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## Proof of Freedom

Pre-border measures and border control protocols constitute critical components in mitigating biosecurity risks, although complete threat elimination remains unattainable. In regions potentially exposed to biological threats, regulatory authorities implement comprehensive surveillance systems as their primary risk management framework. These systems are designed to facilitate early detection protocols, enabling authorities to identify and respond to potential outbreaks before they escalate to levels that could precipitate significant economic disruption, social instability, or environmental degradation.

Surveillance systems also serve a crucial verification function, establishing and maintaining documentation of disease-free status within specified regions or area freedom. Statistical “Proof of Freedom” methods are utilised to verify area freedom status given surveillance data. These verification methods are instrumental in both preserving existing trade relationships and facilitating the restoration of market access following biosecurity incidents.

Biosecurity Commons provides a Proof of Freedom (PoF) workflow that enables users to statistically support claims of area freedom given data from surveillance systems. Utilising either temporal detection records or estimated sensitivities (detection probabilities) of surveillance systems, the PoF workflow can be used to determine the iterative confidence in area freedom provided by a surveillance system over time or multiple applications of the system. Alternatively, the workflow can be used to determine the time, or number of reapplications, required for a surveillance system to provide sufficient evidence of area freedom at a specified confidence level (e.g. 95%).

The Proof of Freedom workflow provides two statistical methods for supporting area freedom:

1. **Hypothesis test PoF:** Formulates a hypothesis that the undetected species is still present with probability  $p$ , which is calculated iterative using surveillance data. If the probability of presence is sufficiently low (e.g.  $\leq 0.05$ ), then we can reject the hypothesis, thus supporting an area freedom claim (e.g. with 95% confidence).
2. **Bayesian PoF:** Uses Bayes theorem to iteratively calculate the probability, or confidence, of freedom if undetected using surveillance data as well as an estimate of the prior probability of freedom. An uninformed prior of 0.5 will result in similar iteratively increasing confidence as the hypothesis method, whereas prior values greater than 0.5 achieve higher confidence in fewer iterations.

For more details about the Proof of Freedom workflow please see the [PoF support article](#).

## Linkages to other workflows

Proof of Freedom (PoF) results can be used to inform the adequacy of a surveillance design allocation produced via a Surveillance Design workflow. The overall sensitivity of a surveillance design allocation may be utilised as an input in the Proof of Freedom workflow. If inadequate area freedom confidence levels are achieved via PoF analysis of the design, then the surveillance design may need to be revisited and adjusted, such as increasing the surveillance allocation.

## Creating a Proof of Freedom Analysis

### Step 1. Create a new project

Select the Proof of Freedom (PoF) workflow and then select “Create a new Project” (see screenshot below).

When creating a new PoF project, users have the option to select an empty template, initially titled “Proof of Freedom”, which can be renamed appropriately, or one of a range of prepopulated templates that have been constructed as examples of the workflow or based on previous case studies (e.g. “Mouse-ear hawkweed Bayesian PoF”).

The empty template is ideal for those wishing to create a brand-new Proof of Freedom analysis as it contains:

- The basic structure of the Proof of Freedom workflow
- No preloaded datasets

By contrast, example templates provide users with the opportunity to see a completed demonstration of how Proof of Freedom analyses can be produced, or if based on a real-world case study, how others have attempted to create a model.

Select a template and then give your project an appropriate title. Users can optionally provide additional descriptive details under the Description, Species name and Species type fields. These metadata are presently unused but will provide future flexibility in filtering and summarising projects.

Once details have been provided, click the green “Create a new Project” button in the bottom right-hand corner to continue.

The screenshot displays the Biosecurity Commons interface for creating a new 'Proof of Freedom' project. At the top, the Biosecurity Commons logo is on the left, and navigation links for 'Workspace', 'Datasets', and 'Workflows' are in the center. On the right, there are links for 'Quick start guide' and a 'Demo' dropdown menu. Below the navigation bar, the page title is 'All projects Proof of Freedom'. A secondary navigation bar includes '+ Create a new Project', 'My Projects', and 'Shared With Me'. The main content area is split into two columns. The left column, titled 'Workflow Template (required)', lists five templates. The first is 'Proof of Freedom (empty project)'. The second is 'Example Bayesian PoF with detection probability' with an orange 'demo' tag. The third is 'Mouse-ear hawkweed Bayesian PoF' with an orange 'demo' tag. The fourth is 'Medfly 5000 traps' with green tags for 'species-name Ceratitis capitata' and 'species-type pest'. The fifth is 'Example hypothesis test PoF with detection record' with an orange 'demo' tag. The right column is titled 'Fill in the following information to create a new Project for this workflow.' and contains a form. It includes a note: 'This project will be saved in "My Projects". You can continue work on a project at any time.' The form has four fields: 'Project Title (required)' with the value 'Proof of Freedom'; 'Description' with the value 'Proof of Freedom'; 'Species name' with the label 'Invasive species (or genus) name' and an empty text box; and 'Species type' with the label 'Type of invasive species' and a dropdown menu. A green '+ Create a new Project' button is located at the bottom right of the form area.

When you start a Proof of Freedom workflow from an empty template you will be presented with the core elements of the PoF workflow on the left side of the screen – “Context”, “Method” and “Proof of Freedom”. Orange exclamation points indicate steps that require attention and, as you progress through the project, these change to green ticks when complete.

## Step 2. Specify your context

Select appropriate details of the context of the surveillance that your PoF is being used to analyse, including:

- **Surveillance type:** The type of surveillance utilized in the design (e.g. surveys, traps, samples)
- **Surveillance quantity unit:** The unit to express quantities of surveillance (e.g. units, hours, traps, samples)
- **Cost unit:** The unit to describe surveillance, management, and/or benefit costs (e.g. \$, hours)
- **Distance/area unit:** Unit for distances or areas where applicable (m or km)
- **Time unit:** Unit for time measures where applicable (years, months, weeks, days, etc.)

The screenshot shows the 'Proof of Freedom' configuration interface. The left sidebar contains a navigation menu with 'Context' selected. The main panel displays 'Context' settings for 'Input Parameters'. The settings include:

- Surveillance type \***: The type of surveillance utilized in the design. Dropdown menu: survey.
- Surveillance quantity unit \***: The descriptive unit to describe surveillance resource quantities. Dropdown menu: hours.
- Cost unit \***: The descriptive unit to describe surveillance resource costs, and incursion management costs or surveillance benefit savings. Dropdown menu: hours.
- Distance/area unit \***: The descriptive unit to describe spatial distances (and areas) when applicable. Dropdown menu: meters.
- Time unit \***: The descriptive unit to describe surveillance time intervals when applicable. Dropdown menu: years.

At the bottom of the main panel, there is a green 'Save' button and a 'Reset' button.

“Save” your selections when finished.

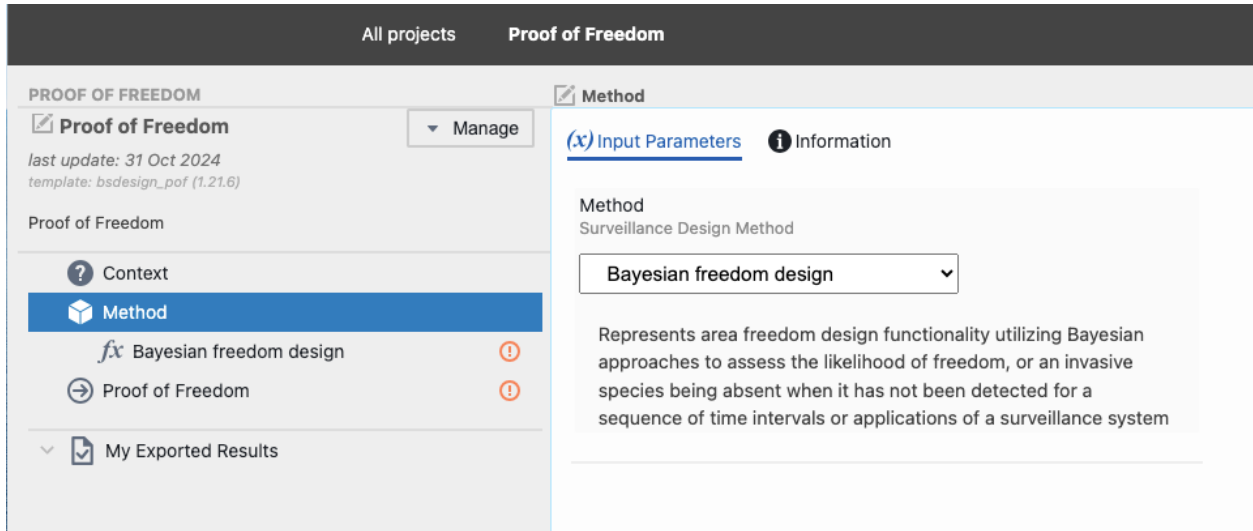
### Step 3. Specify your method

Select your Proof of Freedom method. Currently the following methods are available:

1. **Bayesian freedom design**
2. **Hypothesis testing freedom design**

These methods were described in the first section of this document.

Extended Proof of Freedom methods are anticipated in future versions of the Biosecurity Commons platform.



Depending on the Proof of Freedom method the user selects, different options will become available.

### OPTION 1. Bayesian freedom design

Selecting “Bayesian freedom design” will prompt users to specify the following:

- **Detection input** (*Required*): The type of surveillance data used for the PoF analysis (also determines method alternatives). Choose from:
  - Detection record
  - Detection probability

Results in dynamic inputs:

- Detection record [*when “Detection record” selected*]: CSV table of temporal recording when the invasive species was detected/sighted at previous intervals
- Probability detect [*when “Detection probability” selected*]: The probability of detecting the invasive species given its presence. Also known as system sensitivity or detection confidence for a surveillance system
- Probability persist [*when “Detection probability” selected*]: The probability that the invasive species persists at each time interval. Default is 1 implies that the invasive species will persist across time intervals if present, representing the worst-case scenario when persistence probability is unknown
- **Probability freedom** (*Required*): The prior probability of invasive species freedom or absence used in the first iteration of the Bayesian process. Values are typically estimated via expert elicitation. Default is 0.5 for an uninformed prior

- **Stopping condition (Required):** Determines the condition for stopping the iterative PoF process and producing results for each iteration. Choose from:
  - Number of iterations
  - Target confidence

Results in dynamic inputs:

- Iterations [when “Number of iterations” selected]: The number of time intervals, or sequential surveillance system applications, used to estimate the likelihood of area freedom
- Confidence [when “Target confidence” selected]: The target confidence level (e.g. 0.95) in area freedom, or the probability of freedom (absence) given a sequence of no detection via a surveillance system

The screenshot shows the 'Bayesian freedom design' interface. On the left is a sidebar with navigation options: Context, Method, Bayesian freedom design (selected), DETECTION RECORD (Example PoF detection record), Proof of Freedom, and My Exported Results. The main area is titled 'Bayesian freedom design' and contains 'Input Parameters' and 'Information' sections. The 'Input Parameters' section includes a 'Probability freedom \*' field with a value of 0.6, a 'Stopping condition \*' dropdown set to 'Target confidence', and a 'Confidence' field with a value of 0.95. There are 'Save' and 'Reset' buttons at the bottom. On the right, an 'Example PoF detection record' table is displayed:

	detected*	interval*
1	1	1
2	0	2
3	1	3
4	0	4
5	0	5
6	1	6
7	0	7
8	0	8
9	0	9
10		

“Save” your selections when finished.

## OPTION 2. Hypothesis testing freedom design

Selecting “Hypothesis testing freedom design” will prompt users to specify the following:

- **Detection input (Required):** The type of surveillance data used for the PoF analysis (also determines method alternatives). Choose from:
  - Detection record
  - Detection probability

Results in dynamic inputs:



- Detection record [*when “Detection record” selected*]: CSV table of temporal recording when the invasive species was detected/sighted at previous intervals
- Probability detect [*when “Detection probability” selected*]: The probability of detecting the invasive species given its presence. Also known as system sensitivity or detection confidence for a surveillance system
- Probability persist [*when “Detection probability” selected*]: The probability that the invasive species persists at each time interval. Default is 1 implies that the invasive species will persist across time intervals if present, representing the worst-case scenario when persistence probability is unknown
- **Probability freedom** (*Required*): The prior probability of invasive species freedom or absence used in the first iteration of the Bayesian process. Values are typically estimated via expert elicitation. Default is 0.5 for an uninformed prior
- **Stopping condition** (*Required*): Determines the condition for stopping the iterative PoF process and producing results for each iteration. Choose from:
  - Number of iterations
  - Target p-value

Results in dynamic inputs:

- Iterations [*when “Number of iterations” selected*]: The number of time intervals, or sequential surveillance system applications, used to estimate the likelihood of area freedom
- Confidence [*when “Target p-value” selected*]: The threshold probability (e.g. 0.05) for rejecting the null hypothesis that the invasive species remains present given a sequence of no detection via a surveillance system

All projects    **Proof of Freedom**

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**PROOF OF FREEDOM**    **Hypothesis testing freedom design**

**Proof of Freedom**    Manage

*last update: 31 Oct 2024*  
*template: bsdesign\_pof (1.21.6)*

Proof of Freedom

- Context
- Method
- $f_x$  Hypothesis testing freedom design** ⓘ
- Proof of Freedom ⓘ

My Exported Results

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**Probability persist**  
The probability that the invasive species persists at each time interval (specified by the 'time\_unit' parameter in the 'context'). Default is 1 implies that the invasive species will persist across time intervals if present, representing the worst case scenario when persistence probability is unknown. Only utilized when 'pr\_detect' is given. Temporally changing values may be provided by a numeric vector, the length of which should be sufficient for the expected number of 'iterations', given the specified stopping criteria, else the last value of the vector is repeated

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**Stopping condition \***

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**P value**  
The threshold probability (e.g. 0.05) for rejecting the null hypothesis that the invasive species remains present given a sequence of no detection via a surveillance system. Default is NULL implying that the 'iterations' parameter will be utilized as a stopping mechanism

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“Save” your selections when finished.

## Step 4. Run your Proof of Freedom Design!

Once the Context and Method branches have been successfully configured you will be able to run your Proof of Freedom Design, which will calculate the evidence or confidence of area freedom for the appropriate number of iterations, given the stopping condition.

Click the blue 'Run' button in the bottom left to run your project. The output page will be updated as the job progresses from "Created", "Submitted", "Started" and "Success".

Once it has finished, a green tick will appear next to Proof of Freedom.

The model output will automatically be displayed as a viewable table in the output pane, either:

- **Proof of Freedom - Confidence** (if Bayesian method was used): a table of area freedom confidence (*probability of freedom if undetected*) for each iteration

All projects    **Proof of Freedom**

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**PROOF OF FREEDOM** ✍ Proof of Freedom

✍ **Example Bayesian PoF with detection probability** Manage

*last update: 7 Oct 2024*  
*template: bsdesign\_pof (1.21.6)*

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? Context

📦 Method

*fx* Bayesian freedom design

👁 **Proof of Freedom** ✔

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∨ 📄 My Exported Results

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⏪ **Run (Proof of Freedom)** ▲  
An output is available

📄 Outputs ℹ Information

☰ All data 📄 **Proof of Freedom - Confidence**  
*confidence.csv*

	iterations	confidence
1	1	0.952217987074022
2	2	0.997488322118572
3	3	0.999873663363346
4	4	0.999993659704657
5	5	0.999999681843966
6		

📄 **Export to 'My Results'**

OR

- Proof of Freedom - Evidence (if hypothesis testing method was used): a table of p-values for each iteration, indicating the likelihood of undetected presence, thus providing greater evidence for claiming area freedom as the p-value becomes smaller (less likely)

All projects      **Proof of Freedom**

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**PROOF OF FREEDOM**      **Proof of Freedom**

**Example hypothesis test PoF with detection record**      Manage

*last update: 7 Oct 2024*  
*template: bsdesign\_pof (1.21.6)*

**Context**

**Method**

fx Hypothesis testing freedom design

DETECTION RECORD  
Example PoF detection record

**Proof of Freedom** ✓

My Exported Results

**Run (Proof of Freedom)** ▲  
An output is available

**Outputs**      Information

All data      Proof of Freedom - Evidence  
evidence.csv

	iterations	evidence
1	1	1
2	2	1
3	3	1
4	4	1
5	5	1
6	6	1
7	7	0.629737609329446
8	8	0.421875
9	9	0.296296296296296
10	10	0.216
11	11	0.162283996994741
12	12	0.125
13	13	0.0983158852981338
14	14	0.0787172011661808
15	15	0.064
16	16	0.052734375
17	17	0.04396499084062...
18		

**Export to 'My Results'**

Clicking on the “All data” button allows users to view and download all the outputs.

These sampling surveillance design outputs include:

- **Proof of Freedom - Confidence** (if Bayesian method was used) – A csv containing the area freedom confidence (probability of freedom if undetected) for each iteration
- **Proof of Freedom - Evidence** (if hypothesis testing method was used) – A csv containing p-values for each iteration, indicating the likelihood of undetected presence, thus providing greater evidence for claiming area freedom as the p-value becomes smaller (less likely)
- **Job script** – A copy of the R script used to build the risk map
- **Log file** – A text file containing processes, messages, and other details associated with model runs

- **Metadata** – A .json file containing the metadata required to run the model on Biosecurity Commons
- **Input parameters** (*All models*): Input parameters required to run the Job Script

The screenshot displays the 'Proof of Freedom' project page in the Biosecurity Commons interface. The page is divided into a left sidebar and a main content area.

**Left Sidebar:**

- Project title: **PROOF OF FREEDOM**
- Job title: **Example hypothesis test PoF with detection record** (with a 'Manage' button)
- Metadata: *last update: 7 Oct 2024*, *template: bsdesign\_pof (1.21.6)*
- Navigation menu: Context, Method, Hypothesis testing freedom design (expanded), DETECTION RECORD (Example PoF detection record), **Proof of Freedom** (selected), My Exported Results
- Run button: **Run (Proof of Freedom)** (with a status indicator: 'An output is available')

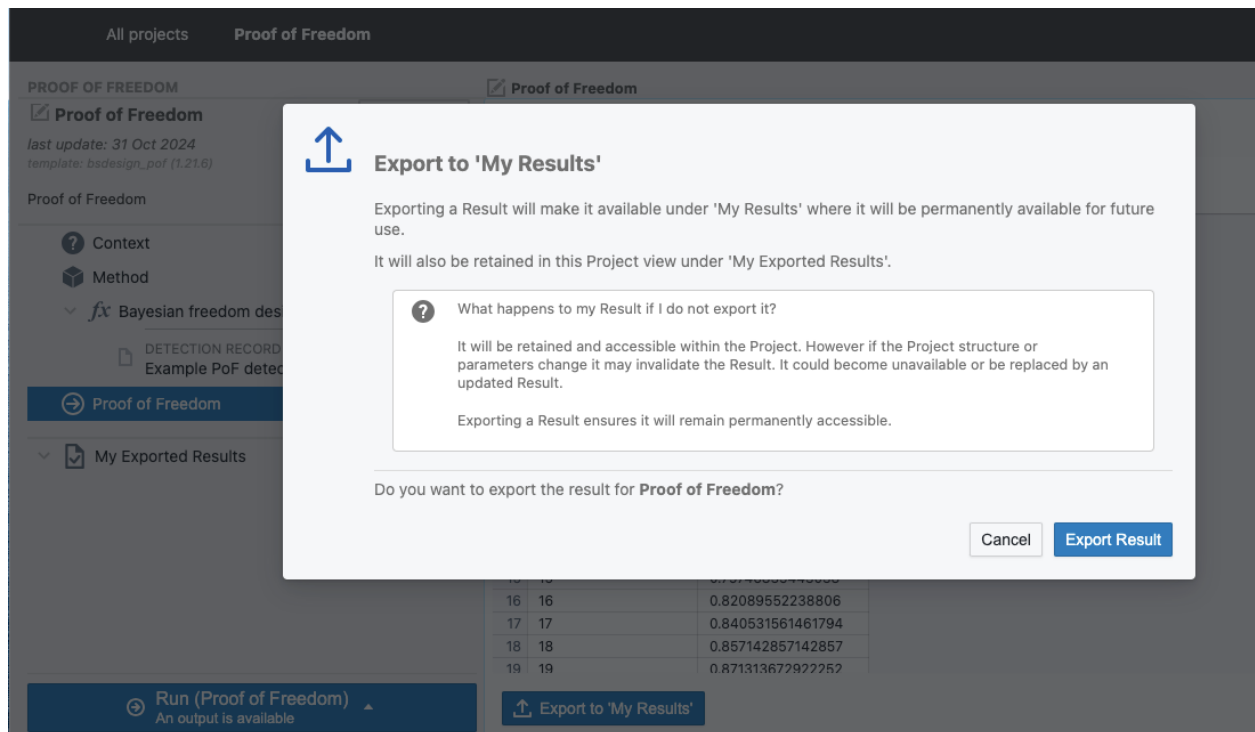
**Main Content Area:**

- Project name: **Proof of Freedom**
- Navigation: **Outputs** (selected), Information
- View job info (with 'Download all' and 'Mode' options)
- Output list:
  - Proof of Freedom - Evidence (evidence.csv) [Download] [View]
  - Job script (bsdesign\_pof.R) [Download] [View]
  - Log file (bsdesign\_pof.Rout) [Download] [View]
  - Metadata (metadata.json) [Download] [View]
  - Input parameters (params.json) [Download] [View]
- Export button: **Export to 'My Results'**
- Page indicator: **1**

## Step 5. Exporting outputs for use in other workflows

Users may wish to export outputs for use in other projects or other workflows.

To do this, view the output of interest, and select “Export to My Results” in the bottom left corner of the interactive map.



This output will now be discoverable in the user’s “My results” database, which in turn makes the layer available for use in other workflows.

