

## 1.0 Decision Tool Overview

The decision tool is intended for use after a preliminary assessment on the viability of eDNA as a sampling method. If eDNA is a viable option for a given project, the decision-making tool can be used to further assess the viability, allowing for simple comparisons and estimates on the basis of cost, sampling power, and several other metrics. It takes simple input through fillable fields and drop-down menus, and provides the relative desirability between eDNA and a chosen traditional sampling method based upon user preferences.

### 1.0.1 Input Overview

The decision tool is dependent upon user input to estimate the costs of sampling, as well as to estimate the relative desirability of traditional and eDNA sampling methods. Users will input numeric values relating to a proposed sampling project, as well as select responses from dropdown menus. Users will be required to have some knowledge of sampling procedures, including the ability to estimate traditional sampling methods' ability to detect the presence and absence of species (although this information may be available in standard operating procedure manuals). Users will also be required to supply the details of a proposed sampling project, including scope (number of locations sampled), number of field workers, and details about potential sampling locations. The user should also be able to make qualitative judgments as to how easy it will be to perform sampling using traditional methods.

Users of this decision tool, whether an individual or group, will be asked to express their preferences regarding various aspects of fish sampling. These include cost, sampling power, lethality, and other factors, and take the form of simple pairwise comparisons, for example "Minimizing the cost of sampling is somewhat more important than maximizing sampling power".

The precise details of how to supply these inputs, as well as a comprehensive guide to the meaning of each field is supplied in this manual.

### 1.0.2 Output Overview

The Decision tool provides two main types of output. The first is an estimation of the cost of sampling, which can be used independently of the rest of the tool. The second is a "desirability score" which represents the expected preference given to either traditional sampling or eDNA sampling, dependent upon the user's input. This second set of outputs is dependent upon the tool being used in full.

The estimate of the cost of sampling is provided in the form of a dollar amount. This amount is associated with a single day of sampling, and includes the cost of labor, travel (depending upon user input), the costs of gear, and the cost of lab work (for eDNA only). This

estimate of cost can be obtained by completing only the cost module, as described later in this manual.

The desirability scores are values ranging from 0 to 1, which are assigned to each of traditional sampling and eDNA sampling. Higher values represent a more desirable sampling methodology for a given project, and lower values a less desirable methodology. The larger the gap between the two, the stronger the preference for one method or the other is. The absolute value of these scores does not hold any meaning, and scores are only comparable within a single sampling project. Thus, a traditional sampling desirability score of 0.7 for one project should not be compared to a traditional sampling score of 0.4 for a different project.

## 1.1 Interface

The decision tool uses an online interface, which displays information about the current sampling project being examined, as well as various buttons and drop-down menus for navigation. Several of these buttons will navigate to new forms for the collection of data surrounding a specific metric. For example, the “Estimate Cost” button will open a form with input fields to describe a sampling project using the relevant characteristics. In general, each of these forms will consist of the same components. In the top left is a cancel button. This will navigate back to the main form without saving any new information added. For example, if the cost form is opened, and the number of sites was previously set to 15, changing the number of sites to 12 and pressing cancel will result in the number of sites staying as 15. At the bottom of the form is the confirm button. This will save all changes made to the values displayed in the form. In order for the confirmation to go through successfully, all fields must be filled with acceptable values. Those that are filled incorrectly or left blank will be highlighted in red. Each form also contains multiple fillable fields. These are labeled with the information required, such as “number of sites sampled” or “number of team members”. The meanings of these are described in detail later. The fields are split into two columns, with the fields relating to traditional (non-eDNA) sampling methods on the left, and eDNA sampling methods on the right. These fields accept numeric and decimal input, and do not require special characters. For example, “120” and “0.5” are valid inputs, “\$250.99” and “Ten” are not. When a form is loaded, if any of the fields have pre-existing values (perhaps defined by the user at an earlier time) they will be automatically filled with those values.

Throughout the main decision tool form as well as the various input forms, drop-down menus are used to select from two or more categories. For example, in the “Calculate Cost” input form, there is a drop-down menu to select the water body type, from between “Lake”, “Stream”, and “Wetland”. Certain of these drop-down menus will have an explanation as default text, for example “Select Waterbody”. The input form will not be able to be submitted (thus saving the input) if this default text is still selected.

The “Rank Preferences” input form accepts input through a number of buttons, associated with the strength of the user's preference. Clicking these buttons will automatically submit the judgment. However, all judgements must be completed or else they will not be saved.

The “Run Model” button will display the relative desirability of the chosen traditional sampling method and eDNA. If the cost, sampling power, preference ranking and site applicability have not been submitted the “Run Model” button will not function.

At any point in the process, information that has been supplied to the model may be modified by re-opening the relevant input form.

Once the main decision tool window is closed all information will be lost. That is, any information relating to the sampling project will be lost between uses of the decision tool.

## 1.2 Caveats

There are several caveats associated with the use of the decision tool. The first that should be mentioned is with regards to the strength of the recommendations provided by the tool. The models within the tool are all built upon extensive data and proven methodologies. Despite this fact, the values presented in the tool are estimates, and should not be used in place of a traditional cost valuation. The final desirability scores presented by the model are intended to highlight situations in which the use of eDNA is a strongly viable option which is likely to meet project objectives. Once again, this tool is intended to augment the traditional decision-making process rather than act as a substitute.

It is also worth discussing situations in which the decision-making tool may struggle. The tool is created with simple sampling projects in mind. There is an assumption within the program architecture that a sampling project focuses on either detecting the presence or absence of species, and represents a one-time evaluation of a waterbody. To expand upon this, ecosystem surveys, monitoring for invasive species, and tracking endangered species all fall under the umbrella of presence/absence studies. A study whose goal, for example, is to monitor the health of individuals, or to determine the biomass of various species present, may be less suited to evaluation with this model. Additionally, studies which require repeated sampling, or other unusual sampling processes may require the user to represent them as a series of one-time projects in order for the tool to handle them.

## 1.3 Project

The decision tool uses a construct called a “Project” to store information. The tool holds two projects at the same time, a traditional sampling project and an eDNA project. These represent the two options the decision tool is comparing. The projects store information, which is supplied through the various input windows throughout the tool. Each project stores the following information, which may be different for each of the tradition and eDNA sampling methods:

**Number of Sites:** How many sites are being sampled over the course of the project.

**Number of Team Members:** How many field technicians will be working on the project.

This is assumed to be constant at all times during the project.

**Sample Area:** What the total Area being sampled across all sites is. The eDNA project does not use Sample Area in cost calculation.

**Average Wage:** The average wage being paid to each team member.

**Travel Costs:** The total cost of traveling associated with a project.

**Power to Detect Presence and Absence:** These two measures represent the power a sampling method has to detect the presence or absence of target species. It should be

represented by a probability between 0 and 1. A power to detect presence of 0.85 means that the sampling method will successfully detect a present species 85% of the time, and a power to detect absence of 0.70 indicates that failure to detect the target species indicates absence with a confidence of 70%.

The waterbody type is one of Lake, Stream and Wetland. Only one waterbody type is stored across the two projects, as it is assumed that the same waterbody is being sampled in each case.

The gear type represents the method of traditional sampling being used. This is stored only for the traditional project, as it is not relevant for the eDNA project. In addition to the type of gear used affecting the effort required for sampling, each gear also contributes different fixed costs associated with acquiring and maintaining the gear.

### 1.3.1 Form Input: Number of Sites

The number of sites is how many separate instances of sampling that occur during a single day, or outing, of sampling. This should not be confused with the number of water bodies being studied, as each waterbody may be sampled more than once. For gear such as seine netting, where the effort is measured in hauls, the number of sites does not represent the number of hauls, but rather the number of applications of standard operating procedure.

To expand on this, the standard procedure for electrofishing may be to make two passes with the electrofishing equipment. Applying this procedure a single time, that is two passes, would be a single “site”. If the same location on a river is studied using six passes, that should be referred to in the model as three sites, as the standard operating procedure is applied three times. Similarly, six passes across three sites should also be referred to as three sites. However, each individual location should be counted at minimum as a single site. Thus, if six passes are made across six separate locations on one or more waterbodies it should be recorded as six sites.

The number of sites is allowed to be unique for both the traditional sampling method, as well as eDNA sampling. This is due to variations in sampling power and procedure that may occur between the two methods. For example, in order to achieve the desired sampling power in assessing an ecosystem three sites may be required when using a traditional method, and only one when using eDNA. The separate values of the number of sites for the two sampling methods reflects this difference.

The number of sites is expected to have an effect on both the effort required for sampling (and therefore the cost), as well as the power of sampling. The relationship between the number of sites and the cost of a sampling method is calculated automatically, using a regression on real-world sampling data. This is discussed further in section 2.1. The relationship between the number of sites and the sampling power is determined by the user. This is likely to be determined by the standard procedures associated with the specific institution or project. The relationship between number of sites and eDNA sampling power is also left up to the user, but comes with several recommendations. As the eDNA technology and sampling procedures mature, and more robust sampling data becomes available these numbers can be adjusted to reflect the most up-to-date information.



### 1.3.2 Form Input: Number of Team Members

The number of team members is representative of how many paid workers will be out in the field at any one time. Thus, if three people are involved in the sampling process the number of team members is three. Volunteers or other workers not drawing a salary should not be counted as team members, as the number of team members and the average wage (discussed later) are used to calculate the cost of labor.

As with the number of sites, the number of team members can be defined separately for both traditional and eDNA sampling methods in order to reflect the differing operational needs which may be present for each method.

### 1.3.3 Form Input: Sample Area

The sample area is only used for traditional sampling. This is due to the fact that eDNA sampling uses a point sampling method; water samples are taken from a single (or several) areas regardless of the size of the waterbody. For traditional sampling, the sample area is the total area covered by sampling over each of the sites. Thus, if a single location on a waterbody is sampled twice (counting as two sites), its area must also be counted twice for the purposes of determining area.

The sample area is different from the surface area of the waterbody. For example, if a large lake is sampled by netting within three 20 by 10 meter sites, the sample area will be 600 meters squared.

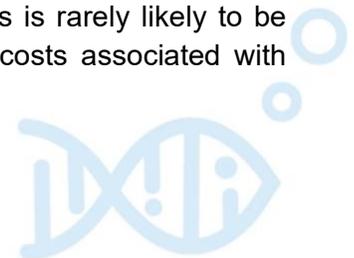
For traditional sampling methods, the sample area affects the effort needed for sampling, and therefore the cost.

### 1.3.4 Form Input: Average Wage

The average wage is defined as the hourly wage paid, in dollars, averaged across team members.. For example, if there are two team members and one is paid \$20 per hour and the other is paid \$21 per hour, the average wage is \$20.50. The average wage may be different for traditional and eDNA sampling methods to reflect any potential differences in expertise and experience needed, as well as the potential increased compensation due to fewer workers.

### 1.3.5 Form Input: Travel Costs

The travel costs are costs associated with travel to and from sample sites, as well as any lodging required. These costs should be as all-inclusive as possible; however, there are certain costs, to be discussed shortly, which should be omitted. Additionally, costs that are associated with each site should be included in the “Per Site Costs” section. Travel costs are allowed to be different for each of traditional and eDNA sampling methods although this is rarely likely to be the case. One example of where travel costs may differ is if there are costs associated with transporting large amounts of equipment such as a boat.



### 1.3.6 Form Input: Sampling Power; Presence and Absence

The sampling power of a given method of analysis, whether eDNA sampling or one of several specific traditional sampling methods is split into two categories, power to detect presence, and power to detect absence. Power to detect presence is a number between 0 and 1, which represents the likelihood that a target species will be detected by the sampling method if it is present in the waterbody. For example, a power to detect presence of 0.9 would indicate that the chosen sampling method has a 90% chance of detecting the target species if it is present. If the target species is not present it will not be detected, but this has no bearing on the power to detect presence. Similarly, a high power to detect presence is not a guarantee of detection even if a target species is present.

Power to detect absence is a number between 0 and 1 indicating the confidence that a species is not present given its non-detection. For example, a power to detect absence of 0.6 would mean that 60% of the time when a target species is not detected that species is not present. It should be noted that while traditional sampling is not subject to false positives, that is detecting a target species when it is *not* present, eDNA sampling is. This could be due to cross-contamination of the waterbody due to birds or boats for example, or errors in lab tests. Even though these cases are unlikely, they should be taken into account when estimating the power to detect absence for eDNA.

The values for both power to detect presence and power to detect absence should be determined by the user. It is assumed that the user will have standard operating procedures which inform the power of traditional sampling methods. Recommended Values for eDNA sampling are provided in section 2.2.

### 1.3.7 Form Input: Waterbody Type

The Waterbody Type is a categorical variable which describes the type of waterbody being sampled. In the current formulation of the cost model, only a single waterbody type can be used, and the same waterbody type is used for both traditional and eDNA sampling. The three types of waterbody are Streams and Rivers, Lakes, and Wetlands. It is possible that a sampling project will cover more than one waterbody type. For example, a project may involve sampling a lake and its tributaries. In these cases, the type of waterbody on which the majority of sampling effort is concentrated should be selected.

### 1.3.8 Form Input: Gear Type

The Gear type is a categorical variable which only applies to traditional sampling. It describes what type of sampling method is being used. The sampling methods as described by the decision tool are each representative of one or more types of gear used. These gears are grouped together because of their operational and statistical similarity. If multiple sampling gears are being used, the most common or most applicable one should be chosen within the model.

At present, the gear types represented in the model are as follows:

**Electrofishing:** This covers backpack electrofishing, and any other electrofishing that is done one foot, as opposed to using a boat. While many electrofishing methods may also involve the use of a variety of forms of nets this gear type supersedes other methods.

Boating: This covers all sampling methods which are performed using a boat. While this encompasses a diverse collection of sampling methodologies a regression analysis of sampling effort has shown that all sampling methods involving boating have a similar relationship with sampling effort.

Haul Nets: This category covers netting methods in which the standard effort is measured in a number of hauls or passes with the net, as opposed to standard measures of time. This includes Seine Netting, Trawl Netting, and other drag netting methods.

Each gear choice also defines certain fixed costs associated with purchasing and maintaining gear. These costs are determined through a survey of all equipment needed, including vehicles such as trucks and boats, major equipment such as electrofishing gear and nets, and minor equipment such as hip-waders and buckets. The costs of these equipment are amortized over their lifetime, with an estimated 80 days of use per year. Tables of values are presented in section 3.

## 2.0 Specific Modules - User Interface and Tool Output

The decision tool is made up of several modules, each serving a different purpose. First, there is the “Sampling Power” module, which allows the user to determine the sampling power of the traditional and eDNA sampling methods. This module also allows the user to determine the number of sites being sampled.

The second module is that of the cost model. This model takes as input a large number of site and project considerations and returns an estimate of the cost associated with sampling. This is performed simultaneously for both traditional and eDNA sampling. This module also provides the option to use a known cost value in place of the calculated estimate for the traditional sampling cost.

The site applicability module asks the user to provide a simple judgment of how well the traditional sampling method is expected to perform in the field. This is not meant to be a comprehensive and all encompassing judgment, but rather a surface level approximation.

The final module is the MCDA preference module. Here, the user determines the relative importance of a variety of aspects, including cost, sampling power, lethality, and more. These preferences are used to make the final MCDA recommendation provided by the decision model.

### 2.1 Main Page

The main page displays the most relevant information to the decision-making process, as well as buttons which will switch to modules for more specific input. Two columns display information relevant to the decision-making process, with information relating to traditional sampling on the left, and eDNA sampling on the right. Number of sites sampled, although not directly relevant to the decision-making calculation, is displayed. Power to detect presence and absence, as well as estimated cost are displayed for both forms of sampling. The method of traditional sampling being examined and the type of waterbody being sampled are also

displayed. When the decision-making model is run the estimated suitability scores of each method are displayed on this page.

There are several buttons in the leftmost column which allow for navigation. The “Set Sampling Power” button will navigate to a page which contains the power module, described below. Similarly, the “Cost” button navigates to the cost module. A drop-down menu allows the user to determine the site applicability. The “Preferences” button navigates to the MCDA Preference module. The “Run” button will run the decision model, provided all other modules are completed.

## 2.2 Sampling Power Module

The sampling power module allows the user to determine the power to detect presence, power to detect absence and number of sites sampled for both traditional and eDNA sampling. The number of sites sampled is carried forward to the cost module. If the number of sites is changed, that change will retroactively be applied to the sampling power module.

Clicking on the “Set Sampling Power” button on the main page will navigate to the window for the sampling power module. Here, the user is presented with six fillable fields. On the left, there are three fields for traditional sampling: Power to detect presence, power to detect absence, and number of sites. Similarly, these three fields are repeated on the right for eDNA. The power to detect presence and absence are determined by the user. These metrics are expected to be dependent on the number of sites sampled. For traditional sampling, this information is expected to be known by the end user, and is likely going to be determined by organizational standard operating procedures. The eDNA power to detect presence and power to detect absence are also inputted by the user. While it is not expected that the users understand the relations between eDNA sampling power and number of samples taken, recommendations are provided, and further reporting on eDNA and future operating procedure development is likely to change these values. At present, a conservative estimate for eDNA sampling is that 12 samples is sufficient to achieve 90% confidence in both the detection of species presence and species absence. Sampling at 5-6 sites is expected to achieve up to 70% confidence in the detection of a species, but fall short of this measure when detecting absence.

The module (and tool as a whole) allows for different sampling methods to have different numbers of sites sampled. Here, the goal of a project may be to achieve a certain sampling power, which may require a different number of sites sampled depending on whether a traditional or eDNA sampling method is used.

There is no information calculated from this module, however the supplied sampling powers are displayed on the main page.

## 2.3 Cost Module

The cost module has a more complex set of inputs compared to the other modules, as well as a definite output. The inputs needed for this module are described in section 1.3. There are two columns for input, the left column for traditional sampling, and the right column for eDNA sampling. There are two inputs outside of the column structure, the first of which is waterbody type. This is considered to be the same for both sampling methods. That is, the toolkit

is making the implicit assumption that all potential sampling projects are targeting the same body or bodies of water. Additionally, the field of sampling gear is exclusive to traditional sampling.

All fields should be filled using numeric values, with the exception of the drop-down menu fields of water body type and gear type. Integer and decimal (ie. 100 and 100.5) numbers are both acceptable, whereas fractional numbers and numbers including non-numeric characters (ie. 5 ½ and \$29.50) are not.

All of the input to the cost model will be saved between uses of the cost model, but will be lost if the main page is closed. For example, once the cost is calculated, the model can be re-opened and changes can be made. It should be noted that the number of sites sampled is the same for the cost and power modules, and changes in one will be reflected in the other.

The cost model supplies two different output values: the estimated cost of traditional sampling, and the estimated cost of eDNA sampling. These estimates are both given in dollar amounts, and represent the cost of the entire proposed sampling project, including wages, transportation, gear costs and lab costs. The gear costs take into account the repeated use of gear as well as the expected upkeep and lifetime of equipment. For the cost of eDNA sampling, it is expected that the total cost will be dominated by wages and lab costs. These cost estimates are displayed on the main page of the tool.

## 2.4 Site Applicability Module

The site applicability module is found on the main page of the tool, and is a simple drop-down menu. This module attempts to capture how well suited to the target site the proposed traditional sampling method is. A simple scale between 1 and 7 is used, with 1 indicating the sampling method is expected to perform quite poorly under the expected project conditions, and a 7 indicating that the project conditions are ideal or close to ideal for a given sampling method.

While this judgment may fail to capture certain nuances of the situation, it has several advantages over an objective or numerical model. The first advantage is that of expertise. Hands-on experience is expected to be a more reliable judge of site applicability compared to a model. Any model would rely heavily on many assumptions, which when taken in sum would likely fail to provide any useful information. Secondly, this module prioritizes ease of use and consistency across users. It requires a minimum of user input, and while different users may judge site applicability slightly differently, it avoids any potential issues of subjectivity in defining site characteristics such as depth, flow etc. which may vary highly between gear types or sampling experience. Finally, any numeric model will fail to account for every possible edge case. While a subjective judgment can be made about a water body with highly unusual physical features, it is impossible to build all possible situations into a model.

## 2.5 MCDA Preference Module

The MCDA preference module allows the user to assign differing levels of importance to various aspects of sampling. Currently, the decision model as a whole considers the power to detect presence, the power to detect absence, the cost of sampling, lethality of sampling, seasonality of sampling, ease of training associated with a sampling method, and the ability to

handle and observe fish. Some of these metrics may be strongly slanted towards one sampling method or another. For example, traditional methods allow for researchers to handle and observe fish, while eDNA sampling does not.

It is likely that both the traditional and eDNA sampling methods will excel in some aspects and be deficient in others. In order to provide a holistic recommendation between two sampling methods, the importance of each of these aspects must be determined. This is done through a series of pairwise comparisons. Each possible pairing of aspects, for example cost and power to detect presence, is presented to the user. They are then asked to determine which aspect has a higher level of importance, and to what degree. To continue the example, it may be decided that cost is much more important than power to detect presence, or else power to detect presence is slightly more important than cost.

The relative importance of an aspect is ranked between 1 and 7, with 1 indicating the two aspects are equally important, and 7 indicating an aspect is much more important than another. Thus, one will never input that one aspect is *less* important, rather A is more important than B, or B is more important than A.

Once these judgments are complete, the responses will be saved until an entire set of judgements is repeated. The pairs of aspects are presented to the user randomly to avoid any potential bias.

With the MCDA preference module and all other modules completed the tool is ready to supply the user with a suitability score for the traditional sampling method and eDNA sampling. These scores are between 0 and 1, with lower scores being less suitable. This score represents an amalgamation of all aspects, weighted by how important each aspect was determined to be.

## 2.6 Decision-Making Model

The decision-making model amalgamates the information obtained from the previous four modules, and provides an estimated “suitability score” for each sampling method. The higher the score, the more preferable a sampling method is expected to be. When both methods have scores which are close together, the methods are expected to be similarly preferable. The numbers given for these preference scores range from between 0 and 1. The actual value has no objective meaning, rather the two values should be compared against one another. A sampling method with a preference score of 0.7 may be preferable when compared to a score of 0.5, and less preferable when compared to a score of 0.9.

The decision-making model can only be run successfully if all other modules are completed. When the “Run” button is clicked, any incomplete modules will be highlighted in red. If all modules are complete, the preference scores will be displayed at the bottom of the main page.



## 3.0 Specific Modules - Underlying Math and Assumptions

In addition to the information surrounding the operation of this tool, more detailed information about the back end is supplied. While all of the essential information for use has been provided earlier in this manual, the explicit detail of the math used in the cost and decision making modules is provided, as well as further assumptions which are being made.

### 3.1 Cost Module

The cost module seeks to estimate the cost of a given sampling project. This is done in two parts. The first, and simpler part is estimating the cost of gear. Real-world costs of equipment are used, and are amortized based on the assumed longevity of each piece of equipment. The amortized cost of gear for each sampling method is calculated annually, and then divided across an estimated 80 days of sampling per year.

The equation used for this is:

$$\text{Amortized Cost} = (i \cdot C) / (1 - (1 + i)^{-L}) + (C \cdot U)$$

Where  $i$  is the interest rate, assumed to be 4.5%,  $U$  is the annual upkeep cost, assumed to be 1% of the cost of equipment.  $C$  is the initial cost of the equipment in dollars, and  $L$  is the lifetime of the equipment in years.

This cost is divided by an assumed 80 days of sampling per year. If more than 80 days of sampling occur then the cost of gear (and thus the overall cost) will be overestimated. If fewer than 80 days of sampling occur, the cost will be underestimated.

The second part of the cost estimation is that of determining the effort required for sampling, and thus the cost paid in wages. Multiple-regression analysis was performed on several years of sampling metadata for both traditional and eDNA sampling in Ontario. Alongside other metrics not used in this work, the date of sampling, area sampled, method used, number of team members, water body data, and real time spent performing sampling. The time spent sampling includes not only the duration of active sampling, but also the time spent setting up gear, tearing down gear, transportation between sites and breaks. Practically, this time (or effort) was calculated based on the difference between the earliest recorded arrival at a site during a day of sampling, and the latest departure. This effort-per-day was used as the regression variable, depending on the number of sites sampled in a day, number of team members, sample area (for traditional sampling only), waterbody type and gear type (for traditional sampling only).

The final cost due to wages is calculated as:

$$C = E \cdot T \cdot W$$

Where:

$$E(t) = e^{(B_0 + B_1 \ln(S) + B_2 \ln(T) + B_3 \ln(A) + B_4 + B_5)}$$

$$E(e) = e^{(B_0 + B_1 \ln(S) + B_2 \ln(T) + B_4)}$$

White  $C$  being the cost,  $E$  being effort,  $T$  being the number of team members and  $W$  being the average wage.  $B$  variables are regression constants.  $B_0$  is the constant term,  $B_1$  is

associated with the number of sites, B2 number of team members, B3 area, B4 waterbody type and B5 gear type.

The total cost using both of these terms is:

$$\text{Cost} = \text{Cost of Wages} + \text{Cost of Gear} + \text{Travel Costs}$$

### 3.2 MCDA Model

The MCDA model compiles user preferences surrounding a variety of metrics to compute a set “desirability scores” for traditional and eDNA sampling methods. While each of traditional sampling and eDNA sampling may excel at one or more metrics (ie. traditional sampling may have a lower cost) it is unlikely that a single sampling method will supersede the other across all metrics. Thus, the user’s preference for each of these many factors is needed to estimate the desirability of each.

The metrics being considered in this model are as follows:

Metric	Traditional Sampling Value	eDNA Sampling Value
Cost	Calculated	Calculated
Power to Detect Presence	Set by User	Set by User
Power to Detect Absence	Set by User	Set by User
Site Applicability	Set by User	5
Seasonality	0	1
Ease of Training	0	1
Lethality	0	1
Ability to Handle Fish	1	0

The cost, power to detect presence and absence, and site applicability have been discussed earlier in this document. The site applicability for eDNA has been set to a fixed value of 5 as eDNA sampling is less sensitive to the physical characteristics of the site, and works well under most normal circumstances.

The seasonality refers to how dependent upon time of year and season the sampling methods are. While many traditional sampling methods may be most effective during spring and fall when waterways are free-flowing, eDNA is viable year round. Including during the winter. Because both the value for traditional sampling and eDNA sampling are fixed, arbitrary values of 0 (less advantageous) and 1 (more advantageous) are chosen. All values assigned to the various metrics are normalized during the MCDA process, so the absolute values used here will have only a negligible effect. This rationale persists for the other metrics.

Ease of Training refers to how easy it is expected to be to train new sampling technicians to use the gear. While some operator skill and discretion may be required for traditional netting, electrofishing and boating methods, eDNA only requires the taking of water samples, the procedure for which is expected to be easy to learn.

Lethality refers to how harmful to fish the sampling method is. While not all traditional sampling methods are expected to be lethal, in general the trapping and handling of the fish represents an outside stressor which may lead to injury or death. This harm may also be an unavoidable consequence of intended sampling; gathering whole or partial specimens for further study. Because eDNA does not trap fish and requires only a water sample, it is not expected to have any adverse effects on fish population.

The Ability to Handle Fish refers to the ability for field workers to manually inspect fish, and make personal, visual confirmation of captured fish. This may include measuring length or weighing fish, sexing fish, monitoring health, etc. Traditional sampling methods allow for these examinations beyond simple presence/absence to be made. eDNA sampling does not afford the opportunity to examine fish. It is less advantageous in scenarios where counting individuals, measuring individuals, or checking for health markers are desired.

The MCDA model is implemented in two parts. The second of these handles the majority of the linear algebra required for generating the desirability ratings. The first part uses a series of pairwise comparisons to generate a hierarchy of metrics, for example a user may rate cost as more important than the power to detect species presence.

The user interface for these pairwise comparisons is described earlier in this manual. These comparisons are stored on a  $n$  by  $n$  matrix, with  $n$  being the number of categories used in comparing traditional and eDNA sampling. A comparison between category  $i$  and category  $j$  is reported in both  $a_{ij}$  and  $a_{ji}$ . Comparisons are made on a seven point scale, with higher numbers indicating a category is more important, and a 1 indicating both categories are equally important. If category  $i$  is rated as much more important (4) than the matrix index  $a_{ij}$  will be filled with a 4, and the index  $a_{ji}$  with the reciprocal,  $1/4$ . Similarly, if category  $j$  is more important these scores will be reversed. In the event that both categories are equally important both indices will be filled with a 1. Indices along the diagonal ( $a_{ii}$ ) will also be filled with a 1.

An important property to maintain throughout these comparisons is that of consistency. That is, if  $a$  is more important than  $b$ , and  $b$  more so than  $c$ , that  $a$  must be even more important when compared to  $c$ . If  $c$  were more important than  $a$ , this would break consistency, and the MCDA model would fail to give useful results. Thoughtful user input is expected to yield fairly consistent results, however perfect consistency is difficult to achieve. One property of a consistent or *coherent* matrix is that the square of the matrix will be equal to the original matrix multiplied by some constant,  $A^2 = CA$ . Another useful property is that repeatedly taking the square of a matrix will bring it closer to coherence. Thus if  $A^n = B$ ,  $B^2 \approx CB$  for high values of  $n$ . Here the matrix obtained from the full set of pairwise comparisons is squared twice to encourage coherence. The weight of each category, relating to its importance, is obtained by taking the sum of each row, and dividing it by the sum of all matrix entries (recall that each category is associated with a row in the matrix). Because the row totals are divided by the matrix

total, this repeated squaring of the matrix does not have an effect on the total magnitude of the weights.

The math used to generate the final desirability scores for traditional and eDNA sampling follows analytic hierarchy process MCDA modeling. The category scores generated in the first half are used to modify the metric values tabulated at the beginning of this section. First, the scores are normalized, by dividing it by the geometric mean of both scores of the same metric. For each metric the “best” and “worst” scores between eDNA and traditional sampling is identified, whether that is the highest score being the best, or in the case of cost, the lowest score being better. The difference between a sampling method and the “best possible” sampling method is determined. For each metric, a sampling method’s score is compared to the best and worst score of that metric (possibly its own) by taking the difference - that is Method Score - “Best” Score. The geometric means of differences from the best scores and the worst scores are calculated, giving what will be called the “distance from best” and “distance from worst”. The final score given by the MCDA model, which is visible to the user, is calculated using the distances. The “distance from worst” is divided by the sum of the two distances. The processes are repeated for both traditional sampling methods and eDNA sampling to produce the final scores given. A higher score is more desirable.

