and the development of general habitat models. U.S. Fish and Wildlife Service, Fish and Wildlife Research 8.

11 Appendices

Appendix A. Database User Guide.

1 Introduction

This user guide provides instructions for database installation, searching, editing and creating new table entries in the Cumulative Environmental Management Association (CEMA) species habitat model database that was developed by LGL Limited under CEMA contract No. 2010-0034 "Synthesis of Habitat Models used in the Oil Sands Region". This database contains summaries of the Alberta Oil Sands EIA species habitat models that were reviewed within the scope of this study. Proponent and project information was also summarized. The database provides easy to use forms that allow users to search species habitat models by species, model type, project and proponent, and to display selected database information. Users that have special password access may also use edit the database and enter new data into the database.

2 Installation Procedure

The database consists of three components that are provided in a *.zip file:

- a Microsoft Access database;
- a Microsoft Access database security file;
- a documentation folder containing:
    i. EIA documentation for the species habitat models in the database;
    ii. a copy of this user guide; and
    iii. a document providing the citations referenced in the "Model History" form of the database.

The database can be installed in any folder on a user's computer using the following steps:

1. Create a folder for the zip file and database.
2. Copy the zip file to the folder.
3. Extract the database ("CEMA Habitat Model Database.mdb"), the database security file (CEMAhab.mdw) and the documentation folder ("PDFs") from the zip file (right click the zip file and select "Winzip->Extract to here"[4]). Note that folder "PDFs" containing the database documents MUST remain in the same folder as the database.
4. Create a shortcut to the database using the following steps:
    i. Right click the Microsoft Access database file ("CEMA Habitat Model Database.mdb") and select "Create Shortcut". A shortcut will be created in the same folder as the database file.
    ii. Right click the database shortcut and select "Properties".
    iii. Edit the Target path on the "Shortcut" tab to consist of the following four components. Each component in the path must be separated by a space.

[4] Note that any compression software that recognizes *.zip files may be used

a. Full path to the Microsoft Office executable MSACCESS.EXE. The path name must be enclosed in double quotes. This executable is located in the program files Microsoft Office folder, e.g., "C:\Program Files\Microsoft Office\Office14\MSACCESS.EXE"

b. Full path to the CEMA Habitat Model Database.mdb. The path name must be enclosed in double quotes, e.g., "C:\CEMA\CEMA Habitat Model Database.mdb"

c. The text /WRKGRP with NO double quotes surrounding it.

d. Full path to the database security file. The path name must be enclosed in double quotes, e.g., “"C:\CEMA\CEMAhab.mdw"

The complete text in the shortcut Target box for the above example would consist of a single line as follows:

"C:\Program Files\Microsoft Office\Office14\MSACCESS.EXE" "C:\CEMA\CEMA Habitat Model Database.mdb" /WRKGRP "C:\CEMA\CEMAhab.mdw"

5. Start the database by double clicking on the shortcut. The database may be used in three modes:

- Database Search/Read Only: To search existing projects and models in the database and display attributes for selected projects and models.
- Data-Entry/Edit: This mode provides the Database Search/Read operations and allows a user to edit existing data in the database or to enter new data. A user may edit data/enter new data by using forms or by directly editing the database tables.
- Admin: This mode is for the system administrator. It provides all the database search and data-entry/edit functions of the other modes but also allows the user to make changes to the forms, database program and user passwords.

The mode is controlled through the user ID and password that must be entered by the user upon starting up the database. Please contact the system administrator for the password needed to access the database in the desired mode.

6. A start page with introductory content is first displayed (Figure 1). Note that this user guide may also be accessed by clicking the “User Guide” button on the start page.

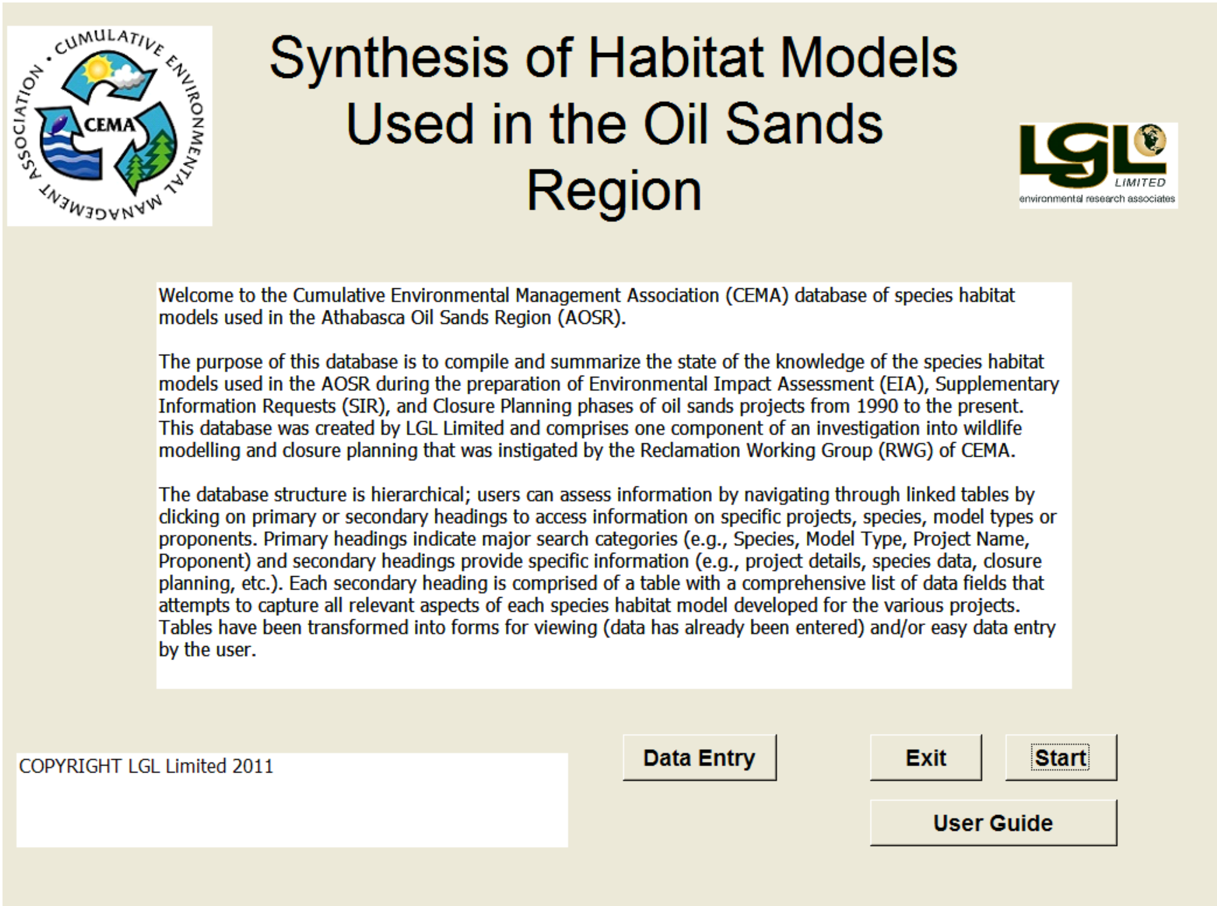


Figure 1. Database Start form. The “Data Entry” button will only be displayed in Data-Entry/Edit and Admin user modes.

3 Database Searching (Read-Only Mode)

The navigation structure when searching the database is shown in Figure 2.

1. General Instructions:
   - Clicking the “left-arrow” button will backtrack through the forms.
   - The "Home" button can be clicked to return to the start page.
   - Selecting the “Exit” button on the start page will terminate the interactive database session and close the database.
2. Read the introduction on the “Start Screen” and then click the "Start" button to proceed to the “Search by” form (Figure 3).
3. Habitat models can be searched by species, model type, project, and project proponent. Select from the appropriate pull-down list and then click the "Projects" or the “right-arrow” button.
4. Again, use the pull-down list to further narrow the search criteria to a specific project and species model if searching by species (Figure 4), model type (Figure 5) or project proponent (Figure 6), and then click the "Projects" or the “right-arrow” button. The “Project” form is then displayed (Figure 7). If the search was made for a specific project, the “Project Form” is also displayed; however the user must now select a particular species model from the pull-down “Select Species/Model” list on the form.

5. The “Project” form presents the rationale for including a species in a particular project EIA and allows the user to display associated company (Figure 9), project (Figure 10) and document information (Figure 11) for the selected project by clicking the appropriate button on the form. The “Model Summary” form may be displayed by clicking the “Model” or the “right-arrow” button on the “Project” form.
6. The “Model Summary” form (Figure 12) presents a summary of a model’s approach, components, assumptions and limitations, and provides details regarding the model’s developers and history.
   - The “PDF” button on the form will open the EIA PDF document at the start page for this model’s documentation so that the user may review the complete documentation that is available for the model.
   - If this model has been newly developed for this project, the “Model History” button may be clicked to present a table showing the historical sequence of EIAs/publications with earlier versions of this model (Figure 13). Clicking the “Citations” button at the bottom of the “Model Summary” form will provide a bibliography of all the citations referenced in the “Model History” table.
   - Click the “Species” button to view the species’ scientific name and conservation status (Figure 14).
   - Click the “Model Validation” or “right-arrow” button to see the “Model Validation” form.
7. The “Model Validation” form (Figure 15) presents a summary of methods and data used to validate the model, data gaps and the validation results. EIA documentation relevant to the model validation may be accessed by clicking the “PDF Page 1” button on the form. A “PDF Page 2” button will be displayed if additional model validation documentation has been provided in another section of the EIA; clicking this button will open the a PDF document at the start page of this extra description.

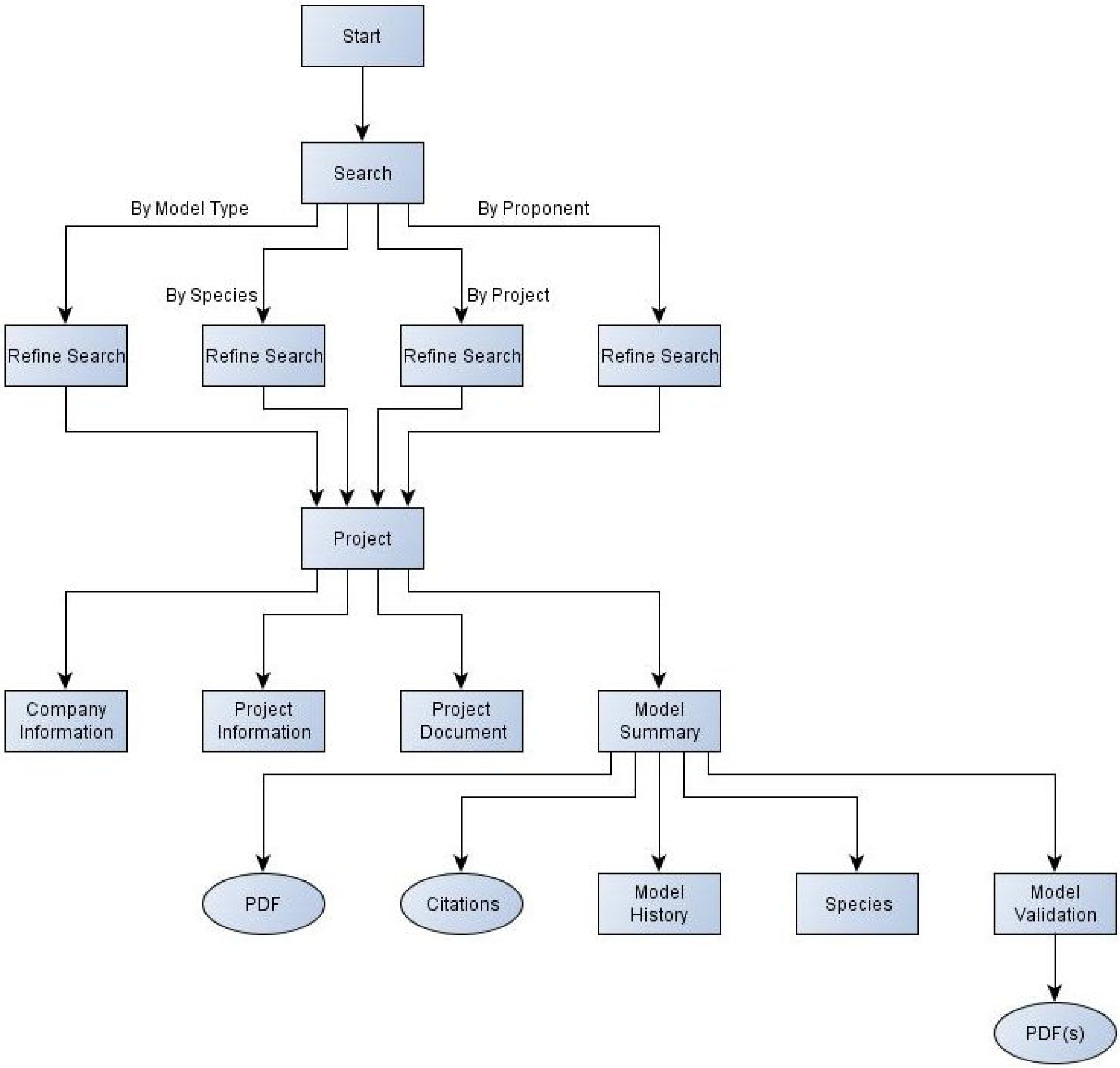


Figure 2. Database navigation structure. The user first searches by species, model type, project or proponent to identify a project and optionally a specific species model in that project. The model summary and validation forms may be displayed for a selected species model. These two forms include links to the EIA PDF documents for the model development and validation. A table showing the model history and a link to a citations document for the model history are also provided from the model summary form.

3.1 Searching

The "Search by" form allows the Habitat Model Database to be searched by species, model type, project or proponent. Select from the appropriate pull-down list and then click the "Projects" button. Click the "left-arrow" button to move to the previous form, the "right-arrow" button to move to the next form or the "Home" button to return to the "Start" form.

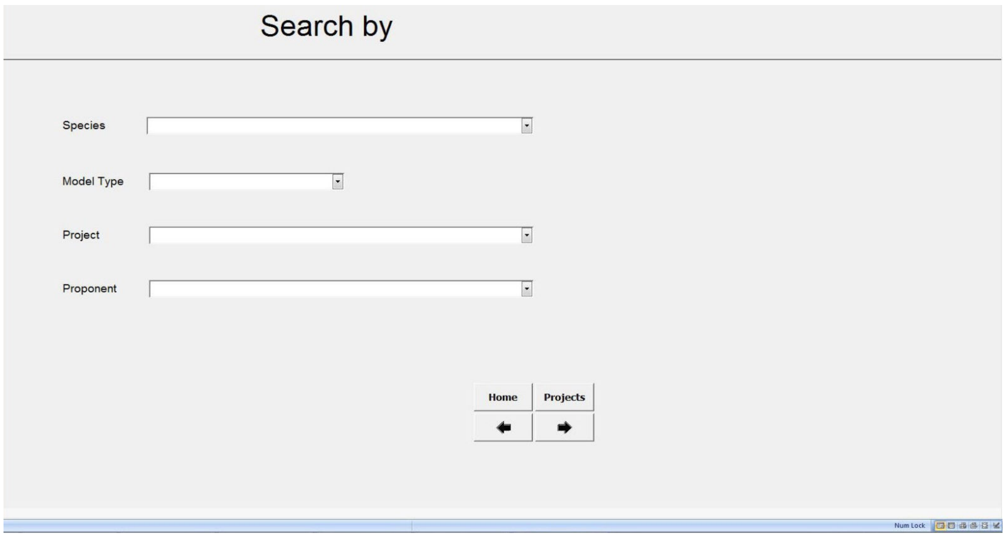


Figure 3. Main Search form.

3.1.1 Search by Species

This form is displayed when the user has searched by species. Further refine the search by specifying the project and model type using the pull-down list. Then click the "Project" or "right-arrow" button to proceed.

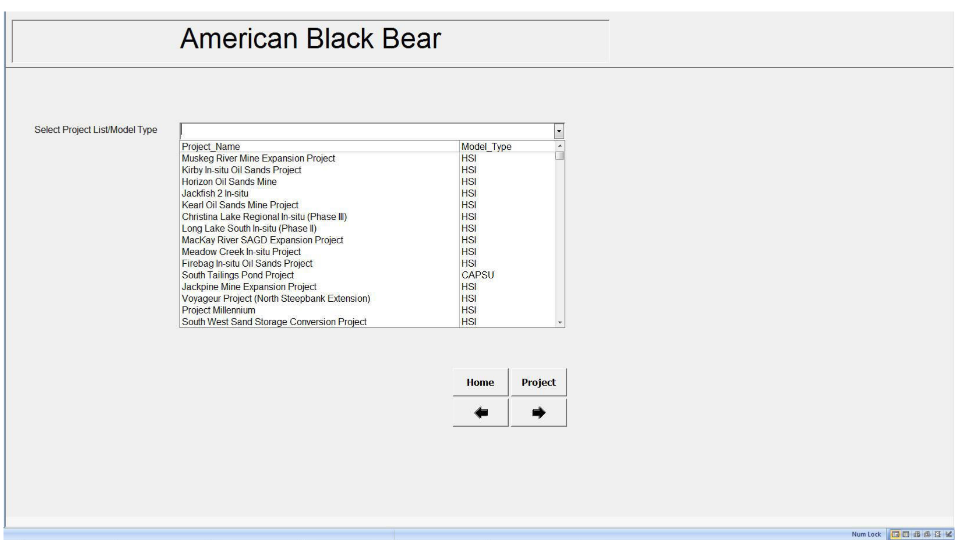


Figure 4. Search by Species form. All existing project/ model type combinations for the selected species (e.g., American Black Bear) in the database are presented in a pull-down list. One project/model type combination must be chosen before the "Project" form can be presented.

3.1.2 Search by Model type

This form is displayed when the user has searched by model type. Further refine the search by specifying the project and species using the pull-down list. Then click the "Project" or "right-arrow" button to proceed.

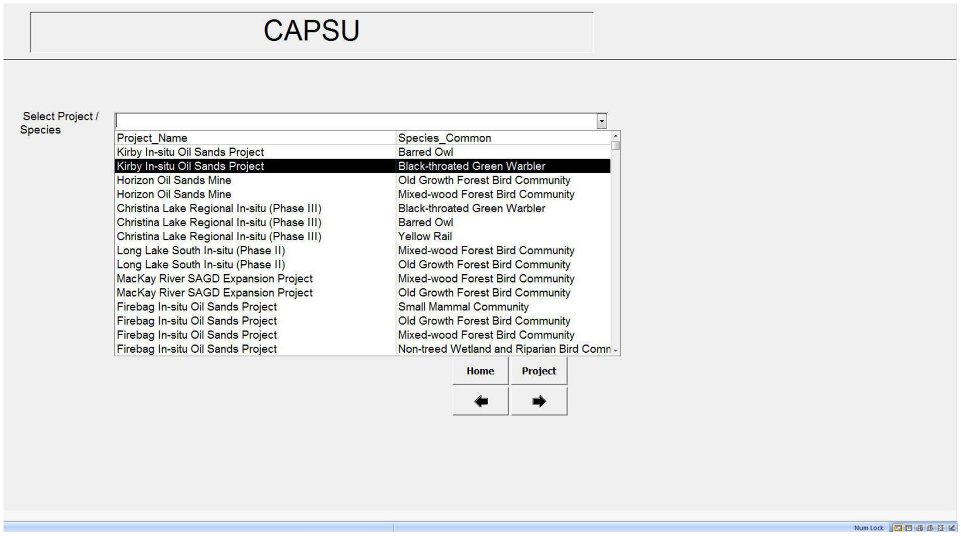


Figure 5. Search by Model Type form. All existing project/ species models of the selected model type (e.g., CAPSU) in the database are presented in a pull-down list. One project/species combination must be chosen before the "Project" form can be presented.

3.1.3 Search by Proponent

This form is displayed when the user has searched by proponent. Further refine the search by specifying the project, model type and species using the pull-down list. Then click the "Project" or "right-arrow" button to proceed.

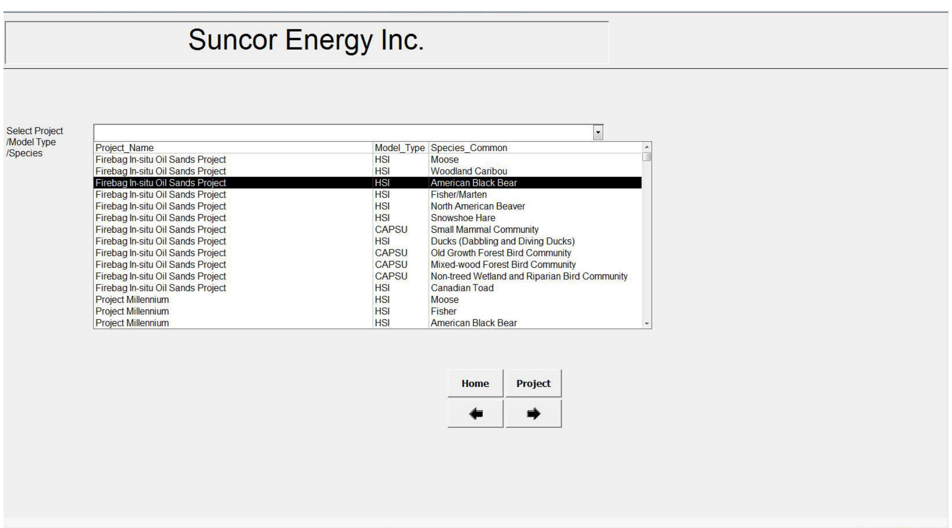


Figure 6. Search by Proponent form. All existing project/ species models for the selected proponent (e.g., Suncor Energy Inc.) in the database are presented in a pull-down list. One project/species model combination must be chosen before the "Project" form can be presented.

3.1.4 Search by Project

This form is displayed when the user has searched by project. The user may click buttons to display information about this project's company, details for this project or the EIA documentation. The user may optionally further refine the search by selecting a species and model type for this project from the pull-down list on the form. The "Model" or "right- arrow" buttons may be used to display the "Model Summary" form if a species model has been specified.

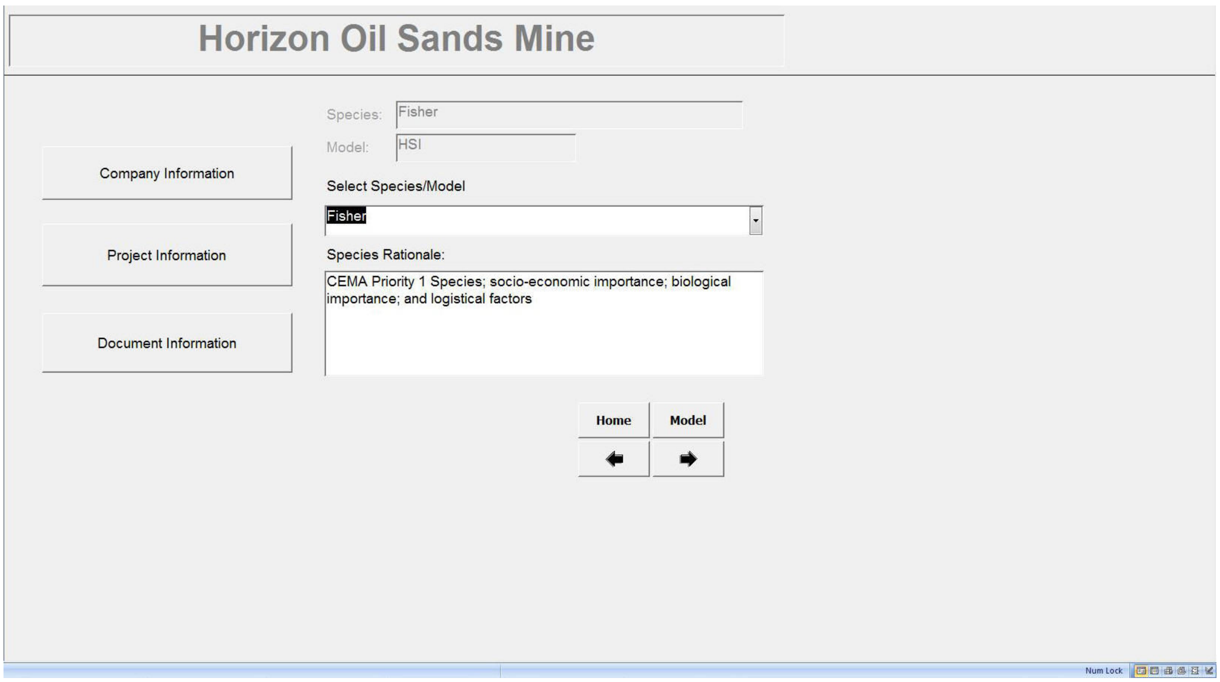


Figure 7. Search by Project form. The user may display company, project and document information, and may choose to specify a species model to review. *Note: If the user arrived to this form via the Search by Species, Model or Proponent path, the "Select Species/Model" and "Species Rationale" text boxes will display the species selected earlier in the search and the rationale for including it in this project. If the user arrived at this form via the Search by Project, then the user must use the pull-down list in "Select Species/Model" box to specify the species. The "Species Rationale" text box will then be filled in.*

3.2 Project Form

The "Project" form is also displayed as a result of refining the search by species, model type or proponent to select a particular project/species model combination that exists in the database. As described above, this form shows the rationale for including this species in this project's EIA and allows the user to see further detailed information about the model, company, project and EIA documents. The "Model Summary" form may be displayed by clicking on the "Model" or "right-arrow" buttons.

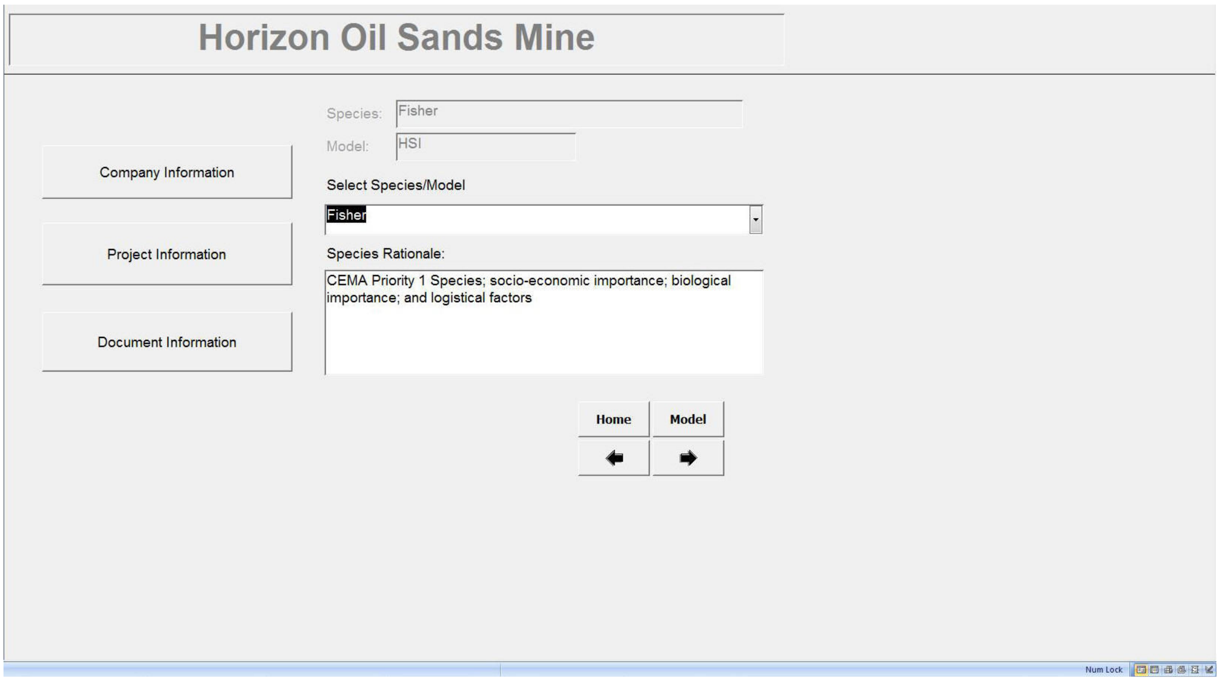
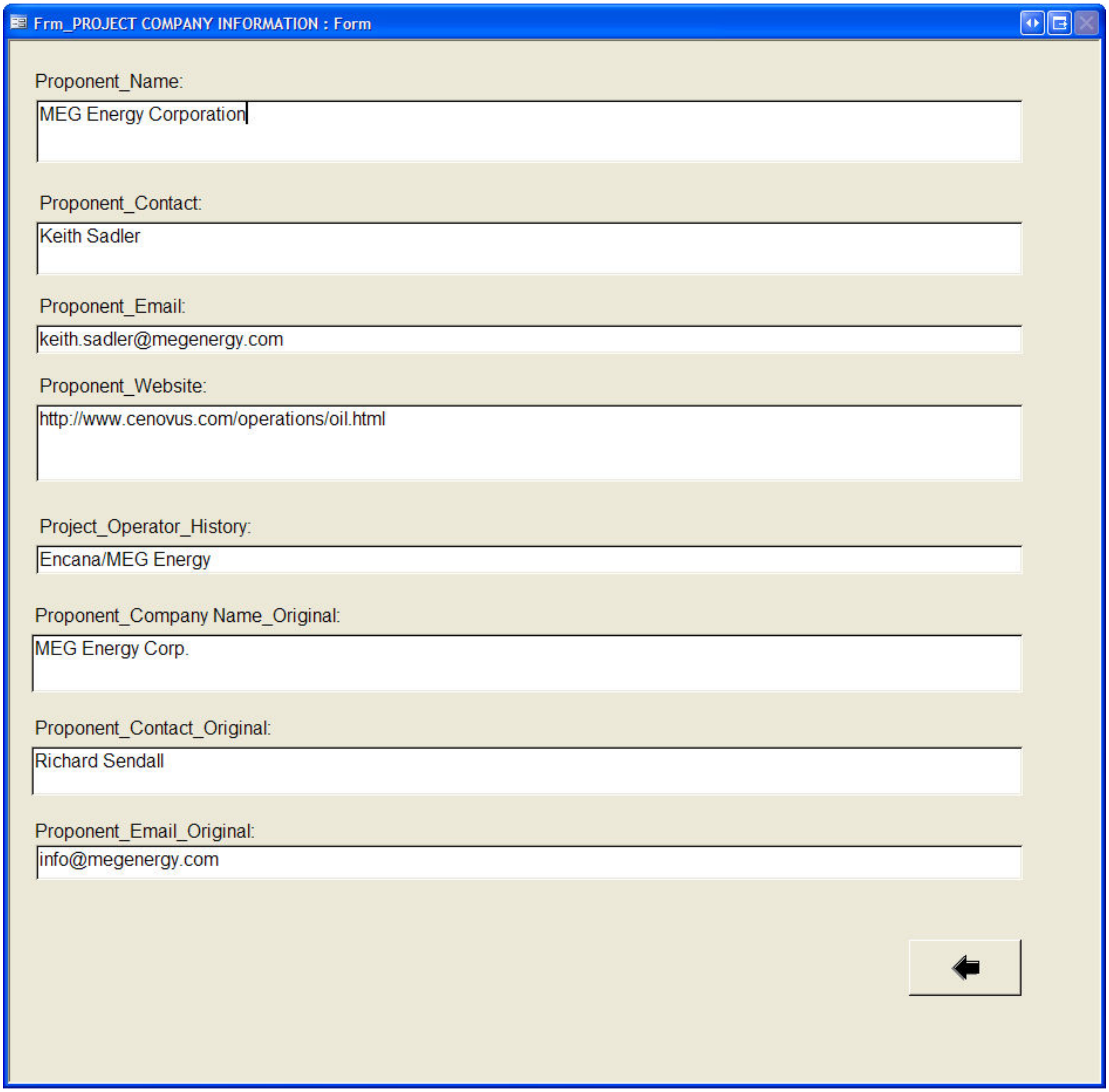


Figure 8. Project form. The user may display company, project and document information. Clicking the "Model" or "right-arrow" buttons will display the "Model Summary" form.

3.2.1 Company Information

Displays the detailed company information. Click the "left-arrow" button to return to the Project form. The form may also be closed by clicking the "X" button located at the form's top right hand corner.


Frm_PROJECT COMPANY INFORMATION : Form

Proponent_Name:
MEG Energy Corporation

Proponent_Contact:
Keith Sadler

Proponent_Email:
keith.sadler@megenergy.com

Proponent_Website:
http://www.cenovus.com/operations/oil.html

Project_Operator_History:
Encana/MEG Energy

Proponent_Company Name_Original:
MEG Energy Corp.

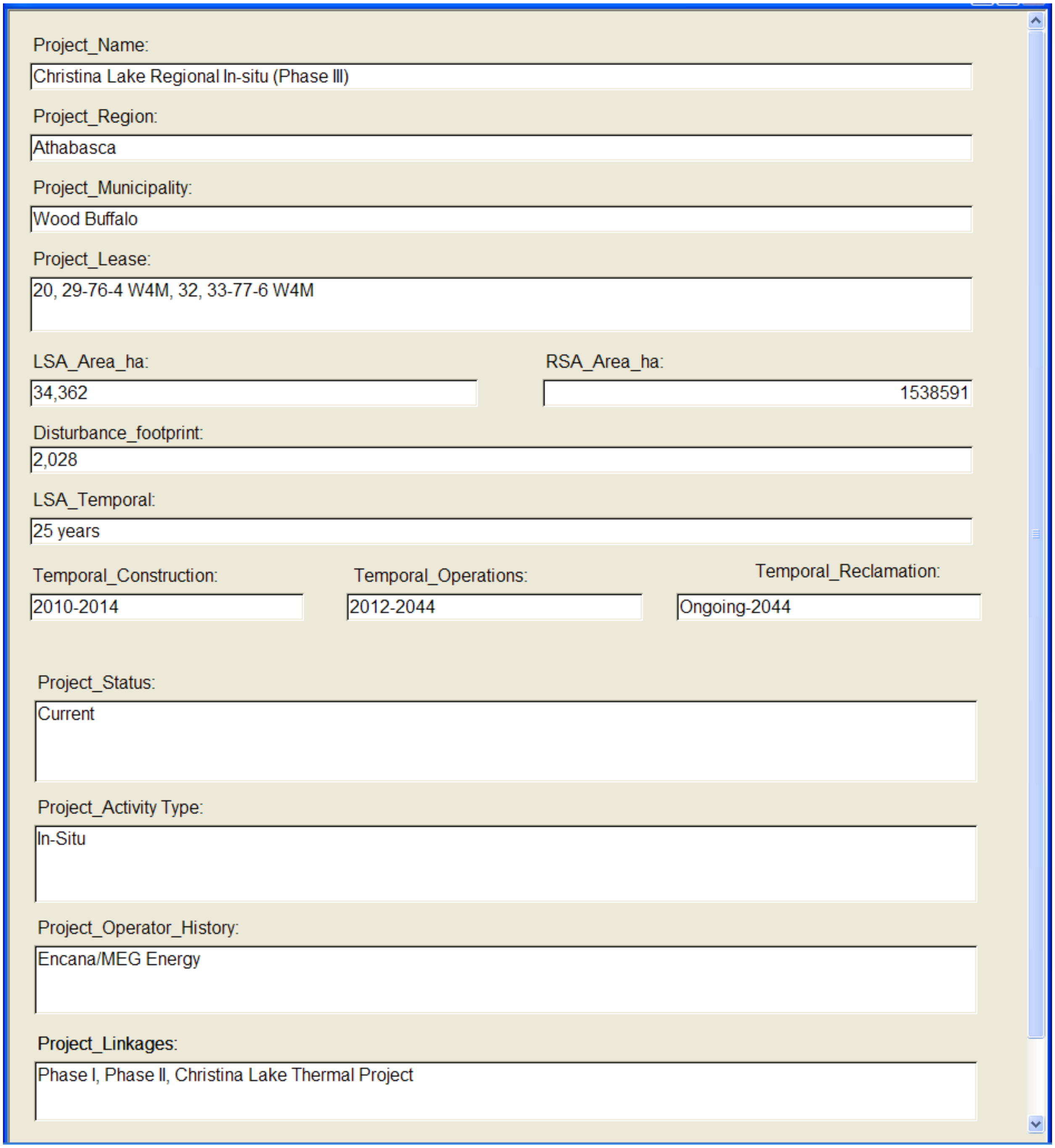
Proponent_Contact_Original:
Richard Sendall

Proponent_Email_Original:
info@megenergy.com

Figure 9. Company Information form.

3.2.2 Project Information

Displays the detailed project information. Click the "left-arrow" button to return to the Project form. The form may also be closed by clicking the "X" button located at the form's top right hand corner.



Project_Name:
Christina Lake Regional In-situ (Phase III)
Project_Region:
Athabasca
Project_Municipality:
Wood Buffalo
Project_Lease:
20, 29-76-4 W4M, 32, 33-77-6 W4M
LSA_Area_ha:
34,362
RSA_Area_ha:
1538591
Disturbance_footprint:
2,028
LSA_Temporal:
25 years
Temporal_Construction:
2010-2014
Temporal_Operations:
2012-2044
Temporal_Reclamation:
Ongoing-2044
Project_Status:
Current
Project_Activity Type:
In-Situ
Project_Operator_History:
Encana/MEG Energy
Project_Linkages:
Phase I, Phase II, Christina Lake Thermal Project

Figure 10. Project Information form.

3.2.3 Project Document

Displays the detailed project document information. Click the “left-arrow” button to return to the Project form. The form may also be closed by clicking the “X” button located at the form’s top right hand corner.

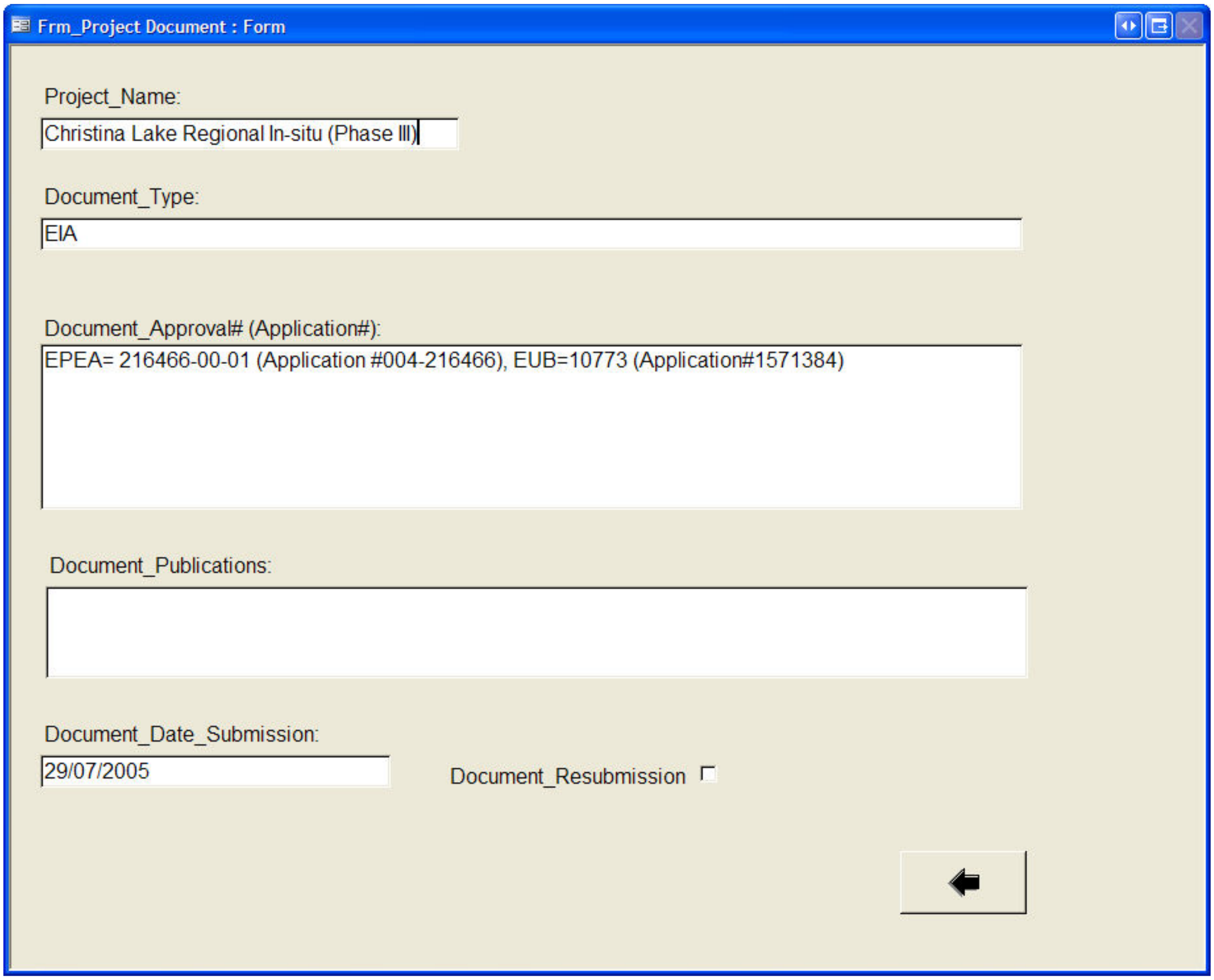


Figure 11. Project Document form.

3.3 Model Summary

As a result of clicking the “Model” or “right-arrow” button on the “Project” form, the user arrives at the “Model Summary” form. This form shows the detailed model information and allows the user to access further data, such as the PDFs for the EIA model’s documentation, Model History, Citations for the Model History, the Species, and the Model Validation.

Clicking the “PDF” button opens the EIA document at the start page for the sections summarizing the model and rationale for its development.

The “Model History” button is only visible if the model is not a novel one. Clicking the “Model History” button opens a form (Figure 13) that lists the previous EIAs reviewed for this project that also used a version of this species’ model. A citation of a published paper that was used as the basis for a model may also be presented in the table.

The “Citations” button may be clicked to open a PDF that provide full citations for the documents referred to in the “Model History” form.

Clicking the “Species” button opens a form with information on the species’ scientific name and conservation status (Figure 14).

Click the “left-arrow” button on the “PDF”, “Model History”, “Citations” and “Species” forms to return to the Model Summary form. Alternately, close the form by clicking the “X” button located at the form’s top right hand corner.

Click the “Model Validation” or “right-arrow” button to proceed to the Model Validation form.

Model_Location: EIA_Appendix_5V_section_1.2.2

Model_Type: RSF

Model_Species: Black-throated Green Warbler

Group: Black-throated Green Warbler

Author: Golder Associates

Author Contact Information: Not clearly specified.

Model_History_Novel: No

Model History Source: Boyce et al. 2002

Model_Disturbance_Summary: Disturbance factors (roads) are explicitly modelled in RSF.

Model_Disturbance_Included: Yes

Model_Description_Summary: Estimate breeding season habitat suitability via used, unused RSF model.

Model_Description_Elements: Mean stand height, proportion of neighbourhood in clearcut, stand age >90 years, >70% deciduous, >70% white spruce; habitat patch diversity (Simpson's index).

Model_Description_Assumptions: Not clearly specified.

Model_Description_Limitations: Estimates breeding season habitat suitability only.

Model_Output: Predicted distribution of high, moderately high, moderate, moderately low, low and unsuitable habitat. Appendix 5-V Figure 13

Model_Scale_Spatial: LSA

Model_Scale_Temporal_Season: Breeding season

PDF | Citations | Model History | Species | Home | Model Validation

Figure 12. Model Summary form.

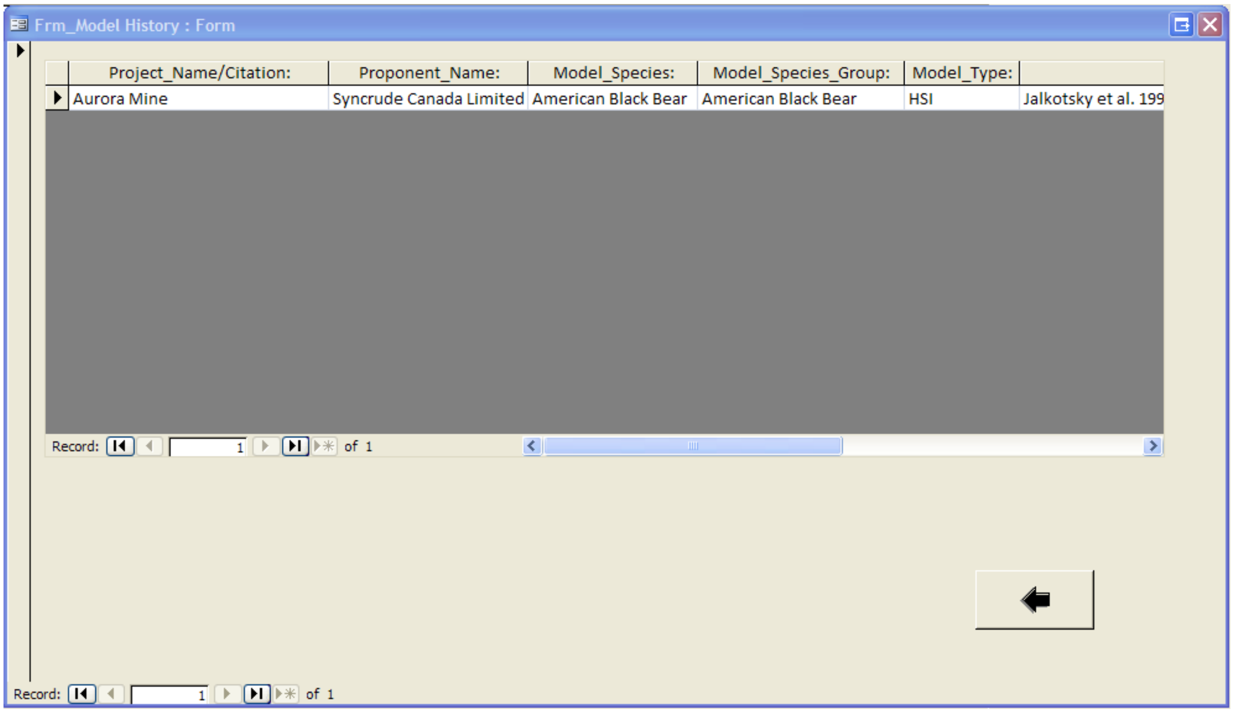


Figure 13. Model History form.

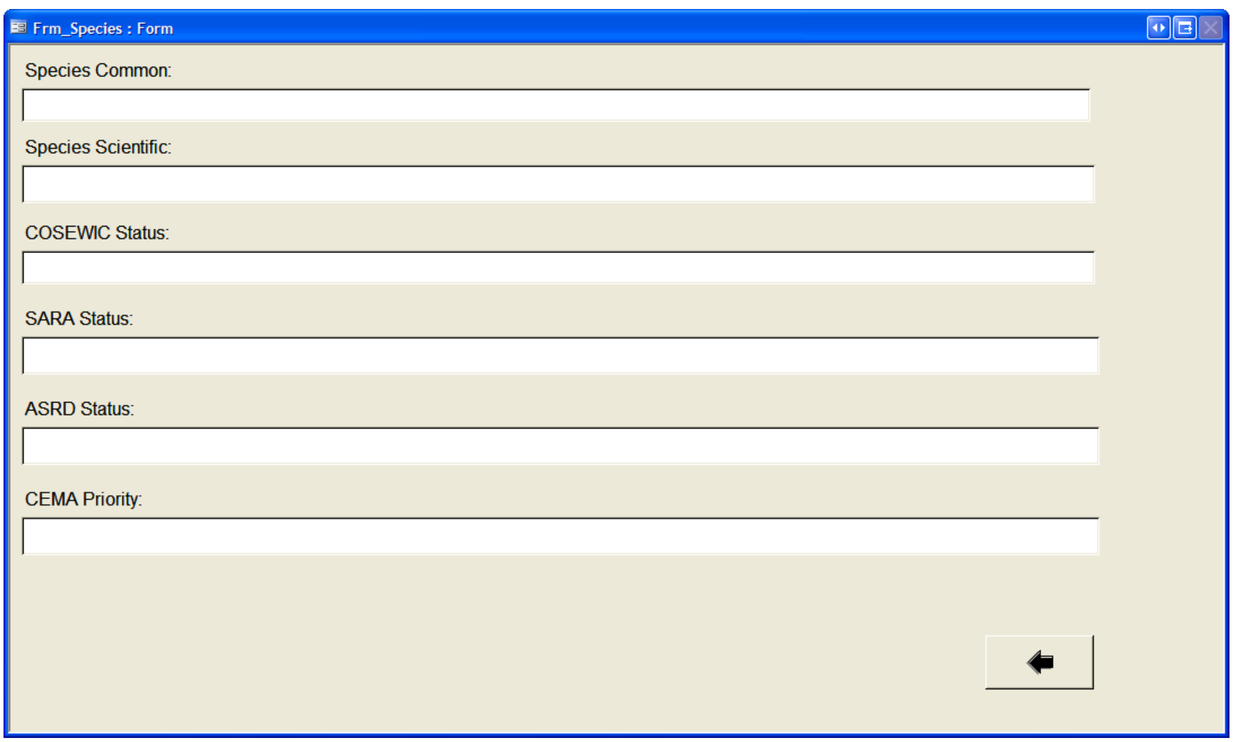
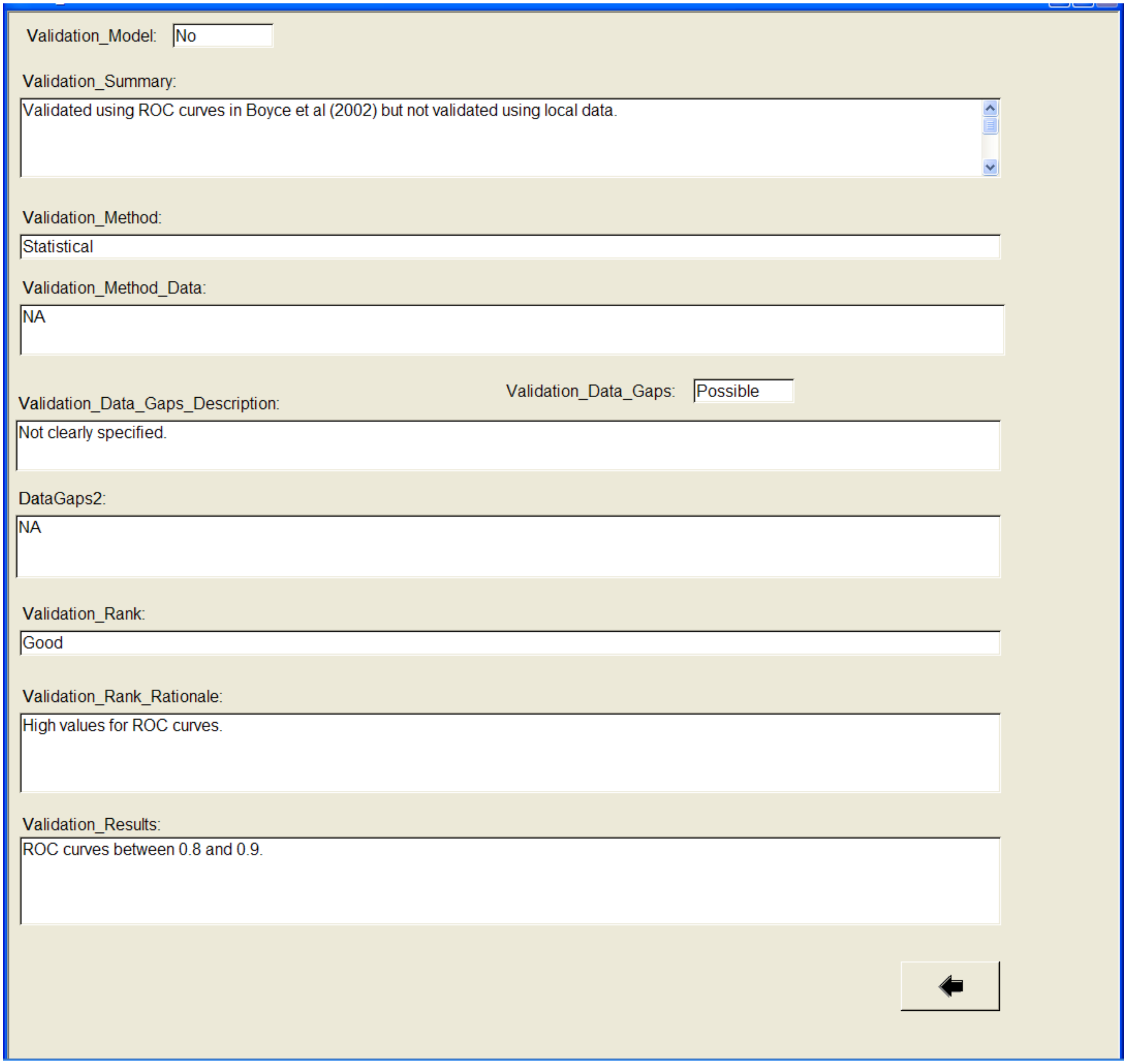


Figure 14. Species form.

3.3.1 Model Validation

The "Model Validation" form (Figure 15) displays detailed information about the methods used to validate the model, data used and data gaps in the validation process, and the validation results. This form also allows the user to open supporting documents (if available) by clicking the PDF button(s). Click the "left-arrow" button to return to the "Model Summary" form. Alternately, close the form by clicking the "X" button located at the form's top right hand corner.


Validation_Model: No

Validation_Summary:
Validated using ROC curves in Boyce et al (2002) but not validated using local data.

Validation_Method:
Statistical

Validation_Method_Data:
NA

Validation_Data_Gaps: Possible

Validation_Data_Gaps_Description:
Not clearly specified.

DataGaps2:
NA

Validation_Rank:
Good

Validation_Rank_Rationale:
High values for ROC curves.

Validation_Results:
ROC curves between 0.8 and 0.9.

Figure 15. Model Validation form.

4 Data-Entry/Edit Mode

4.1 Introduction

As described in section 2 above, a user must enter the correct password when starting up the database to enter the data-entry/edit mode. Both the searchable functions of the database as described in section 3 and the data-entry/edit functions are available to the user in this mode. These functions are selected by clicking the "Start" or "Data Entry" button respectively on the Start form (Figure). Clicking the "Start" button will take the user to the main "Search-by" form (Figure 3). Clicking the "Data Entry" button will display the "Data Entry" form (Figure 16).

Note that the database tables may be used instead of the forms to enter/edit data if so desired. However, use of the database tables to directly enter new records into the database is not recommended because this requires the user to understand the database structure and know how to create the links between the tables. It is recommended that table access only be used for simple editing tasks. The database tables may be accessed by minimizing the displayed form(s) to allow the list of Access objects to be viewed. The user may then click on the "Tables" link to display the list of tables and double click on a table to be edited (e.g. Model Summary, Model Validation, Project Company Information, Project Document Properties, Project Information, Project Model Species, Project Species).

The remainder of this section describes the form based data-entry and editing of the database. These operations are available using the "Data Entry" form (Figure 16). Forms are used to display copies of database records for editing or to allow a user to enter information for a new database record. The information in a form will not be saved to the database until the "left-arrow" button" at the bottom of the form has been clicked. Clicking the "X" box at the top right hand corner of a form will exit that form WITHOUT making any changes to the database. Pull-down lists on the "Data Entry" form may be cleared by clicking the "Clear Data Form" button on the form or by placing the cursor in a pull-down list box and manually deleting the content.

Project, species and model records are linked in the database. Therefore, creating new records also requires that these records be correctly linked for the database to function properly. The record linking will be automatically performed by clicking the "Add New Data" at the bottom of the "Data Entry" form (Figure 16). It is up to the user to decide when newly created records are ready to be linked. As a general guideline, create the records that need to be linked, and then click the "Add New Data" button. For example, if a new species model has been created for a project, ensure that the correct species, project and species model are displayed in the pull-down lists on the "Data Entry" form and then click the "Add New Data" button to link these three items in the database.

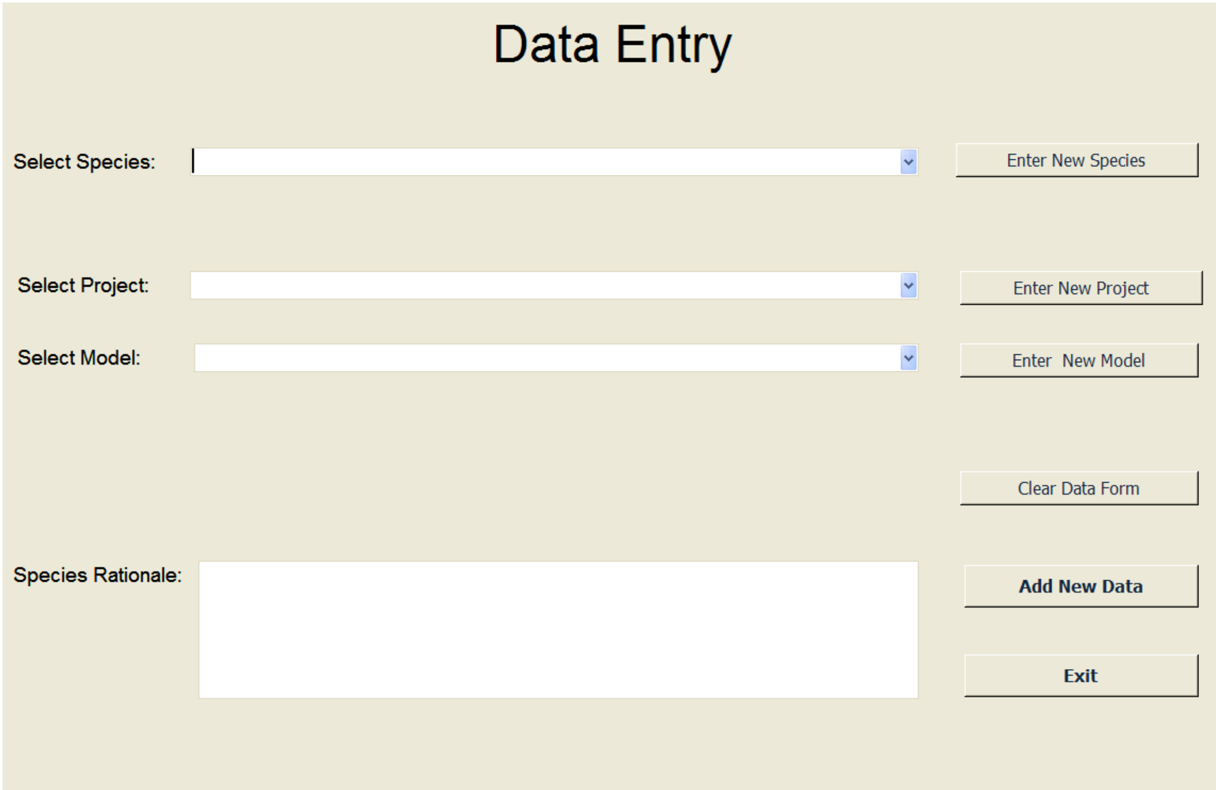


Figure 16. Data Entry form. This form is used to specify an existing species/project/model combination for editing or to create new records in the database.

4.2 Edit Existing Data

Note: at any time the user may click the "X" box at the top right hand corner of a form to exit that form WITHOUT making any changes to the database.

To edit existing information for a particular species (i.e. the Species table) select the species from the pull-down list on the "Data Entry" form (Figure 16) and then click the "Enter New Species" button beside the pull-down list. The current information for the selected species will be displayed in the standard form for that item (Figure 14). Use the form to make the desired edits, then click the "left-arrow" button at the bottom of the form to save the edits and return to the main "Data Entry" form.

To edit existing information for a particular project in the Project Information table, select the project from the pull-down list on the "Data Entry" form (Figure 16) and then click the "Enter New Project" button beside the pull-down list. The "Edit Project" form (Figure 17) will be displayed with the current information for the selected project. Use the form to make the desired edits. The Company Information and Project Document information for the project may be edited by clicking the appropriate button at the bottom of the "Edit Project" form. The standard forms for these items will be displayed (Figure 9, Figure 11); the user may then make the desired edits. Click the "left-arrow" button at the bottom of each form where changes have been made to save the edits. Clicking the "left-arrow" button at the bottom of the "Edit Project" form will return the user to the main "Data Entry" form.

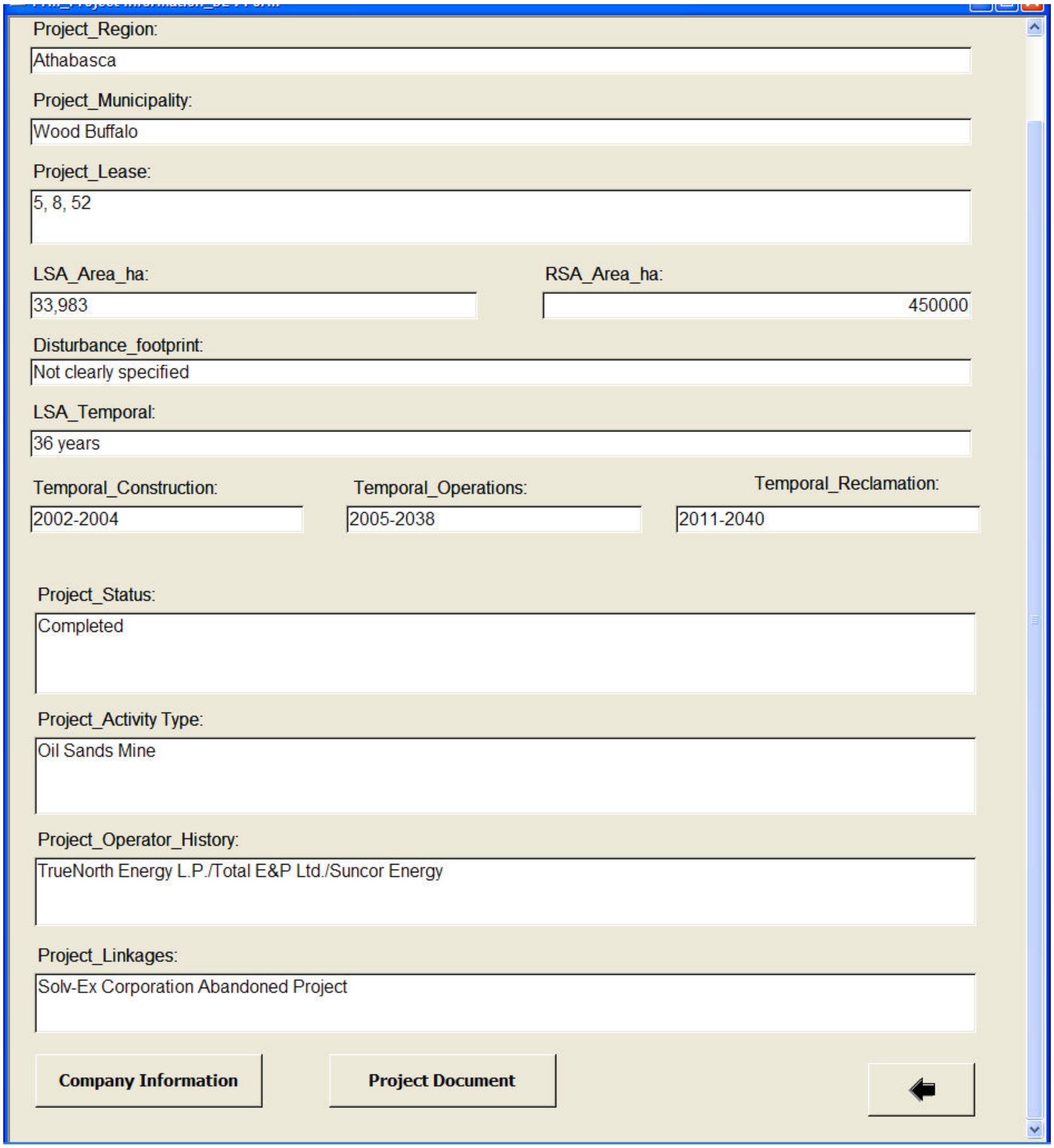


Figure 17. Edit Project form. The company and project document information may be displayed and then edited by clicking the buttons at the bottom of the form.

To edit a particular species model, the species, project and model combination that uniquely identifies the model must be specified by the user using the three drop-down lists for these items on the “Data Entry” form. This requires knowing the combination beforehand; the Data Entry form does not prompt the user for the existing combinations that are present in the database. Once the species, project and model combination has been specified, click “Enter New Model” to edit the Model Summary information that is displayed in the standard form (Figure 12). The Model Validation information may be subsequently selected for editing by clicking the “Model Validation” button at the bottom of the “Model Summary” form. Again, the standard “Model Validation” form (Figure 15) is used to display the current values, which can then be edited by the user. Click the ““left-arrow” button at the bottom of the form to save the edits and return to the main “Data Entry” form.

The rationale for including a particular species in an EIA may be edited directly on the “Data Entry” form when a Species/Project/Model combination has been specified.

4.3 Enter New Data

Note: at any time the user may click the "X" box at the top right hand corner of a form to exit that form WITHOUT making any changes to the database.

4.3.1 Create New Species

To create a record for a new species, click the "Enter New Species" button beside the pull-down list for the species selection on the "Data Entry" form (Figure 16). The standard form for the species (Figure 14) will be displayed. Use the form to enter the information for the new species, then click the "left-arrow" button" at the bottom of the form to save the edits and return to the main "Data Entry" form.

4.3.2 Create New Project

To create a record for a new project :

- Click the "Enter New Project" button beside the pull-down list for the project selection on the "Data Entry" form (Figure 16). A pop up box will be displayed indicating that a Company must be entered.
- Click "OK"; a pull-down list "Select Company" is now displayed above the "Select Project" pull-down list (Figure 18). Select the company from the pull-down list if the new project is for an existing company in the database. Otherwise, click the "Enter New Company" button to the right of the pull-down list, fill in the Company Information form (Figure 9), then click the ""left-arrow" button" at the bottom of the form to save the edits and return to the main "Data Entry" form.
- Click the "Enter New Project" button on the "Data Entry" form. The "Project" form (Figure 10) will be displayed. Use the form to enter the information for the new project. Add the Project Document information by clicking the "Project Document" button at the bottom of the form. Click the "left-arrow" button" at the bottom of the "Project Document" form to save the edits and return to the "Project" form. .Click the "left-arrow" button" at the bottom of the "Project" form to save the edits on this form and return to the main "Data Entry" form.

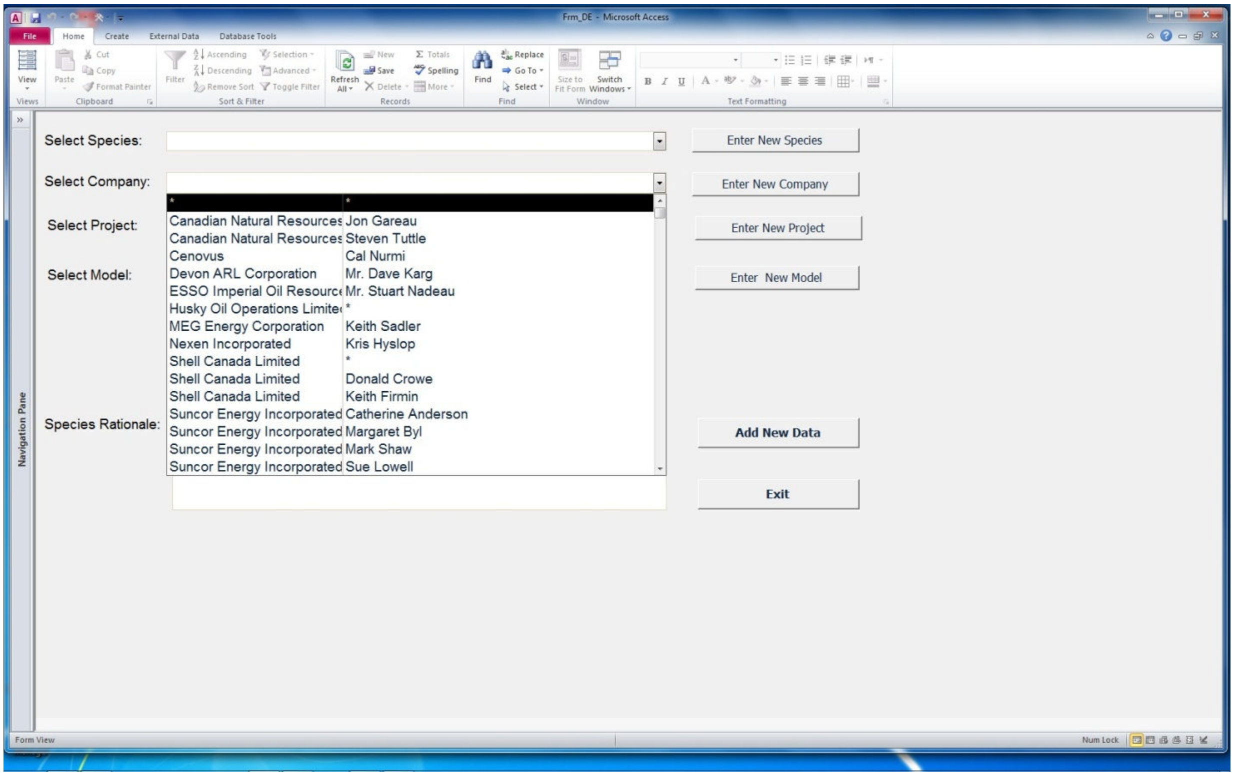


Figure 18. Company pull-down menu during the new project creation.

4.3.3 Create New Species Model

- To create a new species model, a species, project and model combination must first be specified. The species and project must already exist in the database, or must be created as described above prior to creating a new species model record for a project. Note that missing items in the database are indicated when there are no entries in the pull-down list for that item. Before attempting to create a new model, make sure that the “Select Model” pull-down list is empty for the desired model type after specifying the species and project. Then click the “Enter New Model” button on the “Data Entry” form.
- A pop up box will indicate that the Model Type and Model Spatial Scale need to be entered. Click the “OK” button on the box and then enter these attributes in the appropriate boxes that have appeared on the “Data Entry” form (Figure 19).
- Click the “Enter New Model” button to display the “Model Summary” form. Use the form to enter the information for the new model. Click the “Model Validation” button at the bottom of the “Model Summary” form to display the “Model Validation” form. Use the form to enter the validation information for the new model, then click the ““left-arrow” button” at the bottom of the form to save the edits and return to the “Model Summary” form. Again, click the “left-arrow” button” at the bottom of the form to save the edits and return to the “Data Entry” form.
- If this is a new species for the project, enter the rationale for including this species in the project EIA, if needed, using the text box at the bottom of the “Data Entry” form.
- Click the “Add New Data” button on the form to create the links for the new species model in the database.

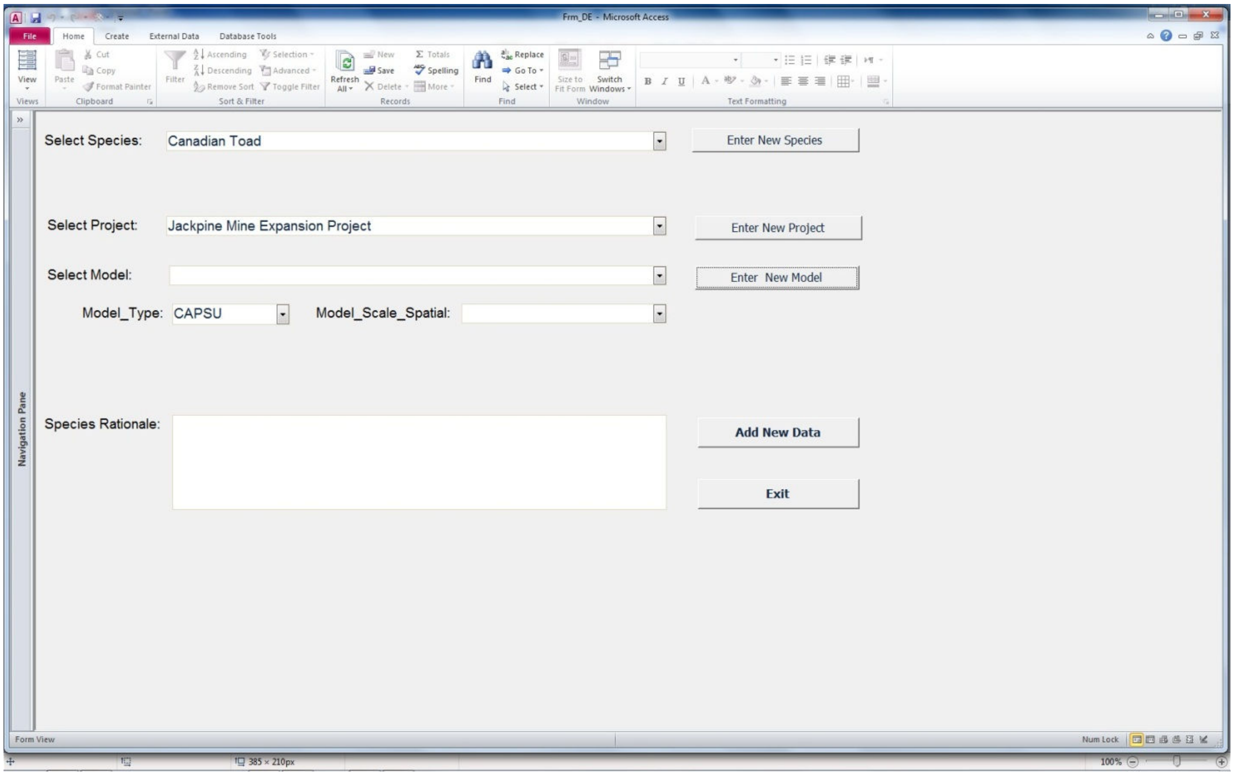


Figure 19. Create Model form.

Appendix B. Database Data Dictionary.

Heading	Field Name	Field Type	Description
Project Company Information			**Name and relevant information for company involved with this project**
	Proponent_Name	Alpha	Operator company for current submission
	Proponent_Contact	Alpha	Operator company contact name
	Proponent_Email	Alpha	Operator company contact email
	Proponent_Website	Alpha	Operator company website
	Proponent_Company Name_Original	Alpha	Company name for original submission
	Proponent_Contact_Original	Alpha	Original submission company contact name
	Proponent_Email_Original	Alpha	Original submission company contact email
	Project_Operator_History	Alpha	Original submission operator company
Project Information			**Name and relevant information for this project**
	Project_Name	Alpha	Name of project (e.g., Christina Lake Regional Project - Phase 3
	Project_Region	Categorical	OS Region (e.g., Athabasca, Peace River, Cold Lake, Other)
	Project_Municipality	Alpha	Wood Buffalo, Peace, Other
	Project_Lease	Alpha	Name or # of lease
	Disturbance_footprint	Alpha	Size of disturbance footprint (ha)
	LSA_Area_ha	Numeric	Size of LSA (ha)
	RSA_Area_ha	Numeric	Size of RSA (ha)
	LSA_Temporal	Alpha	Time period for project (includes construction, operation, closure)
	Temporal_Construction	Alpha	Time period for project construction
	Temporal_Operations	Alpha	Time period for project operation
	Temporal_Reclamation	Alpha	Time period for project reclamation
	Project_Status	Categorical	Active, planned, etc
	Project_Activity Type	Categorical	In situ, mine, upgrader, expansion, etc
	Project_Previous Operator	Alpha	If applicable, previous operator associated with original submission
	Project_Linkages	Alpha	Names of associated projects (e.g., North Steepbank Extension and Voyageur Project)
Project Document Properties			**1 for each document associated with this project**
	Project_Name	Alpha	Project name
	Document_Type	Categorical	EIA, EIS, Supplemental, Panel Report, Comprehensive Study, Closure Plan, etc
	Document_Date_Submission	Alpha numeric	day month and year of EIA submission (dd-mmm-yyyy)
	Document_Publications	Alpha	Hyperlinks to documents (e.g. EIA, EIS, Supplementary Info, Comprehensive Report)
	Document_Resubmission	Binary	Yes or No
	EIA_Document_Author	Alpha	EIA document author
	Document_Approval# (Application#)	Alpha	Document approval number
Project Species			**1 per species that was modelled in the document**
	Species_Common	Alpha	Common Name of Species (e.g., Moose, Fisher)
	Species_Scientific	Alpha	Scientific Name of Species (e.g., *Alces alces* , *Martes pennati*)
	Species_COSEWIC Status	Categorical	Current COSEWIC designation (federal)
	Species_SARA Status	Categorical	Current SARA designation (federal)
	Species_ASRD Status	Categorical	Current Alberta SRD designation (provincial)
	Species_CEMA_Priority	Categorical	Priority 1, 2, 3
	Species_Life History	Alpha	Species life requisite that is relevant to habitat model (e.g., all, food, cover, breeding)
	Species_Habitat_Requirements	Alpha	Types of habitats required to fulfill species' life history
Project Model Species			**Summary of closure plan for model/project**
	Project_Name	Alpha	Project name
	Species_Common	Alpha	Common Name of Species (e.g., Moose, Fisher)
	Model_ID	Numeric	ID of project model record in Model Summary table
	Species_Rationale	Binary	Rationale for modelling the species for this project
Model Summary			**Summary of model (type, sources, methods, output, etc.)**
	Project_Name	Alpha	Project Name
	Proponent_Name	Alpha	Proponent Name
	Year	Numeric	Year EIA was submitted
	Model_Location	Alpha	Location of Closure Plan (Volume_Section)
	Document Directory	Alpha	directory location of model document
	Model Document	Alpha	model document
	PDF Page #	Numeric	model document page number
	Model_Species	Alpha	Species Name
	Model_Species_Group	Alpha	Species Groups
	Model_Type	Categorial	CAPSU, HS, HSI, RSF, other
	Model_Author	Alpha	Name of company that produced model output
	Model_Author_Contact	Alpha	Contact Information for company/lead modeller
	Model_History_Novel	Categorial	Yes, No? or No (Novel model developed or previously developed model for EIA)
	Model_History_Source	Alpha	If Novel Model = No, list model source(s) (e.g., other EIA, literature)
	Model_History_Model_ID	Numeric	Model_ID of historical model preceding this model
	Model_Disturbance_Included	Binary	Yes if model predicts habitat effectiveness (i.e., disturbance is incorporated)
	Model_Disturbance_Summary	Alpha	Rationale for including or excluding disturbance in model predictions
	Model_Description_Summary	Alpha	Summary of model
	Model_Description_Elements	Alpha	Summary of model elements/variables (e.g., stand age, forest edge, canopy cover etc)
	Model_Description_Assumptions	Alpha	Summary of model assumptions
	Model_Description_Limitations	Alpha	Brief summary of model limitations
	Model_Output	Alpha	Identify model outputs - maps, predictions, etc
	Model_Scale_Spatial	Alpha	Spatial scale for model development (e.g., stand, community, landscape, regional, provincial
	Model_Scale_Temporal_Season	Alpha	Season that model was developed for (e.g., all, winter, spring, summer, breeding, etc.)
Model Validation			**Summary of model validation (type, sources, methods, etc.)**
	Model_ID	Numeric	Model ID
	Validation_Location	Alpha	PDF section for model validation documentation
	Document_Directory	Alpha	Folder containing model validation PDF
	Validation_Document	Alpha	Document name containing model validation
	PDF Page #	Numeric	Start page # in Validation_Document
	Secondary Page #	Numeric	Start page # in Validation_Document for additional validation documentation
	Validation_Model	Binary	Yes or No - was model validated by any mechanism
	Validation_Summary	Alpha	Brief summary of techniques used to validate the model
	Validation_Method	Categorical	None, Calculated model outputs, Field data (descriptive), Ground Truthing, Expert Opinion, Statistical, Not clearly specified
	Validation_Method_Data	Alpha	List of species data sources used to validate this species's model (include links)
	Validation_Data_Gaps	Binary	Yes or No if applicable
	Validation_Data_Gaps_Description	Alpha	If Yes to above, what data were missing (or require further study)
	DataGaps2	Categorical	category for data gaps (Insufficient Data, Data in wrong season, NA)
	Validation_Rank	Alpha	Good, moderate, fair, poor, not clearly specified, NA) Ranking of model prediction confidence based on their validation results
	Validation_Rank_Rationale	Alpha	Reasons for rating of model prediction confidence
	Validation_Results	Alpha	Summary of validation results

Appendix C. Model Validation Test Case

Model validation is required to accurately assess the potential impacts to wildlife and their habitats from a proposed project in the AOSR. An accurate assessment of those impacts and the development of a closure plan to mitigate for those impacts is in keeping with Appendix D of AENV (2010), which is a key guidance document used in the development of EIAs and closure plans as they pertain to wildlife. These guidelines provide direction for the return of disturbed wildlife habitat to pre-disturbance habitat capabilities, which is required for all species impacted by each project. The model validation test case aims to provide detailed documented methods and an example of model validation for professionals developing species habitat models in the AOSR. Model validation will determine if the models currently being used in the AOSR are providing a good approximation of the potential impacts to wildlife habitat. An improperly validated model could over- or under-estimate the amount of habitat available to a key indicator resource pre-disturbance. In the case of under-estimating the amount of available habitat, the closure plan will not effectively address the impacts to a given species while an over-estimation may put too much emphasis on the creation of a certain type of habitat at the detriment to others.

Most of the reviewed models are potential candidates for a validation test case because the majority of models were unvalidated and of those models that did have some documented validation, there were many cases of incomplete or inappropriate validation methods applied. The prioritization of models for validation depends on the objectives for this task. Models can be ranked to give priority to Species at Risk, species with limited distribution, species with specific habitat requirements, or species that are particularly sensitive to habitat perturbations. Considerations of traditionally important species to First Nations and Métis may also be included in the prioritization assessment. Practicalities need to be considered when prioritizing models for validation. For example, it will likely be difficult to obtain enough data on cryptic and rare species to meet sample size requirements to achieve adequate power to validate their habitat models.

Discussion to prioritize models for validation and to select a test model as a case study to demonstrate recommended model validation methods was held with the Wildlife Task Group of CEMA Reclamation Working Group during the 29 March 2011 meeting with LGL Limited. It was agreed to select a North American Beaver HSI model as the test species for the following reasons:

1. An HSI model was the preferred model type for this validation exercise because the results of this project indicated that while HSI models were commonly used in EIAs, they were generally not well validated;
2. A beaver model was selected because of this species' importance to First Nations and Métis;
3. Although operators are actively managing beavers and excluding them from their leases and reclamation plots, the 'allowable' use of habitat by key indicator resources (KIRs) is not a consideration during the EIA process and the assessment of predicted impacts to wildlife, nor does it form part of the closure plan. The emphasis (in the closure plan) is on habitat availability, i.e., restoration of pre-disturbance habitat that was impacted by the AOSR operation. Thus having a properly validated beaver habitat model and using these model predictions in the closure planning will provide assurance to regulators and other stakeholders that impacted beaver habitat is made available on a reclaimed landscape (regardless if beavers are able to use those habitats or not); and
4. A properly validated beaver model will provide a more accurate assessment of the extent and location of beaver habitat in the AOSR lease area that was used for this test case because the validation process will be used to improve the model. In addition, the uncertainties of the model predictions will be more clearly understood. These results will provide crucial information to closure planners considering immediate and post-reclamation management of reclaimed plots based on the known distribution of beaver habitat relative to those reclaimed plots. For

example, this information will assist in the selection of reclamation plot locations and better inform managers interested in keeping beavers out of reclaimed plots (to improve the survivorship and vigour of the vegetation).

We evaluated the 16 beaver HSI models used in the reviewed EIAs (Figure 1). We eliminated five models that were not well documented as candidates for evaluation (Mildred Lake, South Tailings Pond, MacKay River, Long Lake South and Joslyn North). The remaining 11 models were sufficiently documented to support a validation procedure. Nine of these models were developed by Golder Associates and two by AXYS. The Golder model was initially developed for the Steepbank project, and then was reused in subsequent EIAs with various modifications. The AXYS model was developed for the Fort Hills project and then reused in the Kearl project with some modifications.

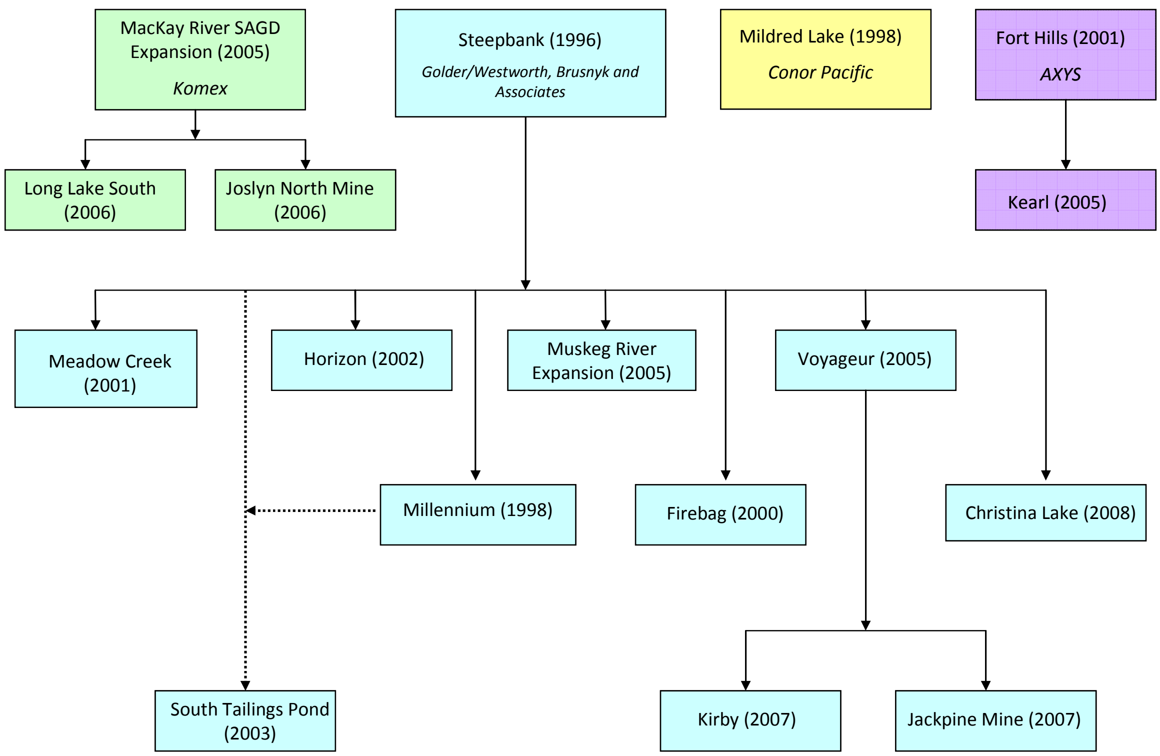


Figure 1. **All North American Beaver HSI models are shown with the project name, year of the model and the company that developed the model.** Cells of similar colour had models developed by the same company. The arrows denote reuse of a model by a later project.

We recommend using the Golder model for the test case because this model was used with minor modifications in the majority of EIAs that were reviewed for this project. The model is fairly simple and predicts all season habitat suitability; the initial version (Steepbank) in the reviewed EIAs was developed by Westworth, Brusnyk and Associates (1996). No HSI model documentation was available for this project; however all subsequent models, with the exception of South Tailings Pond[5], estimated habitat suitability based on food and cover within 100 m of suitable open water (low gradient rivers, creeks, ponds, marshes). Three habitat variables of %woody vegetation cover, %deciduous tree and shrub cover, and distance to water were included in the model. The Millennium and Firebag models also

[5] The South Tailings model was a CAPSU model that ranked ecosite/wetland phases based on combining the results of HSI modeling in the Millennium (Golder 1998) and Steepbank (Westworth, Brusnyk and Associates (1996) project with habitat preferences determined using field observations.

incorporated stream gradient and a disturbance coefficient (DC) whereby HSI values were reduced by 50% within 1000 m of roads and 500 m of plants and camps, and by 25% within 500 m of utility corridors and 100 m of mine facilities. The final HSI equation is quite simple with all habitat variable SI values and the DC (if included in the model) multiplied together. The model uses thresholds in the % woody vegetation and % deciduous tree/shrub SI relationships, which will allow sensitivity analyses of these relationships to be conducted. As discussed earlier, sensitivity testing of thresholds is particularly recommended because model predictions are likely to be strongly affected by small differences in threshold levels (Van Horne and Wiens 1991). It is likely that some indication in the variation of these thresholds can be extracted from the literature, but data collected in the AOSR is required to ensure project-specific and region-specific validation of the models can occur.

In contrast, the AXYS model is more complex with parameters of % of deciduous tree canopy cover, deciduous tree structural stage, % deciduous shrub cover, bank suitability, channel type, and stream gradient. The AXYS model contains categorical SI relationships and consequently it will be more difficult to test the sensitivities of these relationships. In addition, this model was not specifically developed for the Athabasca region but was taken from the USFWS (Allen 1983).

There are three main versions of the Golder model. Millennium and Firebag are very similar; both include stream gradient and DCs. Firebag simply added a fourth disturbance type (active mine sites) for DCs. A second model version that only included three habitat variables (%woody vegetation cover, %deciduous tree and shrub cover, and distance to water) was used for five projects (Horizon, Muskeg River, Voyageur, Meadow Creek and Christina Lake). The Voyageur model was then modified for both the Kirby and Jackpine projects by adding effects of water table drawdown on beaver habitat suitability. This was done by through the use of a 2,100 m buffer around the mine footprint and crest of the Athabasca escarpment in the Kirby model and by including effects of a 0.1 m water drawdown isopleth in the Jackpine model. The Kirby model downgrades habitat suitability by 50% within the buffer, whereas the Jackpine model reduces habitat suitability within the 0.1 m isopleth to nil. We recommend that either the Kirby or Jackpine model be used for the validation test case. The actual test model will be selected from these two versions based on the available GIS layers for including water drawdown effects in the study area. The version of the model selected should be the one that allows the most accurate assessment of these effects to be calculated for input to the model.

The HSI model for beavers assumes that the suitability values for adjacent terrestrial habitat are equally significant in determining what qualifies as suitable habitat for beavers. The overall HSI model is calculated as:

> **HSI = (SI(1)) x (SI(2))**, for terrestrial habitat areas within 100 m of the waterbodies or marshes;
>
> HSI = 1.0 for all aquatic habitats (waterbodies and marshes); and
>
> HSI = 0.0 for areas >100 m from aquatic habitats.

The following sections present a workplan to validate the selected model. The objective of the workplan is to clearly describe the steps needed to implement a thorough validation of the model. We have broken the workplan down into tasks to be completed in sequence. The initial task consists of preparatory work that identifies the study area and collates all necessary data to run the model. Subsequent tasks mirror the four recommended validation steps described above in section 3.2.2.

Using this approach, a beaver model will be validated through a process of internal model review and calibration, external expert review, field studies to collect habitat data to validate the SI relationships, and field studies to assess the distribution of beavers in the selected project area(s) to correlate areas of high, moderate, low, or nil suitability to actual beaver presence.

4.4 Workplan Steps

4.4.1 Task 1: Identify model validation study area and collate data

The study area to apply the model for validation will be identified in consultation with CEMA. The study area needs to provide sufficient habitat variability so that the full range of habitat suitability will be included in the study area. It is anticipated that data from one of the operators that is involved with CEMA will be available (e.g., Suncor). All required model GIS layers at both the LSA and RSA scales (i.e., base layers including DEM, AVI to provide vegetation ecosite phases with associated vegetation characteristics at the LSA scale and Landsat cover classes for the RSA scale, an additional vegetation layer for shrub cover, and a hydrology layer) will be required. Alternately, base GIS layers that can be used to derive model input variables will need to be obtained. All GIS polygons, base layers and associated attributes will be prepared within a GIS so that the model can be run to produce both SI and HSI scores for validation in the subsequent tasks. In addition, the model output will be mapped into the four habitat suitability classes and compared to the original EIA mapping for the model to ensure that the GIS data collation and implementation of the model's equations has been correctly performed.

It is recommended that a biologist with good knowledge of beaver habitat use within the study area assist with the model calibration task. An additional beaver expert may be required to conduct the external review task.

Available species occurrence data for the study area will be obtained and collated to assist in verification of predicted model outputs. These data include baseline studies that were conducted for the study area's EIA(s). Related documentation that clearly describes the survey design, identifies sampling methods, location of transects etc. also needs to be acquired. In addition, regional monitoring programs (e.g., the Alberta Regional Monitoring Initiative (ABMI), the Government of Alberta Fisheries and Wildlife Management Information System (FWMIS) and wildlife corridor research) will be reviewed to determine if these data may supplement test data. These data may be used in the model validation process if they were collected at a scale that corresponds to the scale at which beaver habitat was modelled. These historical data may also provide important information regarding multi-year habitat use in the study area, as recommended in the model validation methodology above. The use of these data will be examined in detail in Task 5, below.

4.4.2 Task 2: Author Review

The work in this step focuses on validating the internal model structure. The model documentation will be reviewed to ensure that all model assumptions and limitations are clearly and correctly stated. Errors in documentation will be corrected if possible, and errors that can not be corrected due to insufficient information will be flagged.

The model components and relationships will be assessed to check that appropriate habitat variables were used, and that the mathematics and graphs for the SI and HSI relationships are consistent with the assumed habitat relationships for the species. Sensitivity testing will be done on each SI relationship and the HSI equation, with the most sensitive model components clearly identified so that subsequent validation can prioritize these items. In particular, the field program design must include steps to test the most sensitive model assumptions so that their effect on the variability and uncertainty in model predictions can be clearly understood.

Roloff and Kernohan (1999) also recommend that two sources of error in input data be assessed for how this affects interpretation of final HSI output. These errors include: i) sample error in assigning values to vegetation structures in mapped polygons; and ii) inaccurate spatial depiction of mapped polygons. Depending on the data sources used to build the GIS, it is likely that errors associated with (i) are more pervasive than those associated with (ii). The base layers and mapped polygons of the project selected to conduct the model validation should be evaluated for accuracy, both in terms of accurate polygon labels (which will inform the user of the vegetation features, landform, soil moisture, and soil nutrients) and in terms of the map scale.

4.4.3 Task 3: Calibrate Model

This task involves running the model in the GIS to predict HSI scores for each habitat polygon. The HSI outputs will be inspected to assess if a reasonable spread of predicted HSI values from 0 to 1 is produced so that habitat quality can be discriminated among sites (Brooks 1997). We will then assess the HSI predictions to determine how well they reflect known habitat suitability, i.e., do areas predicted to be high suitability habitat match up with a biologist's professional knowledge of the area. A biologist familiar with beaver habitat use will be used to assist with this assessment. We will calibrate the model by modifying the SI relationships and HSI equation as needed, with HSI predictions regenerated and inspected. This is an iterative process that continues until acceptable HSI score output is achieved or limitations in species habitat relationship knowledge and/or input variable accuracy prevent further improvement to the model. All changes to the model and the rationale for each change must be clearly documented. Any limitations with model calibration also need to be clearly documented, with a discussion provided as to how this limitation may constrain use of the model predictions when assessing impacts to North American Beaver by Oil Sands projects or when using model output for reclamation planning.

4.4.4 Task 4: Expert Review

The model outputs and results of the previous two tasks will be submitted to the beaver biologist identified in Task 1 for an external review of the model. Any improvements recommended by the review will be assessed and incorporated if feasible. The model calibration task will be repeated if changes to the model have been made. The final changes to the model will be clearly documented. Recommended changes that are not implemented will also be fully documented and the rationale for not making the change will be clearly described.

4.4.5 Task 5: Design field program and validate model with field data

The objective of this task is to validate the model with empirical data to assess the model's performance and further refine the model as needed. Note that the model refinement involves an iterative process of repeating Tasks 3-5 until satisfactory model performance is achieved or no further improvements can be made to the model given the constraints of available data, information regarding beaver habitat relationships and/or budget.

While the model's predictive power across the entire range of habitat quality should be evaluated to ensure that the model is robust and to assess the accuracy of model predictions across all HSI values (Roloff and Kernohan 1999), this step may be constrained by the actual habitat suitability within the study area. Note that limitations in knowledge regarding species habitat relationships and availability of appropriate and accurately measured habitat variables may restrict the ability to improve the model performance. In this case, the caveats and limitations in regard to using the model predictions for the purpose of a project's assessment of impact to the modelled species or when using the model in a reclamation plan need to be clearly documented.

The field validation program will sample both habitat data and species observations to ground-truth the SI relationships and to validate model predictions of habitat suitability. The field program will also include work to assess the accuracy of the base vegetation mapping used to predict habitat suitability and how this accuracy may affect model outputs. We will consider other methods in more detail to allow some level of confidence to be applied to the final HSI scores that are predicted by the model.

The following steps are suggested for a field program to validate a beaver model with empirical data:

1. Obtain GIS layers used in the EIA to model and assemble these layers in a GIS. Note this step will be performed as part of Task 1. Map the distribution of beaver habitat suitability for the selected project area using the version of the beaver model produced by Task 4, above;
2. Obtain previously collected data on the distribution and occurrence of beavers in the project area (if available). Note this step will be performed as part of Task 1 ;
3. Review beaver habitat requirements and consider how that information was used to develop the assumptions of the beaver HSI model that is being validated. Note this step will be performed as part of Task 2;
4. Stratify the project area based on area of high, moderate, low, and nil habitat suitability habitat by overlaying a grid onto the mapped area and randomly selecting 10 – 12% of all polygons for field verification;
5. Conduct field survey work to collect habitat data in those cells selected for field verification to test the SI relationships. Data collection will focus on habitat variables in the model (i.e., woody vegetation cover, deciduous tree and shrub cover and distance to water, but other habitat variables considered to be important to beaver habitat selection will also be collected, time permitting);
6. Conduct aerial survey work in those cells selected for field verification to determine the density of beavers (as indicated by the number of lodges or dens per km) and to determine the presence of beavers in each category of habitat suitability. The development of the study plan, including the timing of the aerial surveys will need to consider potential disturbances and negative impacts to other species (e.g. Woodland Caribou);
7. Perform statistical analyses to correlate field habitat values collected in step 5 (above) against the model's SI relationships.
8. Perform statistical analyses to correlate the field data collected in step 6 (above) and other beaver observations obtained through task 1 with the predicted HSI values derived using the overall HSI equation for the selected model;
9. Correlate areas of observed high beaver density (lodges or food caches per km) with higher habitat suitability for the project area and compare with the mapped output produced by the original model. Overlay AVI, forest cover, or other biophysical data onto the map to determine if there is a single or suite of parameters in the available data that could be used to improve the model;
10. If needed, modify model based on validation results and with any new parameters deemed significant and redo Tasks 1-5;
11. Use the final validated model to re-map the distribution of high, moderate, low, and nil suitability habitats. Summarize the total area for each category of habitat suitability. Compare the spatial extent and total area for each category of habitat suitability to output from the original model; and
12. Generate a report discussing the methods and results of the model validation exercise, including maps depicting any spatial differences in habitat suitability for the project area assessed. Provide recommendations on how to improve the North American Beaver HSI model with a fully-documented the final validated model for consideration.

Additional information on the suggested field program is provided below.

The field program should utilize a stratified-random approach that samples a proportion of all areas that were mapped as having high, moderate, low, or nil-rated habitat in the original EIA. In this case, the strata are comprised of the four habitat suitability categories that are correlated to the HSI values derived from the overall HSI equation (see above). To facilitate the selection of sample areas with the selected project area, the habitat suitability map produced for the model version resulting from Task 4 should be projected in a GIS using the same spatial extent as delineated by the original project boundary[6] and overlain with a grid (either 500 m X 500 m or 1000 m X 1000 m). Grid cells within each category of habitat suitability will then be selected (at random) such that approximately 10 to 12% of the total mapped area is selected for field verification (which is consistent with the 10 to 12% sampling intensity recommended by RISC (1996) for a landscape-level study). The number of grid cells selected for sampling could also be determined via a power analysis to ensure that enough cells are sampled to provide a biologically meaningful interpretation of the data. This should be considered prior to grid selection.

Field surveys should coincide with the time of year when beavers are most active, when their lodges are most visible, and when beavers will be storing food for the winter (Banfield 1981; Novak 1987). Aerial surveys (cache counts) are typically the easiest way to survey a large area in a short time and provide a good indication of the number of active colonies in a given area owing to the fact that there is generally one cache per colony (Banfield 1981; Fuller and Markl 1987; Potvin et al. 1992). Given the size of the areas mapped in most of the EIAs, aerial surveys will also be the most efficient (and only logical) way to complete the surveys. We suggest that a minimum of two surveys occur – one in late fall/early winter when beavers are caching food (after leaf-fall and before freeze up) and one in the summer to document beaver activity associated with newly established colonies (after juvenile dispersal). All work will be georeferenced so that metrics such as distance to project infrastructure, roads, etc. can be determined in a GIS. Prior to conducting field work all existing (available) data should be reviewed to determine the location of recent and/or historical beaver lodges and to assess if and how previous beaver surveys were conducted for the project area.

Aerial surveys will enable an assessment of the location of beaver lodges or bank dens, evidence of recent cuttings (which will be stored as winter food) and any other sign of beaver use (e.g., visual observations). Observations of all beaver activity will be made. These include presence of beaver lodges, browse, etc. The density of beaver sign (e.g., number of lodges per km) can be used to determine areas or habitats of high use. Habitat variables in these high use habitats will be examined to determine if habitat variables that are not in the current model seem to be good predictors of beaver habitat use. If so, these variables will be considered for inclusion in the model.

Two statistical analyses using an area corrected response variable will be performed with beaver observation data. These analyses will provide an indication if the HSI model does a good job of identifying (and mapping) high, moderate, low, and nil suitability habitat based on the density of beavers. Beaver density will be used as the explanatory variable (because it can be corrected for survey effort). Beaver densities will be correlated to the HSI score for the grid or habitat value being sampled and Manly's selection ration followed by a G-test for significance will be performed to determine the level of accuracy associated with the HSI model. In addition, when describing species-habitat relationships, multivariate analyses are often useful tools to describe the relationships observed in the field. Many of these analytical techniques do not have the same sample size requirements as other parametric statistical techniques and rely more on expert interpretation. The use of multivariate analyses such as PCA or RDA will be considered. For example, it may be possible to assess the relationship between beaver density and habitat type (extracted from AVI data, for example).

Although the model we recommended for validation does not include DCs, a consideration of how moderating effects, such as proximity to roads, infrastructure, or changes to the hydrologic regime of the area might affect the model output is recommended. Because few data exist to support the application of field data to this assessment, assumptions about the effects of the DCs on beavers will need to be gleaned from the peer-reviewed and/or grey literature. Preferably, literature specific to the

[6] The spatial extent may be reduced, if needed, to eliminate habitat impacted by industrial operations.

AOSR will be used to assess how the DCs will affect beavers and beaver habitat. The magnitude of those impacts will also need to be considered in terms of the immediacy of the impact (short, mid, or long-term relative to a beaver life cycle) and whether or the not the impacts will have population-level, family-level, or individual impacts. Recommendations about improvement to the beaver model will be made as part of the reporting process (see below).

An estimate of effort to validate the model will be made as part of the experimental design. When investigating the relationships between wildlife and their habitats and alterations to those habitats, it is necessary to ensure that the sampling intensity will sufficiently enable a meaningful interpretation of results obtained from statistical testing. The peer-reviewed literature will be reviewed to obtain estimates of variation for the species in question for use in a power analysis. The power analysis will provide an estimate of the required sample size to ensure that the number of cells sampled in each suitability category will enable an estimate of the variation within each category. Because of the inherent variability associated with most wildlife populations, particularly those that are highly mobile (e.g., Moose, birds, some furbearers) it is suggested that the critical level of alpha be set at 0.1 because it may not be feasible to implement the sample size returned from the power analysis. It is more important that an appropriate biological interpretation of the data be made that is supported by statistical testing rather than simply reporting the significance of a statistical test without interpretation.

4.4.6 Task 6: Reporting

A report will be written that fully documents the methods and results for each of the five tasks. These results will be used to make an overall assessment of the model. The limitations, uncertainties and caveats of using the model predictions will be clearly described. Recommendations for improving the model will also be made. The final model resulting from the validation process will be fully documented.

The model validation process that was used for this case study will also be evaluated. While these methods are based on those recommended in peer-reviewed literature, we may find practical limitations to the methods or additional ways to improve them. For example, part of the validation process described above aims to improve the estimation of uncertainty in model predictions of habitat suitability and new methods will likely be developed for this purpose. We will synthesize the findings of the test case validation to modify the model validation recommendations made in Task 4 as needed, and to add new recommendations to improve the process.