

Supplemental Information: AIS Explorer 5 Step User Guide

Supp.1. Stage 1 – Selecting species and lakes of interest

The user first specifies which species they would like to develop an intervention scenario for by selecting from a drop-down menu. At the time of publication, these choices include zebra mussel (*Dreissena polymorpha*), starry stonewort (*Nitellopsis obtusa*), or ‘all’ species (both zebra mussel and starry stonewort).

The user will then select a list of lakes of interest by picking individual lakes and/or groups of lakes from a data table of potential lakes within the selected jurisdiction(s). A total of 8,315 lakes are selectable. Each entry in the table contains relevant details about the lake, including the division of waters (DOW) lake identifier, the county or counties that the lake resides in, and invasive species present in that lake (zebra mussels and/or starry stonewort). The selected lakes for inspection will be carried over into Stage 2.

Supp.2. Stage 2 – Define effort

The user sets an overall effort percentage for each of the three intervention categories – watercraft inspections, hot water decontamination and education and outreach. We define effort as the proportion of total boats visiting that lake yearly that are subjected to the intervention. For example, if 1000 boats come through a lake and 200 are inspected, the inspection effort is 20%. The total number of boats coming through each lake was determined by an adjacency matrix from Kao et al. (2021).

The selectors for effort are populated by default percentages that yield the following approximate numbers of boats intervened upon across all chosen lakes: 1) watercraft inspections: 20,000 across all chosen lakes or 15% effort, whichever is lower; 2) hot water decontaminations: 140 across all chosen lakes or 0.1% effort, whichever is lower; 3) education and outreach: 40,000 boaters reached across all chosen lakes or 50% effort, whichever is lower.

These values were chosen to keep effort levels realistic. However, users can apply these default values to their entire selection of lakes, set their own values, or edit the effort for each lake and/or intervention type individually within the data table view on the lower half of the tab. In real-time, the total number of boats to be intervened upon is displayed for reference. The selected intervention effort percentages are then carried through into Stage 3.

Supp.3. Stage 3 – Define effectiveness

The user sets an effectiveness percentage for each of the three interventions. We define effectiveness for a given intervention as the proportion of risky boats intervened upon that are rendered harmless by that intervention. For example, if 200 risky boats are inspected and the effectiveness is 80%, 160 boats fewer boats will be risky when they enter their next lake. We acknowledge that, in reality, an intervention’s effectiveness should be measured per boat (e.g., an individual boat’s risk is reduced by 80% following inspection rather than reduced to 0%), not as a proportion of all boat movements (e.g., 80% of boats now have 0% risk and 20% of boats have 100% risk following inspection). Regardless, the outcomes would be the same mathematically and our approach is more intuitive for estimating effectiveness values for end users.

A range of default effectiveness estimates are provided for each intervention method, but these default values can be modified. Default values were obtained from a study completed by Angell et al. (2024) wherein researchers observed boaters and trained AIS professionals as they attempted to remove AIS from a boat that had been staged with AIS. The study estimated that, on average, watercraft inspectors were 79% effective, hot water decontaminators were 84% effective, and boaters were 56% effective in AIS removal; these values were set as the “medium” effectiveness default values in the tool. The “low” and “high” effectiveness levels are set to the lower and upper 95% confidence interval bounds of the estimates from Angell et al. (2024).

Users can apply these default values to their entire selection of lakes, set their own custom values, or edit the effectiveness for each lake and/or intervention type individually within the data table view on the lower half of the tab. The selected intervention effectiveness percentages are then carried through into Stage 4.

Supp.4. Stage 4 – Define cost

The user sets a cost estimate for each of the three intervention categories on a per-intervention basis. Default values are provided but can be modified. The default cost values per AIS intervention were determined using spending data obtained through interviews with county AIS managers. We prioritized county-level AIS managers given the availability of the annual Minnesota AIS Prevention Aid funding (\$10 million) shared between counties (n = 87) with individual autonomy to make spending decisions (Minnesota Department

of Revenue 2024). County managers were selected based on the completeness of summary data provided to the MN DNR describing their AIS spread prevention plans to ensure we captured a variety of prevention strategies, budget amounts, and geographic location (Minnesota Department of Natural Resources 2023c). County managers were emailed using a standardized email template asking for voluntary participation in this study and informing them of what monetary information we would be collecting (Angell et al. 2024a). Cost estimates were collected for watercraft inspection, hot water decontamination, and boater education.

Interviews lasted approximately one hour, with email conversations following the interview, if needed. During the interviews, itemized spending information was obtained for each prevention method of interest (Table 1). Funds spent on multi-year equipment were divided by the expected lifespan of the equipment to obtain an annual equipment expense. For example, if the expected life of a tablet is 2 years and the cost is \$500, the annualized cost would be \$250.

To estimate the average cost per intervention, we first determined the total cost of watercraft inspection, hot water decontamination, and boater education for each interviewed county. The total cost was then divided by the number of interventions conducted. For example, if \$10,000 was spent on watercraft inspection and the county manager reported doing 500 inspections, the result would be \$20/inspection. The cost-per-intervention values were then averaged across counties to obtain one cost-per-intervention value for each of the three prevention types.


The user can apply these default values to the entire selection, set their own custom values, or edit the total yearly cost for each lake and/or intervention type manually. The default 'total yearly cost' for each lake is determined by multiplying the cost per intervention by the number of those interventions performed at each lake. The user can also see an overview of the overall costs as well as total costs for each intervention category. The total yearly costs per lake are then carried through into Stage 5.

Supp.5. Stage 5 – Summary

Here, the user can view a summary table of the settings they have specified in the preceding four stages. The table includes the lakes they have selected, lake details, effort and effectiveness percentages, and total yearly cost for each intervention category.

Once the user is satisfied with their settings, clicking 'Submit' will allow them to enter a name for the model run, along with their email address, before clicking 'Run' to send the model run to the AIS Explorer OpenCPU API for later processing. At this point, the user is free to continue using the AIS Explorer dashboard – the *Intervention Impact* simulation model will run in the background and the user will receive an email with a link to their results once the model is complete.

Supp.1. Stage 1 – Selecting species and lakes of interest



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Based on DNR infested water list - updated July 13, 2022

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 Choose lakes

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This tab allows users to evaluate the impact of different intervention scenarios on the risk of new infestations of invasive species, with each scenario able to have different levels of effort, effectiveness, and cost. Settings will be saved to allow for comparisons between multiple scenarios. Before beginning your first scenario, you may find it helpful to assemble some of the following general data:

A) A list of the lakes you plan to intervene at in your scenario;
 B) A list of the interventions you plan to try at each lake;
 C) Data on how intensively you plan to do those interventions (e.g., how many days will you plan to inspect at Lake X?);
 D) Data on how effective you expect the interventions to be (e.g., how much will your inspections at lake X reduce risk by, do you think?);
 E) How much you roughly expect each of these interventions to cost.

Don't worry: We will provide default values for elements C-E, but you will be able to override these with your own values.

Species

Select species: All

County

Select the county or counties containing lakes of interest. You can select lakes from across several counties by choosing each county one at a time.

Select county: Atkin

Non-focal lakes

These are lakes where interventions will not be placed and for which detailed outputs will not be provided. However, interventions placed elsewhere may still reduce risk for these lakes.

Not sure which lakes you want? Use Lakefinder to help you choose!

Focal lakes

These are lakes where interventions can be placed and for which detailed outputs will be provided.

Q

Lake Details	DOW number	Infestation status
Pine County: Atkin	01000100	🟢
Split Rock County: Atkin	01000200	🟢
Sandabacka County: Atkin	01000300	🟢
Dutch County: Atkin	01000400	🟢
Rice County: Atkin	01000500	🟢
Mud County: Atkin	01000600	🟢
Jay County: Atkin	01000700	🟢

🟡 Zebra Mussel
🟢 Starry Stonewort
🟢 Not infested

Q

Lake Details | DOW number | Infestation status

No data available in table

inspect >

< Don't Inspect

Inspect All >>

<< Don't Inspect All

Next →


Other resources:
 Minnesota Aquatic Invasive Species Research Center (MAISRC)
 Find out more about the MAISRC research behind this tab.

Drop down menu where users can select which aquatic invasive species they want to avert with their prevention plan. They can choose from zebra mussels, starry stonewort, or both.

Drop down menu where users can select the county(s) in Minnesota to apply interventions within.

Users can search and select which lakes of interest they want to apply intervention at within the county(s) selected.

Supp.2. Stage 2 – Define effort



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Based on DNR Invasive water list - Updated July 13, 2022

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To model the prevention of invasive species spread, the simulation will first need to understand how intensive your prevention activities will be. We refer to this as your scenario's "effort." Below, first select a default effort for each intervention across all focal lakes. The default effort you set in this step should reflect your intentions. For example, if you intend to inspect a relatively high proportion of boats that visit your lakes, set effort for that intervention to a high percentage.

$$\text{Effort} = \frac{\text{Number of boats intervened on}}{\text{Total number of boats visiting a lake per season}}$$

The model thinks about effort in terms of the percentage of all boats visiting a lake over an entire season that will experience a given intervention, so it'll be helpful if you think in this way too.

Set default intervention effort

Select an average effort percentage for each intervention to apply to all your focal lakes. You will be able to customize these percentages at the lake level below. You should strive to keep your effort values realistic using the estimates of boat totals shown. The default effort values we've provided are based on limited county-level averages from across the state but may not be appropriate for your context, so you should change them as you see fit.

Watercraft inspections
A standard watercraft inspection only.

Effort:

If you applied this effort to all your focal lakes, we'd estimate that would mean inspecting approximately **20026** boats over the course of the season.

Hot water decontamination
A watercraft inspection coupled with and followed by a decontamination with a hot water decontamination unit.

Effort:

If you applied this effort to all your focal lakes, we'd estimate that would mean "decontaminating" approximately **140** boats over the course of the season.

Education and outreach
Education and outreach activities could include special signage at specific lakes, handouts and fliers, special events, and staff time by inspectors educating boaters rather than conducting inspections.

Effort:

If you applied this effort to all your focal lakes, we'd estimate that would mean affecting approximately **40052** boats over the course of the season.

Apply to all lakes

Edit intervention effort for selected lakes

If you would like to customize which lakes get which levels of effort, you can adjust those levels here for every lake.

The boat total estimates shown are based on modeling work by MAISRC researchers. For more details, [see the study published here](#). These estimates are likely imperfect, but they accurately reflect relative trends in boater activity at the state level. Treat them as guidelines rather than perfect estimates.

Show entries

Lake details	Watercraft inspections		Hot water decontamination		Education and outreach	
	Boats	Effort (%)	Boats	Effort (%)	Boats	Effort (%)
Pine (DOW: 03000100) County: Albin	207	<input style="width: 60px;" type="text" value="34.3"/>	2	<input style="width: 60px;" type="text" value="0.1"/>	413	<input style="width: 60px;" type="text" value="28.6"/>
Split Rock (DOW: 01000200) County: Albin	7	<input style="width: 60px;" type="text" value="34.3"/>	1	<input style="width: 60px;" type="text" value="0.1"/>	14	<input style="width: 60px;" type="text" value="28.6"/>
Sandabacka (DOW: 03000300) County: Albin	10	<input style="width: 60px;" type="text" value="34.3"/>	1	<input style="width: 60px;" type="text" value="0.1"/>	19	<input style="width: 60px;" type="text" value="28.6"/>
Dutch (DOW: 03000400) County: Albin	14	<input style="width: 60px;" type="text" value="34.3"/>	1	<input style="width: 60px;" type="text" value="0.1"/>	28	<input style="width: 60px;" type="text" value="28.6"/>
Rice (UCW: 03000500) County: Albin	27	<input style="width: 60px;" type="text" value="34.3"/>	1	<input style="width: 60px;" type="text" value="0.1"/>	53	<input style="width: 60px;" type="text" value="28.6"/>

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Other resources:
[Minnesota Aquatic Invasive Species Research Center \(MAISRC\)](#)
 Find out more about the MAISRC research behind this tool.

Users can adjust the average effort applied to the lakes of interest for three common prevention activities, including watercraft inspections, hot water decontamination, and education and outreach.

Users can customize the effort for each intervention at individual lakes of interest.

Supp.3. Stage 3 – Define effectiveness

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Based on CNR infested water list - updated July 13, 2022

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To model the prevention of invasive species spread, the simulation will also need to know how effective it should think your prevention activities will be. Below, first select a default effectiveness for each intervention to apply to all your focal lakes. You will be able to customize these percentages at the lake level below. For example, if you expect your inspectors to remove a relatively high proportion of invasives from boats, set effectiveness for that intervention to a high percentage.

$$\text{Effectiveness} = \frac{\text{Number of risky boats made unrisky}}{\text{Total number of boats intervened on}}$$

The model thinks about effectiveness in terms of the amount each intervention will reduce the risk of a boat spreading an invasive species to a new lake by as a percentage, so it'll be helpful for you to think in this way too.

Set default effectiveness

The default effectiveness estimates provided are based on MAISRC research. For more details, [see the work described here](#). Treat them as informed approximations to help you select realistic values, though you may choose other values if you prefer.

Watercraft inspections

Effectiveness (Qualitative): Low (50%)

Effectiveness (Quantitative): 50

Hot water decontamination

Effectiveness (Qualitative): Low (70%)

Effectiveness (Quantitative): 70

Education and outreach

Effectiveness (Qualitative): Low (20%)

Effectiveness (Quantitative): 20

Apply to all lakes

Edit intervention effectiveness for selected lakes

If you would like to customize which lakes get which levels of effectiveness, you can adjust these levels here for every lake.

Show 10 entries

Lake details	Watercraft inspections		Hot water decontamination		Education and outreach	
	Level	Effectiveness (%)	Level	Effectiveness (%)	Level	Effectiveness (%)
Pine (DOW: 01000100) County: Atkin	Low	50	Low	70	Low	20
Split Rock (DOW: 01000200) County: Atkin	Low	50	Low	70	Low	20
Sandbacks (DOW: 01000300) County: Atkin	Low	50	Low	70	Low	20
Dutch (DOW: 01000400) County: Atkin	Low	50	Low	70	Low	20
Rice (DOW: 01000500) County: Atkin	Low	50	Low	70	Low	20

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Other resources:
[Minnesota Aquatic Invasive Species Research Center \(MAISRC\)](#)
 Find out more about the MAISRC research behind this tab.

A default effectiveness for each intervention is provided and users can toggle between low, medium, and high or input their own effectiveness to be applied to all lakes of interest.

Users can customize the effectiveness of each intervention at individual lakes of interest.

Supp.4. Stage 4 – Define cost

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Based on DPH Inland water lab - updated July 13, 2022

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On this tab, we'd like to help you estimate how much your scenario might cost to implement per season. While this feature is optional, and the numbers you enter here will not affect how the simulation behaves, using this tab may help you ensure that your scenario is realistic and implementable in your context.

Given the **effort** and **effectiveness** values you've specified, how much do you expect each intervention at each lake to cost over one season?

Set default cost

Select the default cost for each intervention type **on a per-boat basis**. The default per-boat cost estimates we've provided are based on limited county-level averages from across the state, but they may not be appropriate for your context, so you may adjust them as you see fit. That said, you should strive to keep them realistic for your context.

Watercraft inspections 20 ± \$	Hot water decontamination 302 ± \$	Education and outreach 0.4 ± \$
Reset to default	Apply to all lakes	

Edit estimated yearly cost per lake

Here, we've estimated the single-season costs for each intervention at each lake by multiplying the per-boat costs you selected above by the estimated numbers of boats being intervened on from the bottom part of the Effort tab. You can adjust these cost estimates as you wish, but it could be more realistic to change the values that go into the calculation instead. That said, if the estimates you are getting here are wildly off from what you were expecting to see, consider whether your effort values (tab 2) or per-intervention costs (this tab) are accurate and realistic. You can also increase or decrease the costs of specific interventions at specific lakes here, such as if you are planning to spend more on education and outreach at just a few lakes.

Show 10 entries

Lake details	Watercraft inspections		Hot water decontamination		Education and outreach	
	Intervention	Estimated yearly cost (\$)	Intervention	Estimated yearly cost (\$)	Intervention	Estimated yearly cost (\$)
Pine (DOW: 010003001) County: Aitkin	Effort: 14.3% (Approx. 207 boats) Effectiveness: Low (50%) Per boat cost: \$20	4129.84	Effort: 0.1% (Approx. 2 boats) Effectiveness: Low (70%) Per boat cost: \$302	622.73	Effort: 28.6% (Approx. 413 boats) Effectiveness: Low (20%) Per boat cost: \$0.4	165.19
Spell Rock (DOW: 010002009) County: Aitkin	Effort: 14.3% (Approx. 7 boats) Effectiveness: Low (50%) Per boat cost: \$20	131.56	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Per boat cost: \$302	36.65	Effort: 28.6% (Approx. 14 boats) Effectiveness: Low (20%) Per boat cost: \$0.4	5.28
Sandabacka (DOW: 010003000) County: Aitkin	Effort: 14.3% (Approx. 10 boats) Effectiveness: Low (50%) Per boat cost: \$20	180.18	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Per boat cost: \$302	22.81	Effort: 28.6% (Approx. 19 boats) Effectiveness: Low (20%) Per boat cost: \$0.4	7.21

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Overview

Here are the total per-season costs we've calculated for your scenario, based on your selections. Make sure these totals feel reasonable to you before proceeding.

Total yearly cost of interventions \$467,235.57	Inspections \$400,520.12	Hot water decontamination \$50,695.17	Education and outreach \$16,020.28
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Other resources:
 Minnesota Aquatic Invasive Species Research Center (MAISRC)
 Find out more about the MAISRC research behind this tab.

A default cost for each intervention will be provided for users to apply to the lakes of interest or users can input a custom cost for each intervention.

Users can customize the cost of each intervention at individual lakes of interest.

An overview of the total amount of money spent based upon previous inputs will be displayed as well as a breakdown of how much was spent on each intervention. The user can decide if the plan matches their budget and either proceed to the final stage or revert back to previous stages to alter their prevention plan to match their budget.

Supp.5. Stage 5 – Summary

1 Choose lakes 2 Define effort 3 Define effectiveness 4 Define costs 5 Review settings

This tab summarizes the settings you've selected. If you're satisfied with your selections, hit "Submit" to begin the simulation!

Summary of model settings

Species: Zebra mussel, Starry stonewort

Included lakes: 351 lakes belonging to 6 counties (Aitkin, Carlton, Cass, Crow Wing, Mille Lacs, Pine)

Lake details	Watercraft inspections	Hot water decontamination	Education and outreach
Pine (DOW: 01000100) County: Aitkin	Effort: 14.3% (Approx. 207 boats) Effectiveness: Low (50%) Yearly cost: \$4129.84	Effort: 0.1% (Approx. 2 boats) Effectiveness: Low (70%) Yearly cost: \$522.73	Effort: 28.6% (Approx. 413 boats) Effectiveness: Low (20%) Yearly cost: \$165.19
Split Rock (DOW: 01000200) County: Aitkin	Effort: 14.3% (Approx. 7 boats) Effectiveness: Low (50%) Yearly cost: \$131.56	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Yearly cost: \$16.65	Effort: 28.6% (Approx. 14 boats) Effectiveness: Low (20%) Yearly cost: \$5.26
Sandabacka (DOW: 01000300) County: Aitkin	Effort: 14.3% (Approx. 10 boats) Effectiveness: Low (50%) Yearly cost: \$180.18	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Yearly cost: \$22.81	Effort: 28.6% (Approx. 19 boats) Effectiveness: Low (20%) Yearly cost: \$7.21
Dutch (DOW: 01000400) County: Aitkin	Effort: 14.3% (Approx. 14 boats) Effectiveness: Low (50%) Yearly cost: \$274.56	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Yearly cost: \$34.75	Effort: 28.6% (Approx. 28 boats) Effectiveness: Low (20%) Yearly cost: \$10.98
Rice (DOW: 01000500) County: Aitkin	Effort: 14.3% (Approx. 27 boats) Effectiveness: Low (50%) Yearly cost: \$535.63	Effort: 0.1% (Approx. 1 boats) Effectiveness: Low (70%) Yearly cost: \$66.88	Effort: 28.6% (Approx. 53 boats) Effectiveness: Low (20%) Yearly cost: \$29.81

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Submit ↗

Other resources:
Minnesota Aquatic Invasive Species Research Center (MAISRC)
Find out more about the MAISRC research behind this tab.

An overview of the user's selections are provided in the summary for each lake of interest. The summary includes the effort and effectiveness of each intervention applied at each lake as well as the total annual cost per lake.