Processing Camera Trap Data with CamTrap Pro

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CamTrap Pro Overview

CamTrap Pro can add tags to files and produce a map-based or text report of animals found in collections of camera trap images as detection events over a period of days or weeks. Detection events occur when an animal appears in a single image, or a sequence of images where the time between successive images does not exceed a specified duration (commonly 10 minutes). Detection of animals can be performed by visual inspection, simple time and pixel-based algorithms or machine vision models. Results from classifiers using the generic Megadetector mode (such as EcoAssist) can be loaded as JSON files. Classification results can be applied without the host computer needing an Nvidia GPU. Species-specific models can be used by EcoAssist and tags automatically generated from classification results.

Installing and Running CamTrap Pro

CamTrap Pro can be downloaded from
https://captionpro.com.au:444/AlekaConsulting/index.php/camtrap-pro-download-form/
CamTrap Pro processes only JPEG format image files taken from camera traps. It adds Windows tags to files, optionally from a fixed range of values, and summary and occurrence reports of tagged files can be generated and exported. Images containing animal images are detected and flagged using JSON files generated by machine learning programs such as EcoAssist. These images may constitute a very small proportion of images recorded by camera traps. Tagging of images containing animals with the animal identity can be performed visually or using a species-specific image classifier, and can be applied directly to recorded images, or to the subset containing animals as detected via machine learning using the Megadetector model. A tutorial video for CamTrap Pro operation can be viewed here.

Camera Trap Data

Camera trap data comprises a large number of digital image (and sometimes video) files collected by cameras triggered by a relative change in the levels of infra-red radiation reaching a sensor from two halves of an image field. Changes may be produced by an animal entering the field of view of the sensor, or by movement of objects or shadows within the sensor field. An infra-red flash is used to record monochrome images from triggerings occurring at night. When triggered, the camera may record single images, a sequence of images or a short video when triggered. Data is commonly stored on a removable SD card as JPEG format images, and traps may be active for many days between data collections. The date and time recorded by the camera (and possibly other local information) is shown in a bar above or below the image. Dates and times may not correspond to the actual time of image collection, as the camera local time may not be correctly set. Image file names usually contain a number which increases sequentially. An example of an image obtained with such a camera during daytime is shown below:

Figure 1 Daytime Camera Trap image of a rabbit

An image recorded at night is as shown below:

Figure 2 Night-time Camera Trap Image of a Cat

Although the appearance or movement of animals occupying a significant proportion of the sensor field will trigger the camera, movements of leaves, grass, camera position or changes in solar illumination will also trigger the camera, resulting in the images recorded not showing any animals. These non-animal triggerings may constitute up to 95% of the images recorded. Triggerings from the presence of animals which are not of primary interest (such as foxes) may also comprise a significant proportion of images recorded. Changes in the physical environment of the sensor field (such as removing grass and branches affected by wind) may help reduce non-animal triggerings, but may result in animals avoiding the area.

If a bait (which may be peanut butter, sesame oil or carrion) is included within the camera field of view, animals such as foxes or crows may spend considerable time moving around in order to eat it, resulting in large numbers of images of the same animal appearing in sequential images, closely spaced in time. The images below show a fox circling a bait.

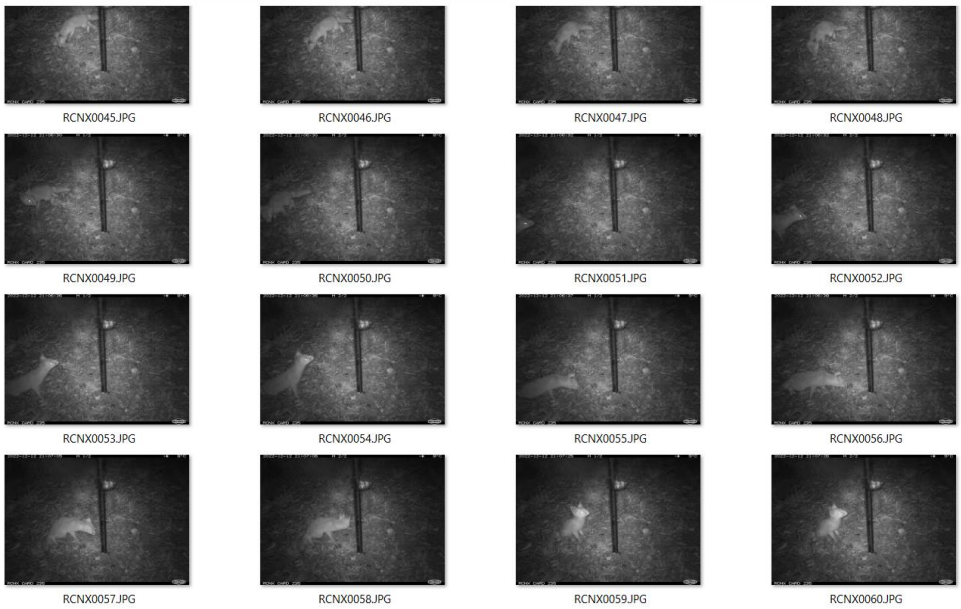


Figure 3 Fox circling a bait

Non-baited traps in highly modified environments lacking extensive vegetation cover (such as urban areas) have a low rate of non-animal triggering. Datasets may cover many months (presumably with periodic battery changes) and record numerous short detections as animals move across the camera field of view. Longer detections occur, but are rarer. A section of such a dataset is shown below:

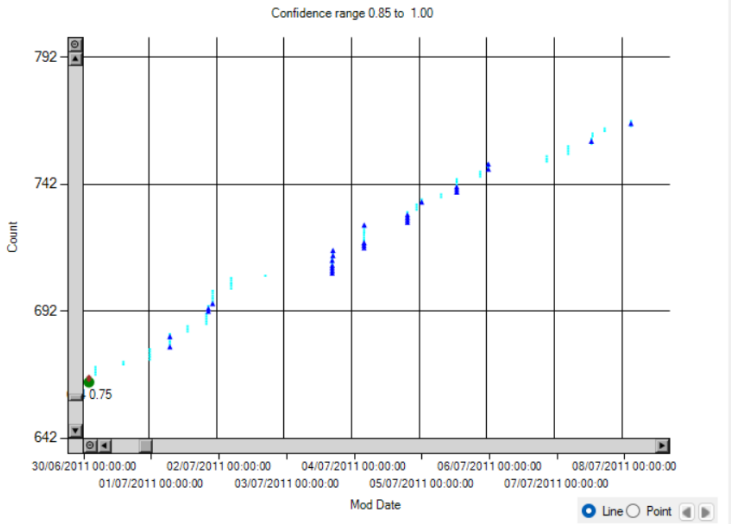


Figure 4 9-day section of a 1-year Count vs Time Profile of an Urban, Non-baited Dataset

Automated methods of detecting the presence of animals in an image using machine learning have been developed, notably MegaDetector, which can be run from the EcoAssist application. EcoAssist requires a powerful local machine with at least 16 Bytes of RAM. An Nvidia Graphics Processing Unit (GPU) greatly speeds processing. EcoAssist can use MegaDetector in generic mode, where it detects any animal, or it can be trained to identify particular species. Training a detector requires very large numbers of training images and is prohibitively slow on machines which do not have an Nvidia GPU, but application of detectors is possible on such machines.

Machine learning facilities such as Megadetector are highly effective for common animals, but require substantial computing resources. By contrast, non-fatigued human vision is fast and extremely accurate in detecting animals, but the task of detecting animals in the thousands of images taken even by a single camera is daunting, and some projects may use dozens of cameras. CamTrap Pro has been designed to facilitate inspection of large numbers of camera trap images and tagging of images in which animals appear using the Windows Tags field to store the species names of animals appearing. Some simple detection algorithms which do not require training are provided, as well as an interface to results obtained from Megadetector or a custom classifier. Megadetector is used only to detect the presence of animals. Tagging to indicate which species are present can done visually or using a custom classifier. The 8000-image, 10-month dataset shown in part in Figure 4 from a non-baited trap in a highly modified area with little vegetation records animal detections in most images, but only a few detections each day. Such datasets are best analysed using a species-specific classifier to identify the species of detected animals.

CamTrap Pro Data Requirements and Processing

In order to use CamTrap Pro for camera trap analysis, images in JPEG format should be within a folder structure on storage which is not read-only, as numerous temporary files are created in the image data folder. If the selected folder is read-only, no files are loaded. For multi-camera data sets, the images should be stored 1 or 2 levels below a folder whose name represents the camera identity. If individual images have EXIF Date or Windows Modified Date metadata the images can be sorted in time order. The image Modified date may reflect the time of processing rather than the time of image collection, but this date can be reset within CamTrap Pro if required.

Camera trap data from many cameras collected over multiple time periods may be organised by grouping images from the same camera, or the same time period or both. To make best use of the time profile capability of CamTrap Pro, data should be organised by camera (or by site if different cameras are used at the same site. Shortcuts to folder can be used to do this without changing the organisation of the original data. The images should be in a folder structure as shown below.

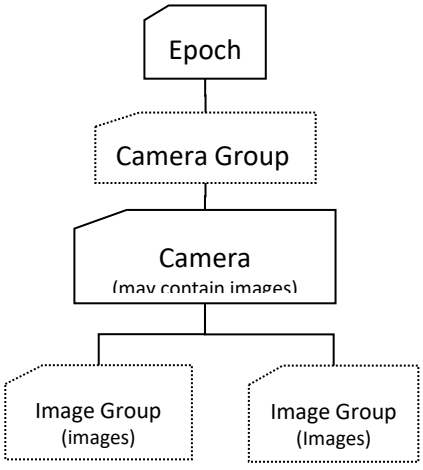


Figure 5 Folder Tree Structure

Folders with dotted borders are optional, but Image Group folders are commonly present. Image Group folders contain up to a fixed number of files (either 100, 1000, or 10000) with the folder name containing a sequential number starting at 100 in the manner of digital cameras. When additional images are added and the number of files in the Image Group exceeds its limit, a new folder is created

and file sequence numbers restart. Details of the folder structure should be set in the Options->General tab.

Images may be contained directly in camera folders, and there may be groups of cameras at the same site (identified by the Camera Group folder) to facilitate detection of individual animals by their body or face markings. Each camera folder should have a unique name. The Epoch folder should contain images collected over a period of time. The name of the Epoch folder is used for correcting Modified date/time values.

CamTrap Pro will operate if this structure is not present, but functionality such as Camera Info or time setting using Epochs will not work.

Some examples of folder structures are shown below:

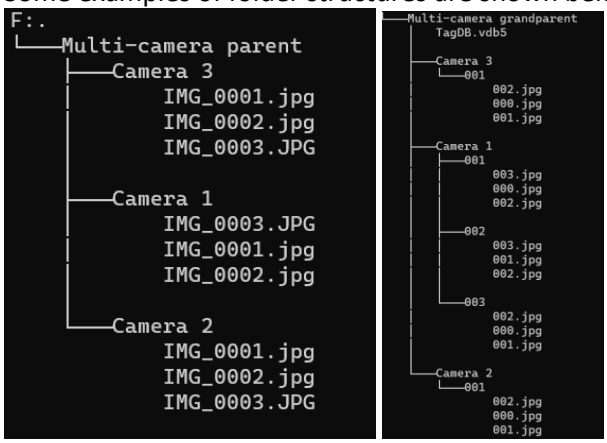


Figure 6 Example of multiple camera folder trees using parent (left) and grandparent (right) structures.

The parent (or grandparent) folder of the camera folder is the epoch, or time period over which all the images below it were recorded. An example is shown below:

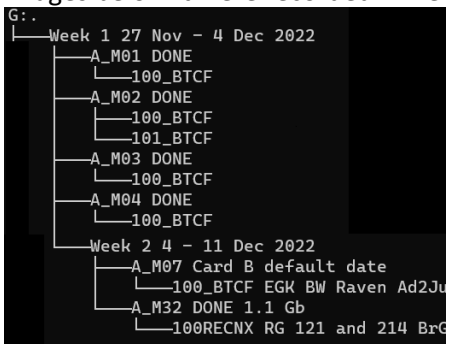


Figure 7 Folder structure showing epoch, camera and image group folders

Two epochs (Week 1 27 Nov- 4 Dec 2022 and Week 2 4-11 Dec 2022) are shown, with 4 camera folders during the first epoch and 2 in the second. Data can be processed either by individual camera or collectively.

A database storing tag occurrence data (TagDB_EpochName_CameraName_.vdb5) is created in in the folder above the folder containing the first image file. EpochName and CameraName are as defined in Options. This database should not be deleted.

Progress bars are shown for long-running operations, but the estimated run duration may not be accurate. Storage speeds strongly affect processing times, so any external storage should have a high access speed. Solid state drives generally have faster access speeds than magnetic drives.

Reviewing Camera Trap Data with CamTrap Pro

Camera traps may be used in a wide range of purposes including feral animal monitoring, species monitoring, density estimation, and game detection. They may be located in highly accessible areas, where scenes may frequently include vehicles and humans, or off-track where moving objects are much more likely to be animals (or birds). Baits (peanut butter, sesame oil or carrion) may be used to attract animals into the camera scene. Multiple cameras are usually deployed.

An indicator of the presence of animals in a baited camera trap is to examine the cumulative time profile of all the images. As animals often spend some time moving around the bait, the camera is triggered multiple times with a very short interval between images. Profiles of image count as a function of time and the same profile with visually assigned animal detections marked in red (shown by checking Analysis->ShowTagged) is shown below:

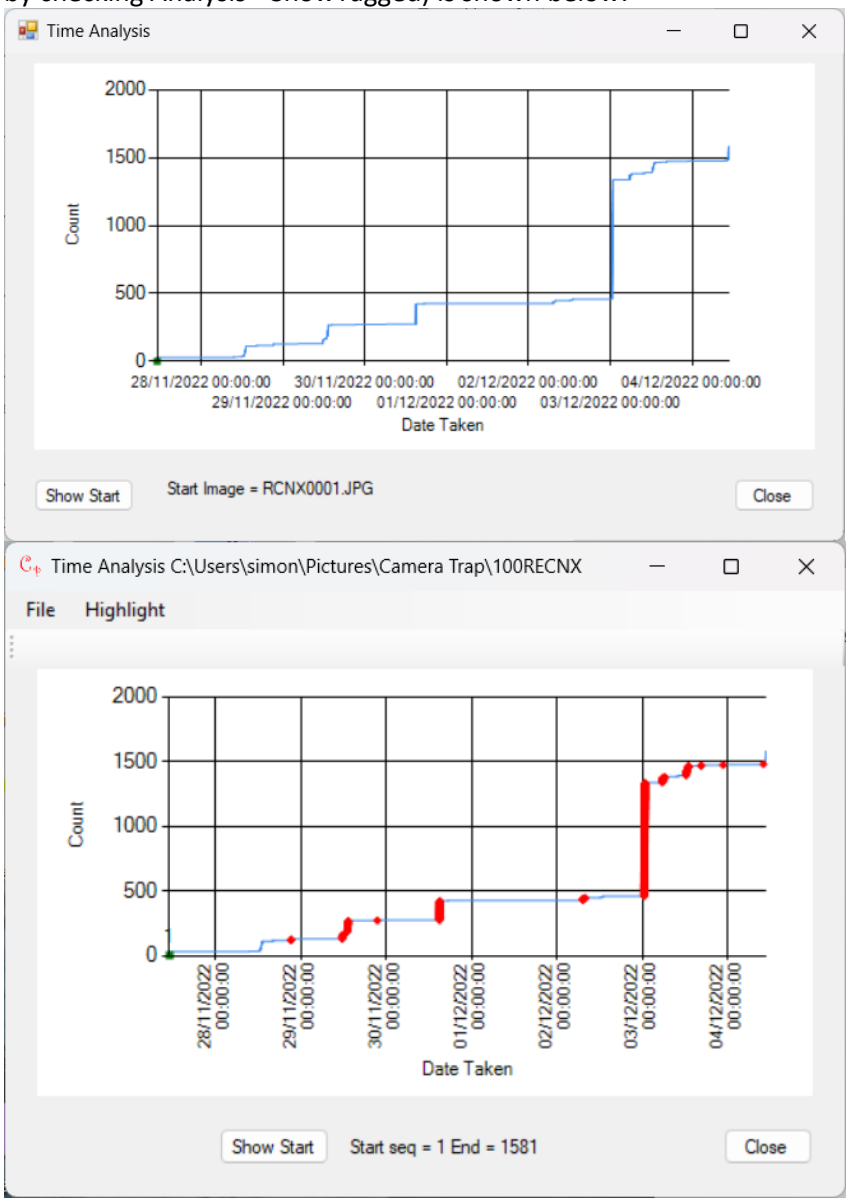


Figure 8 Image count vs time over 7 days (top) with one or more animal detections shown in red (bottom)

It may be seen that animal detections are associated with a rapid increase in image count over a short period appearing as a vertical step, and that almost all camera triggerings are due to the presence of an animal.

A plot for a different data set over a similar period with mainly false triggerings, and animal detections shown in red, is shown below:

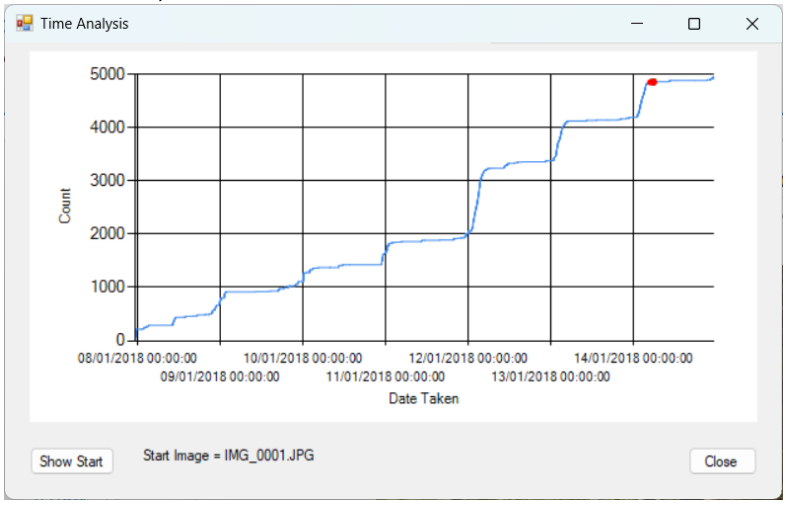


Figure 9 Image count vs time over 7 days with a single animal detection shown in red.

This data set (from a baited camera) only recorded a single animal over 8 images out of 5000 collected over a 7-day period. The animal was not attracted to the bait. Most triggerings were from moving vegetation or changing shadow areas. Triggerings were less frequent at night, giving rise to the stepped profile.

A data set from a single day using a non-baited trap is shown below:

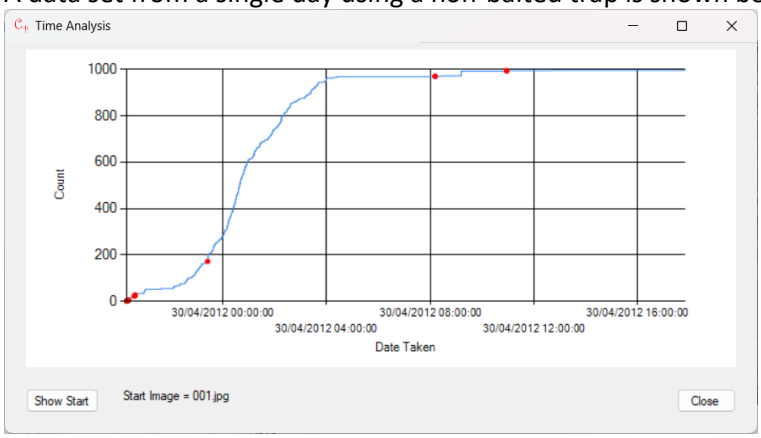


Figure 10 Image count vs time over a single day, with animal detections shown in red.

As non-baited traps only record animals passing, detections are less distinctive amid false triggerings from moving vegetation or shadows. Few images of animals are recorded. The step shown at 0900 hrs is from multiple triggerings when an animal passed very close to the camera, but the incomplete and unfocussed view meant that the animal could not be identified.

Data Required from Processing

Data required from a camera trap data set is the species of animal detected, and sometimes the frequency of detection, or the identity of the animal. This data can be obtained by inspection of individual images using built-in computer facilities, and then adding metadata (usually as tags) to indicate the presence of an animal in an image. This process is very labour-intensive and without a large and competent volunteer labour force it is not an option, especially when a single camera may record thousands of images in a single day. Automated methods using machine learning (such as Megadetector) provide an alternative. The implementation of Megadetector in CamTrap Pro only identifies images containing animals – species labelling must be done manually, or a species-specific classifier can be used.

Using CamTrap Pro to Examine Camera Trap Data

Where file Modified Date is the same as Date Taken, processing will be faster if File Order in Folders is set to Modified Date or Folder->Modified. Pre-set text strings should be created to include the names of all animals expected to be detected. If individual animals are to be identified, specific names should be added (eg Goanna Rex). Unexpected animals may be added to pre-sets during inspection.

Loading Data

Camera trap images are usually contained in one or more folders per camera or site with filenames which include a sequence number in the manner of images from digital cameras. There may be multiple folders for the same camera corresponding to different time periods or different locations. Camera folders are usually the parent or grandparent folder of the image files. The time period over which images below a folder is known as the epoch and is usually the folder containing the camera folders. Either of these can be selected in the Options screen. The image filenames usually contain a sequence number, and may include a constant string or a representation of the date on which the image was taken. The date on which the image was taken is often stored in one or more of the EXIF date fields (Date/Time, Date/TimeOriginal, and Date/TimeDigitized). One of these dates is shown in Windows File Explorer as the image date. The file Modified date will be the same as this date unless the file has been processed in some way. Any folders containing images to be processed should not include the string .jpeg or .jpg in their name, as this may cause external programs such as EcoAssist to crash. If file Modified dates are to be changed, files should not be read-only.

The File menu of CamTrap Pro is shown below:

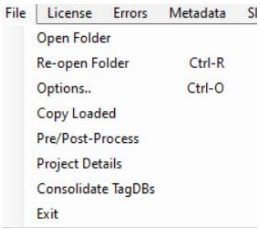


Figure 11 File Menu

After Opening or Re-opening a folder, a screen is shown allowing a subset of camera folders to be processed where there is more than one camera folder below the selected folder:

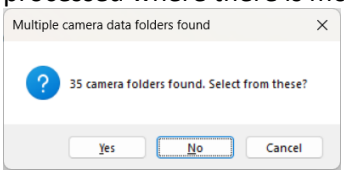


Figure 12 Multiple camera folder screen

Clicking Cancel aborts the loading process and clicking Yes allows camera folders to be selected from the screen below:

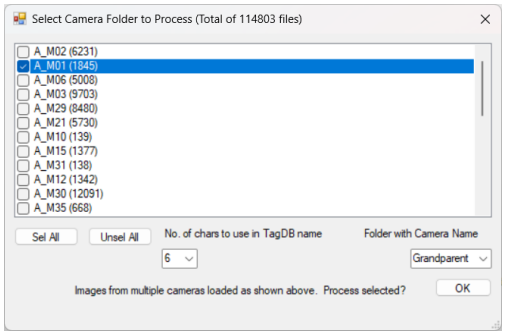


Figure 13 Camera Data Selection Screen

The File count in each camera folder is shown in brackets after the name. Either the Parent of Grandparent of the image files can be selected as well as the camera name. Data may be grouped by epoch of recording and then by camera or site. A site may use the same camera for a number of epochs, or different cameras. If data is grouped by epochs, a view of the data by camera can be created via the Re-order button in Pre/Post Processing screen.

Options – General

The Options tabs General and Advanced are shown below via File->Options:

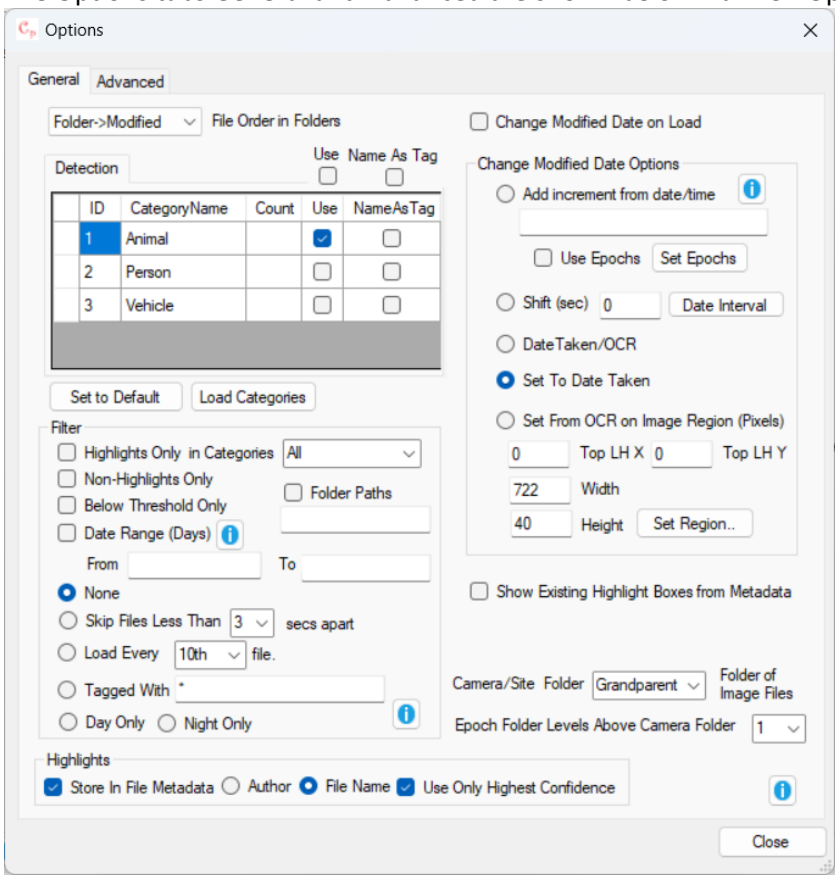


Figure 14 Options – General Tab

File Order in Folders

File Order in folders specifies the ordering of files within the selected folder as Modified Date or Folder->Modified (default). The default options order files by Modified date within camera folders. Modified date may be changed by checking the Change Modified Date on Load checkbox, using options specified in the Change Modified Date Options box.

Change Modified Date on Load

Changing the Modified date to reflect the actual date and time at which the image was recorded is useful if the count vs time profile is used and is required if highlighting is to be performed using the Changes or Sequences options. It is not required if machine learning algorithms are used to detect animals in images and only the number of images in which animals appear is required.

If the checkbox is checked, one of the following options can be selected. After loading with the checkbox checked, it is automatically unchecked.

Option	Description
Add Increment from Date/Time	Sets the Modified Date to the specified date plus the time difference between the current image Modified date and the first image loaded. If

	there is a gap between the date of the first image and the start of the recording epoch, images before the start of the recording epoch should be deleted via the Check Times Pre-Processing screen. This option can correct for camera time not being set to the time at which the camera was first triggered as it preserves the time interval between images. Date Formats can be like any of the following: **01/10/2022 22:35** **01/10/2022 10:35 PM** **1/10/2022 7:35 AM** **1 Oct 2022 10:35 PM** **Oct 1, 2022 10:35 PM** This option is disabled if Use Epochs is checked.
Use Epoch	Check to use a different specified date if the Epoch folder matches the Epoch name entered via Set Epoch and the Modified date is earlier than the Start Date of the Epoch or later than the End Date. Allowable date formats are as above. Epoch names and starting dates are specified by clicking Set Epochs.
Shift	Add or subtract a number of seconds from the existing Modified Date. Calculate button shows web site for calculating interval between 2 times.
Date Taken/OCR	Set Modified Date to EXIF or Reconyx Hyperfire directory metadata fields Date/Time, Date/Time Original or Date/Time Digitized, or File Modified Date in the File metadata directory. If neither of the preceding metadata fields are found. If this does not exist or is invalid, use OCR on a region of the image as described below.
Date Taken	Set Modified Date to EXIF or Reconyx Hyperfire metadata directory fields Date/Time, Date/Time Original or Date/Time Digitized, or File Modified Date in the File metadata directory. If this does not exist or is invalid, the Modified date is unchanged. If further change to the time is required, the Shift option can be used after Date Taken.
Set from OCR on Image Region	Get Date from OCR on region of image where date is shown. The region is selected using the Set Region button. Failed date extractions are logged in file SetDateFromImageFails.txt which is created in the loaded folder.

If this option is checked after files have been loaded in Modified Date order, the option to re-load the files to reflect the changed order is shown. The checkbox is unchecked after loading.

Set Region

Clicking this button allows selection of a file within which the date is shown as below:

Figure 15 Screen from which to select date region

Clicking and dragging and releasing shows a red box, which should contain the date region. The date region should allow for the increase in length caused by multiple digit values in the date string and should generally include the region up to the first non-date character as shown above. The top and bottom of the region include all of the data digits.

The colour of the background (black or white) should be specified, and the format of the year, month and day parts of the date string.

Clicking OK transfers the pixel dimensions of the date area to the Options screen. These values can then be edited. The Top LH Y value should not be less than zero.

Set Epochs

This screen is accessed via the Set Epochs button. It allows definition of the epoch name and range of allowable date/times, either by entering rows one at a time or pasting epoch with each epoch name and on a new line with name, start date and start date limit separated by a tab character. The Start Date Limit must be equal to or after the Start Date. If the Modified date/time of a file loaded is outside this range, Modified dates are shifted to use the Start Date specified plus the difference between the Modified date of the first file and the Modified date of the current file. This facility is used to make the Modified dates of the loaded files correspond to the date at which the photo was actually taken, which may not be the time recorded in the Date Taken metadata.

The Epoch name must exactly match the name of the Epoch folder. If the Epoch folder name is not found, the option to continue leaving Modified date unchanged or to stop loading is presented. If the recorded Modified date is before Start Date or after the End Date, then this date is used for the first image and time differences are added onto this. Epoch names, start or end dates can be added, removed or edited. Allowable date formats are as defined in Change Modified Date on Load. Update

should be clicked before closing the screen if data is not added by pasting. The Epoch name is the name of the folder 1 or 2 levels above the camera folder as defined by Epoch Levels Above Camera.

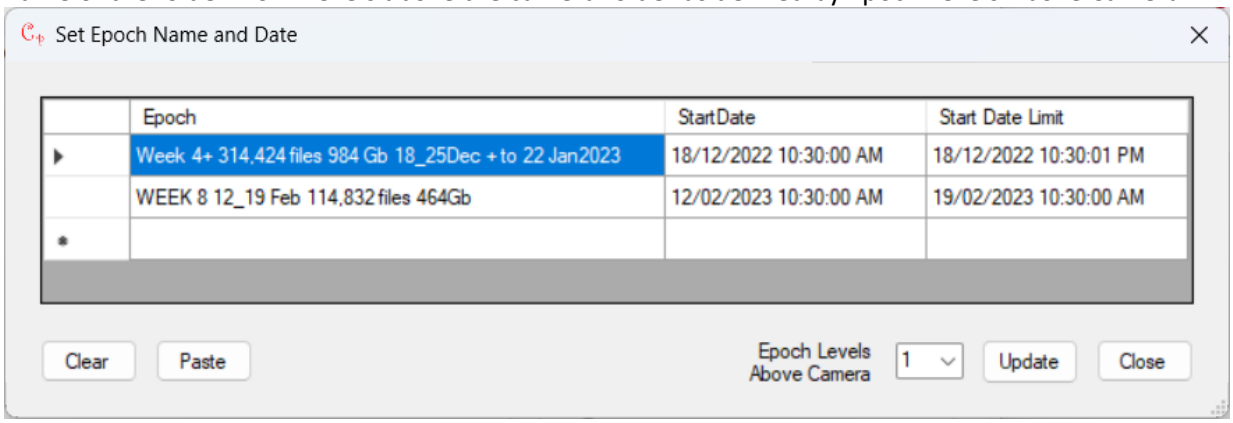


Figure 16 Epoch name, start date and start date limit definition

Detection and Name As Tag

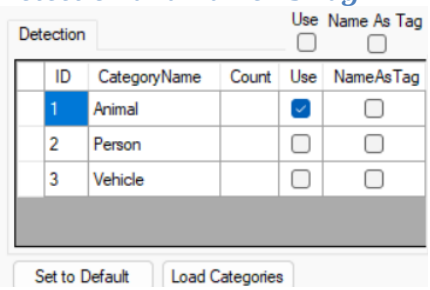


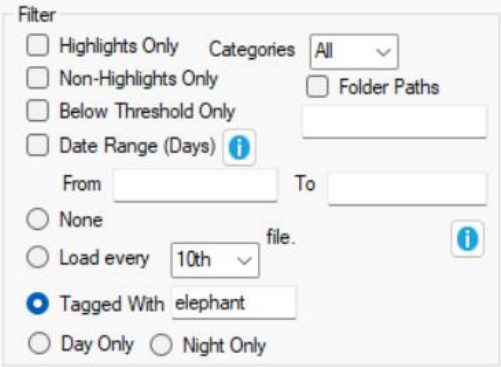
Figure 17 Detection Category Grid

The Detection grid is used to show detection category names, the number of files with detections in that category (after using Machine Learning) and whether highlight detections with the category within the range specified in Confidence Range are used, and whether category names are applied as tags. The Megadetector classifier uses IDs 1,2 and 3 for animals, humans and vehicles respectively. Classifiers which identify particular species will have their own numbering scheme as shown above, which is defined in the detection_categories node of the JSON file. The category name is shown in the 2nd column (CategoryName), the number of detections (Count) in the category in the 3rd column, whether to highlight detections with that category in the 4th column (Use), and the option to use the category name as a tag is set with a checkbox in the 5th column (NameAsTag). The Use checkbox above the grid sets or clears the Use parameter for all categories, and the Name as Tag checkbox does the same for the NameAsTag parameter.

The Set To Default button restores the default categories of animal, vehicle and person used by Megadetector. Load Categories loads the categories defined in a JSON file

The Count column is empty before any JSON file is loaded. After one is loaded, the number of detections with a particular category in the file are shown.

Filter



Highlights Only

If this is checked, only files which have had highlights created will be loaded. If highlighting from Megadetector is used, these are files where there has been a detection with a confidence between the upper and lower bounds specified. The highlight categories shown in the combo box to the right will be shown. "All" includes all highlight categories. Other single categories can be selected from the dropdown list, which shows the category name followed by its numeric code.

Non-Highlights Only

If this is checked, only files which have not had highlights created will be loaded. These will generally not contain images of animals, but will contain images of animals where the detection confidence is outside the range specified.

Below Threshold Only

If this is checked, only files with at least one detection below the lower threshold will be loaded. If any animals of interest are shown, the lower bound of the detection confidence range should be decreased. However, the number of false detections will increase.

Date Range (Days)

If this is checked, only files with Modified dates between From and To (in whole days) are loaded. The time part of any date/time entered is ignored. If To is empty, it is assumed to be 1 day after the From date. If specified, the To Date must be after the From Date. Examples of acceptable date formats are shown below:

01/10/2022
1/10/2022
1 Oct 2022
Oct 1, 2022

None

This option loads all files in the selected folder.

Skip Files Less than N secs Apart

This option skips loading for files whose Modified date is equal to or less than a specified number of seconds after its predecessor. This option can greatly reduce the number of files loaded, as there a generally a number of images showing the animal recorded as the animal moves within the camera detection area. The value for image count and duration will be affected, but not the number of detection events, which occur when an animal appears in one or more images separated by less than 10 minutes. The reduced data set can be copied using Copy Loaded and then processed using machine learning. The reduced number of files will speed processing. As detection events are used to estimate species abundance, using this filter setting will not affect abundance estimates.

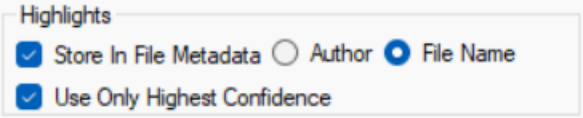
Load Every Nth File
This option reduces the number of files loaded by decimation using the selected factor and is useful for loading a sample of file to check start and end times for camera data for large data sets.

Tagged With
This option only loads files which have had a tag applied. The default * value loads files with any tag. Tag names can be matched by adding the tag name (or names) in the text box to the right of the radio button. Matching is done via Regular Expressions, so multiple names can be matched if separated by a | symbol, and partial matching is also possible. A tutorial on Regular Expressions can be found here.

Day Only
This option only loads images where a 10x10 thumbnail image is not monochrome. It is useful for detecting animals which are only active during the day. Non-monochrome images are defined as those where at least one pixel has red, green and blue pixel values which differ by more than 4. Non-monochrome images are recorded during daylight after camera triggering. This option slows loading considerably.

Night Only
This option only loads images where a 10x10 thumbnail image is monochrome. It is useful for detecting animals which are only active at night. Such images are produced at night when a change in the sensed infra-red radiation between two halves of the image triggers an infra-red flash. Monochrome images are defined as those where at no pixel has red, green and blue pixel values which differ by more than 4. This option slows loading considerably.

Folder Paths
Data sets may include hundreds of folders for different combinations of cameras, locations and epochs. This functionality allows filtering of folder names to only include folders containing specified text when the check box is ticked. Matching is done using Regular Expressions, so multiple match strings can be added if separated by a | symbol.

Highlights


Store in File Metadata
The category, confidence value and corner co-ordinates of detections in the defined range can be stored in either in file name (if the File Name is selected) or in the Author metadata field (if Author is selected) if Store In File Metadata is checked. If File Name is selected, details of each detection is added as a comma-separated string between pairs of sequential underscore characters, giving file names of the form shown below:

RCNX0118__117,1,0.968,0,0.116,0.141,0.735,__.JPG

Processing is much faster when highlight information is stored in the file name.

If the file name with detection metadata added exceeds 260 characters in length, detection metadata will be removed until the length is less than 260 characters. A warning will be logged if no metadata can be added to the name, but processing will not stop. Warnings can be viewed via the Errors top-level menu item.

Use Only Highest Confidence

If Use Only Highest Confidence is checked, only the single detection with the highest confidence is stored. If it is not checked, multiple detections in the same image may be stored, sometime resulting in excessively long file names, is metadata is stored in the file name. Note that multiple animal detections will still be stored and be visible in Tag Occurrences if this option is checked.

Show Existing Highlight Boxes from Metadata

Checking this checkbox examines metadata for all loaded files to see if highlight data is stored and allows display of highlight detection boxes without reloading a JSON file. However, checking this option slows file loading considerably.

Camera/Site and Epoch Folders

Camera trap data from multiple cameras is usually stored as a folder tree where the camera name (or site name) is the folder name containing the images (parent) or the folder above this (grandparent). The folder defining the time period within which data below it collected is known as the epoch, and is the folder above the camera name or the folder one level above this depending on the setting of the Epoch Folder combo box. The value can also be set in the Pre/Post process Files screen.

Open Folder/Re-open Folder

To load files from a folder, the option File-> Open Folder… should be selected and the folder containing the files browsed for. The menu option File->Re-open Folder opens the last loaded folder again. If the data is on a removable USB drive, the top level folder (eg F:) may contain an inaccessible System Volume Information folder. If this is present, data cannot be loaded using the drive letter as the opened folder. Data should be copied to a folder within the top folder of the drive in this case.

If no folder has been previously selected, a browse screen is shown. After opening the folder, a screen similar to that shown below will appear if there is only one camera folder below the selected folder:

Options – Advanced

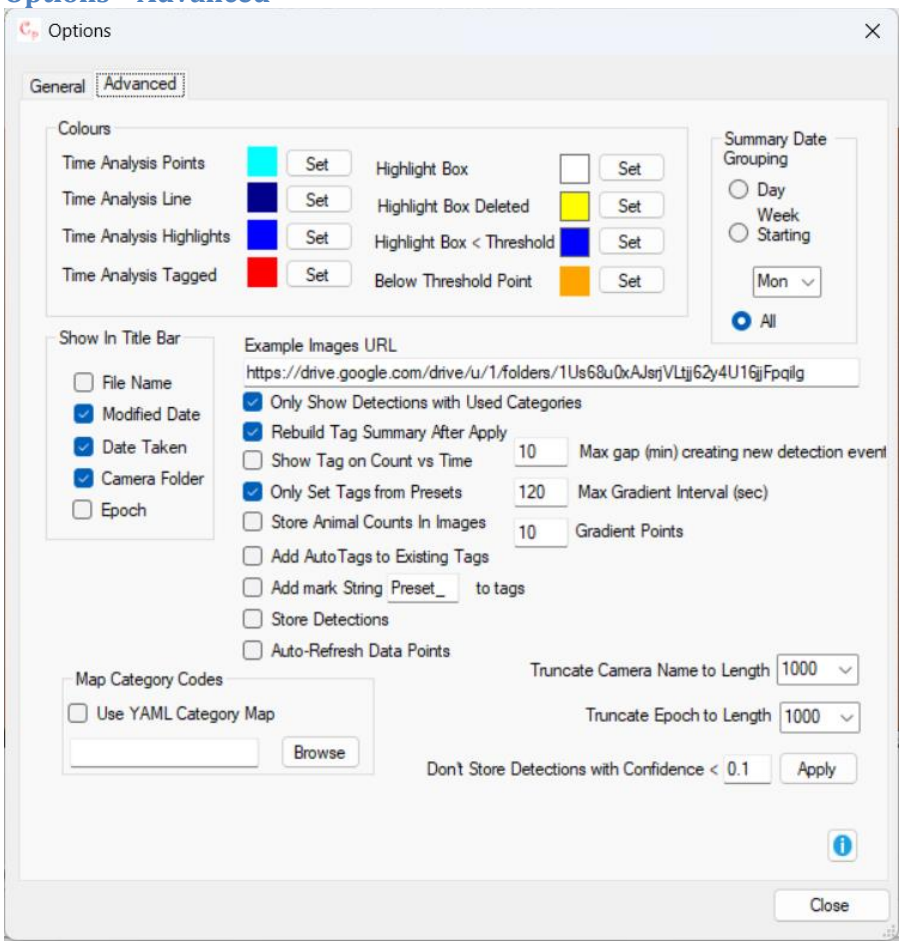


Figure 18 Options - Advanced Tab

Colours

The colours used for highlight boxes and annotations in the time profile can be set from this area.

Summary Date Grouping

Tag Summaries can be presented over a time interval of a day, a week (with the week starting on the day as defined in the Summary Grouping box) or over all times.

Show In Title bar

These checkboxes control what information about the displayed file is shown in the title bar above the image on the main form. As file names may be very long if highlight data is stored in the file name, it may be useful to omit this if viewing only highlighted data.

Example Images URL

This specifies the URL to be opened when clicking on Example Images in the Presets screen. It should contain example images of all the expected animals.

Only Show Detections with Used Categories

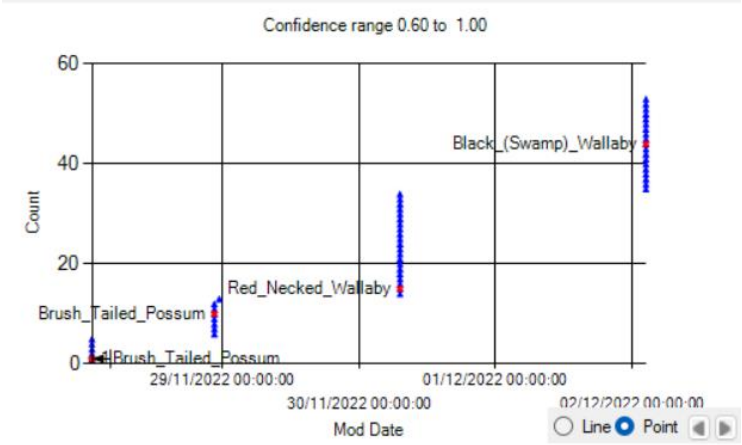
If this option is checked, only detections from categories flagged with Use (in the General tab) will be stored. Otherwise, all detection are stored. Checking this option can speed processing where large numbers of tags are generated automatically.

Rebuild Tag Summary After Apply

Checking this option rebuilds the tag summary after each tag is applied. This may take some time if a range of images have a tag applied to them via Batch Apply. In this case, this option should be unchecked and a tag summary generated after all images have been tagged. The Tag Summary and Occurrence appears as shown in Figure 86 on page 66.

Show Tag Text on Count vs Time

This option displays the text of tag beside the image highlighted in red if Show Tagged is selected in the screen shown in Figure 60. The display is as below:



Only Set Tags from Presets

If checked, tags can only be applied from the list shown in Presets. Tags cannot be entered or edited in the Tag box on the main screen.

Store Animal Counts in Images

If checked, the minimum and maximum number of animals appearing in a detection event is stored in the Tag Summary data. Checking this option slows processing.

Add AutoTags to Existing Tags

If checked, tags generated from Categories via the Name as Tag settings are added to any existing tags applied to tags already applied. This option is useful for comparing the performance of machine learning classifiers with manually applied tags. However, it slows processing.

Add Mark String to Tags

If checked, the mark string specified is prepended to any existing tags on load. This allows these tags to be excluded from the Clear operation executed from the Pre/Post Process screen. The action is implemented when data is reloaded after checking this option. Processing will be very slow as tags have to be retrieved from all files. The mark string should not be present in any tags.

Store Detections

If checked, detection details are stored in TagDB and are used for creating a Detections plot as described on page 72. Processing of JSON file is faster if this control is not checked.

Auto-refresh Data Points

If checked, all data points on the Count vs Time Plot are refreshed after applying a tag. The refresh process can be stopped by clicking Cancel.

Max Gap (min) Creating New Detection Event

This value specifies the time interval in minutes between successive images with the same tag above which a sequence is regarded as distinct from its predecessor. If the gap is greater than this value, the

sequence before and after the gap are regarded as different detection events. The default value is 10 minutes.

Max Gradient Interval

The average gradient of the count vs time profile (in images per second) is shown to the right of the sequence when right clicking on point as shown below.

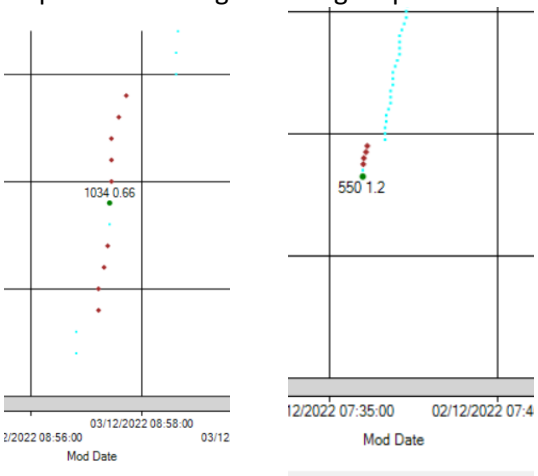


Figure 19 Count vs Time Gradient with no animal present (left) and with animal present (right)

Where a point is separated in time from its successor by more than the value specified, it does not contribute to the average value. Points contributing to the average value are shown in brown. A gradient value is not shown if there are no points contributing to it.

The gradient value is useful in determining whether the camera is being triggered by a moving animal or by moving vegetation. Gradient values are generally higher if an animal is causing the camera triggering.

Gradient Points

The value set in this box sets the maximum number of points over which the average gradient is calculated. Points may not be used if the time interval exceeds the threshold set in Max Gradient Interval.

Map Category Codes

This functionality is only required is using an Australian species refinement classifier with EcoAssist 5.2. The Browse button should be used to select the file C:\Program Files\EcoAssist_files\models\cls\Goanna\class_list.yaml. It should be unchecked in other cases.

Truncate Camera Name to Length

The camera name will be truncated to the specified number of characters if the length is less than the specified value.

Truncate Epoch to Length

Epoch will be truncated to the specified number of characters if the length is less than the specified value.

Copy Loaded

This option allows loaded files to be copied to a destination folder. Folders below the destination folder contain data from folders below the loaded folder. This option allows saving of a copy the data after applying any of the filters specified in Options.

Pre/Post Processing

The File->Pre/Post Processing screen as shown below is used to perform a number of pre- and post-processing functions:

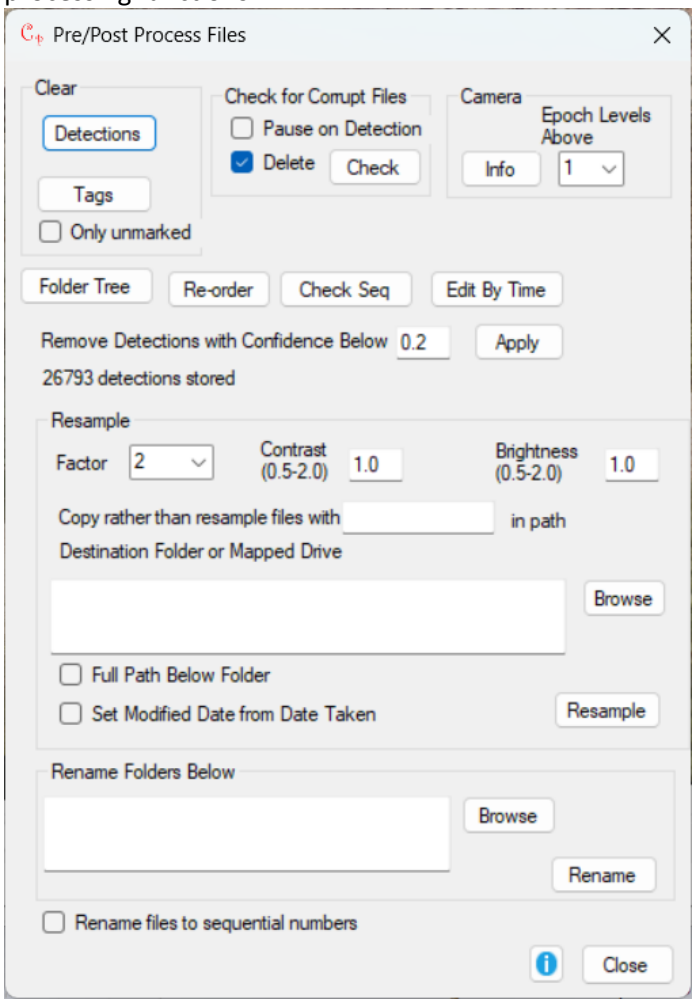


Figure 20 Pre/Post Processing screen

Clear Detections

Any highlight data stored in the file name or the Windows Authors field of file metadata is cleared via this button.

Clear Tags

Tag data stored in the Windows Tag metadata field is removed via this button. If Only Unmarked is checked, only tags which to not contain the mark string defined in Options are removed. Processing is much slower if this option is checked

Check for Corrupt Files

Corrupt JPEG files may appear in the loaded data and cause the program to crash or behave unpredictably. Clicking the Check button with Delete checked will remove these files and reload the data. The Pause checkbox allows processing to pause if a corrupt file is found. Processing may take some time for large file collections. A list of corrupt files is created in the loaded folder with name CorruptFiles.txt.

Camera

The Info button in the Camera box shows the epoch over which images were recoded, the camera name and manufacturer, the number of files in the camera folder, the Modified dates of the first and last files in the camera folder, and the duration of the time interval between recording of the first and

last images as shown below. Data must be loaded in Path or Folder->Modified Date order (as selected in the Options screen.

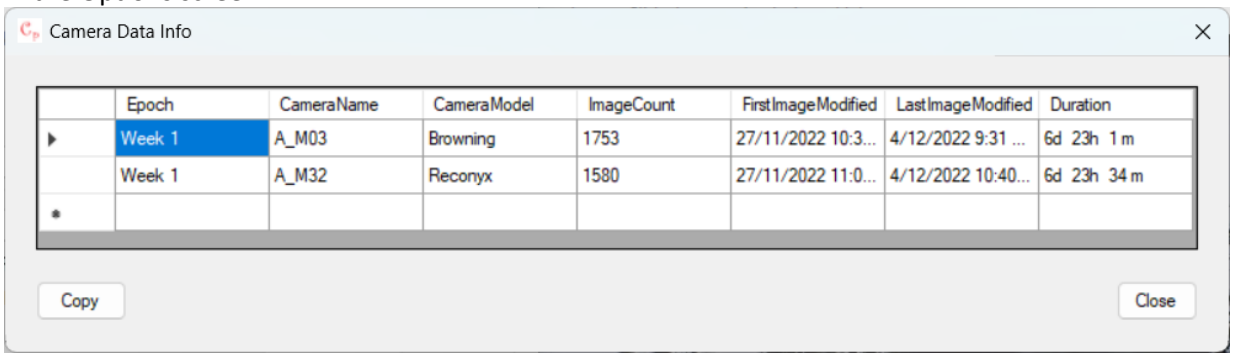


Figure 21 Camera Data Information

CameraName is the name of either the grandparent or parent folder of the file containing the images. The Epoch of images in the Camera folder is the folder either 1 or 2 levels above the Camera folder as selected by the Epoch Levels Above combo box. If the duration of a particular folder is much greater than others, or is negative, this may be due to the presence of some images with inconsistent dates. These can be removed via the Edit By Time button.

Folder Tree

This button creates a file showing the folder structure beneath a selected folder and whether that folder contains any JPEG files. The file is displayed by Notepad on completion. This display is useful for ensuring that the folder structure is amenable to automated analysis with CamTrap Pro

Re-order

This option is used to reorganise data grouped by epoch and camera to be grouped be grouped by camera only. Folders with the camera name (optionally truncated) will be created in a folder named Shortcuts which is created in a selected folder. Within each camera folder, shortcuts to the camera folder for each epoch will be created as shown below.

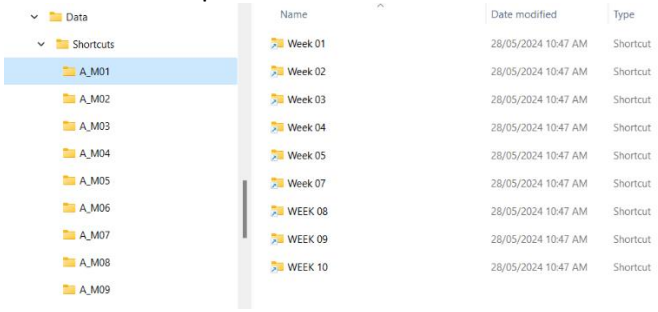


Figure 22 Shortcut folders created to display data organised by Epoch

Shortcuts to folders are processed in alphabetic order, so the Epoch names should be changed to be in the desired order in order to create profiles such as the one shown below. Where numbers are included in the Epoch name, shortcut names should be padded with leading zeros. Epoch rather than camera changes are shown on the plot as shown below:

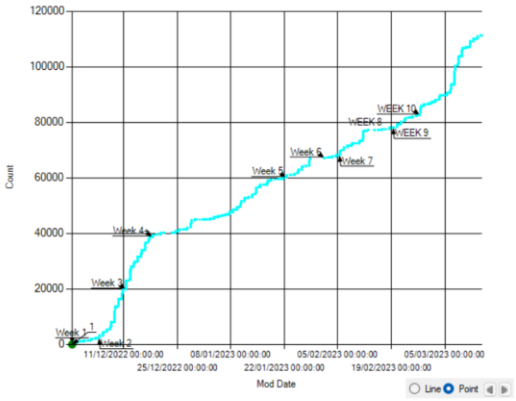


Figure 23 Count vs Time profile from shortcut folder

Note that if shortcuts are created on an external drive mapped to a drive letter, the shortcuts will only work if the drive has the same mapped letter. If it has changed, the message "No image files below selected folder" will appear. The drive letter used is shown in the name of a file created in the Shortcuts folder.

Check Seq

This option is used to detect when the image sequence number embedded in the file name increases by more than one in sequential files, indicating that a file is not present. The distribution of time intervals (in seconds) between successive images is also shown. The filesystems used on the SD cards containing the camera images do not usually record times to an accuracy of less than 1 second. A text file listing is created in the loaded folder with the name MissingFilesAndIntervalDistrib.txt and this file is shown in Notepad on completion.

Remove Detections with Confidence Below

When processing large data sets from multiple cameras, there may sometimes be large numbers of low-confidence detections in the Tag database. If this is the case, the display of all detections may be very slow. It can be sped up by removing the low-confidence detections from storage. Once this has been done the lower limit of the detection range will be the maximum of the value set and the value specified in the text box (default 0.1).

Edit By Time

Pre-processing may be necessary to obtain correct recorded dates. If no date/time is set on the camera, the first image date/time recorded will be the default date/time (often the date of camera manufacture) or the date/time of the last use of the camera. The time interval between images will be correct. In order to correct this, the date/time of the first image can be set in Options and the Modified date of subsequent images set to this date/time plus the date/time difference between this image and the first image. If the first few image use the default date/time and later ones use the correct date time, these default date/time images should be removed to ensure that the count vs time profile is comparable with cameras with the correct date setting. This operation can be performed via the Edit By Time button. This allows deletion of images within a selected time range via the count vs time profile for the loaded files as shown below:

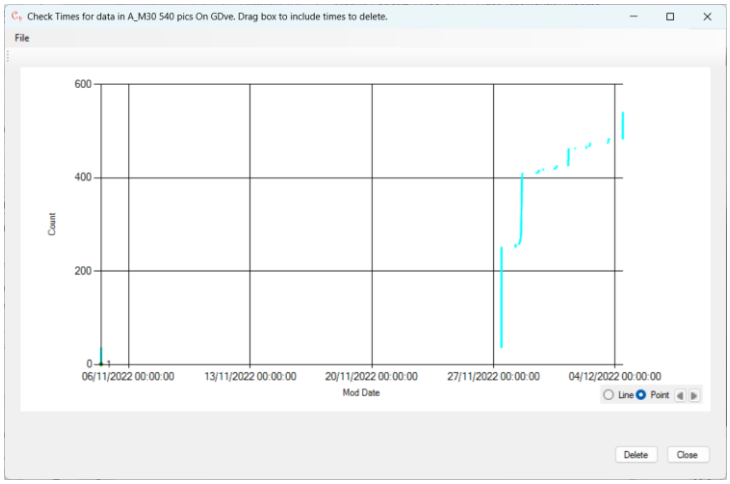


Figure 24 Edit by Time screen

If Delete is clicked after dragging a box around points to be deleted, images corresponding to points within the box will be deleted after confirmation. Images corresponding to points can be viewed by right-clicking on the point.

Resample

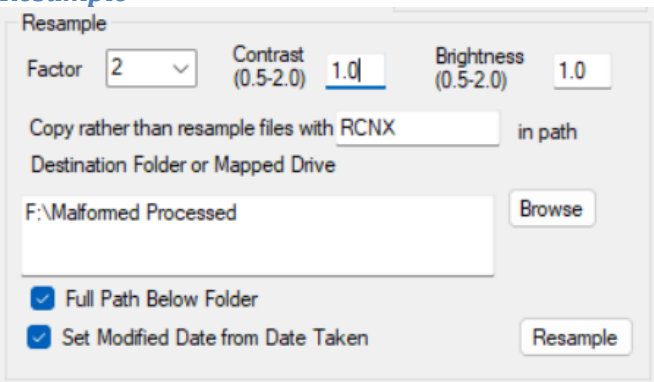


Figure 25 Resample Options

This option allows resampling and adjusting of the loaded images to pixel dimensions either 1x, 2x or 4x smaller, depending on the Factor setting. The contrast and brightness attributes of images can be adjusted via the Contrast and Brightness values, which must be between 0.5 and 2.0. Increasing the values above their default values of 1.0 increases the attribute, and reducing it to less than 1.0 reduces it.

If a string is provided in the 'Copy rather than resampled files with' text box, files containing the string in their path are copied rather than resampled and their attributes are unchanged. This allows selective resampling. If Full Path Below Folder is unchecked, the subfolder identifies the camera folder and is either the name of the parent folder, or the name of the grandparent folder followed by the parent folder name of the current image file. If the checkbox is checked, the entire path of the folder (without the source drive letter) containing the file is appended to the selected drive or folder and is the destination folder for processed files. Any existing folders or files in the destination folder are deleted.

Files containing a specified string in their path can be excluded from resampling and are copied to the destination folder unchanged.

Resampling speeds up certain CamTrap Pro operations, such a slideshow display and detecting changes between images and increases the speed of machine learning processing by applications such

as EcoAssist. Resampled files have only the EXIF fields Date Taken, Date/Time Original and Date/Time Digitized copied from the loaded files. Adjusting contrast or brightness may improve the performance of machine learning algorithms in detecting animals.

Rename Folders Below

This option is used to change the name of folders below a selected folder to include the name of their parent folder in their name. The folders which have their name changed are one level up from the bottom of the folder tree. The folder tree should have all image files at the same level. An example of the changed name structure is shown below:

```
F:\Rosenbergs Goanna 2018 Camera Survey Naas Valley All photos 677Gb 420k files>tree
Folder PATH listing for volume Crucial X8
Volume serial number is 9648-74CF
F:.
├───Week 1
│   ├───Week 1 Site 01
│   │   ├───Centre
│   │   │   └───101IMAGE
│   │   ├───Left
│   │   │   └───100IMAGE
│   │   └───Right
│   │       └───100IMAGE
│   ├───Week 1 Site 02
│   │   ├───Centre
│   │   │   ├───100IMAGE
│   │   │   └───101IMAGE
│   │   ├───Left
│   │   │   ├───100IMAGE
│   │   │   └───101IMAGE
│   │   └───Right
│   │       ├───101IMAGE
│   │       ├───102IMAGE
│   │       ├───103IMAGE
│   │       ├───104IMAGE
│   │       └───105IMAGE
```

```
F:\Rosenbergs Goanna 2018 Camera Survey Naas Valley All photos 677Gb 420k files>tree
Folder PATH listing for volume Crucial X8
Volume serial number is 9648-74CF
F:.
├───Week 1
│   ├───Week 1 Site 01
│   │   ├───Week 1 Site 01 Centre
│   │   │   └───101IMAGE
│   │   ├───Week 1 Site 01 Left
│   │   │   └───100IMAGE
│   │   └───Week 1 Site 01 Right
│   │       └───100IMAGE
│   ├───Week 1 Site 02
│   │   ├───Week 1 Site 02 Centre
│   │   │   ├───100IMAGE
│   │   │   └───101IMAGE
│   │   ├───Week 1 Site 02 Left
│   │   │   ├───100IMAGE
│   │   │   └───101IMAGE
│   │   └───Week 1 Site 02 Right
│   │       ├───101IMAGE
│   │       ├───102IMAGE
│   │       ├───103IMAGE
│   │       ├───104IMAGE
│   │       └───105IMAGE
```

Figure 26 Folder Tree before (Top) and after (Bottom) renaming

It is used when there are multiple cameras per site which need to be distinguished if existing camera names (for example, Left, Right and Centre) are repeated at different sites.

Rename File to Sequential Numbers

This option is used to change the file name to the position of the file in the loaded sequence. It is used if file names do not contain sequential numbering.

Project Details

The name of the project and the site over which cameras are deployed can be specified via the File->Project Details option, which shows the screen below:

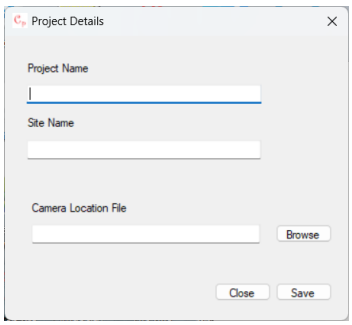


Figure 27 Project Details screen

Project Name is the name of project (eg Deer Control) and Site Name is the name of the group of cameras whose data is being processed. All parameter are optional, but Map functionality will not be available unless a camera location file is specified. The camera location file is a tab-separated text file with three columns of data per line. The first column should contain the camera name (eg A_M01). The second and third columns should contain the latitude and longitude of the camera in decimal degrees.

Consolidate TagDBs

This option is described in Consolidating Summaries in the Analysis section.

Processing Data from Multiple Cameras

Data from multiple cameras can be processed in one pass by CamTrap Pro by selecting the folder above the individual camera or site names. File Order in Folders should be set to Modified Date for Folder->Modified Dare, and the Modified Date of images should be set to the time at which the image was recorded. Incorrect Modified Date values may be due to processing after image capture altering the image Modified Dates, or camera internal clocks not being correctly set. If Modified dates are not reset, the Count-Time profiles will not appear as shown in the examples, but may have a stepped appearance over a short space of time. If the aim of processing is only to detect the appearance of particular animals, Modified Dates do not have to be reset, but time durations in the summary report will be incorrect.

If multiple folders are present below the selected folder, the screen below appears:

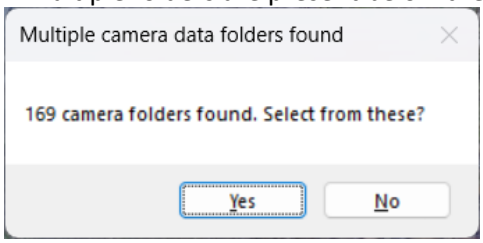


Figure 28 Multiple camera data folder screen

Selecting No treats files as though they were in a single folder, and count vs time profiles are stacked if folder order is Folder->Modified or summed as a single profile if order is Modified. Selecting Yes allows selection of camera data sets as shown below as multiple folders and displays count vs time profiles starting from the origin.

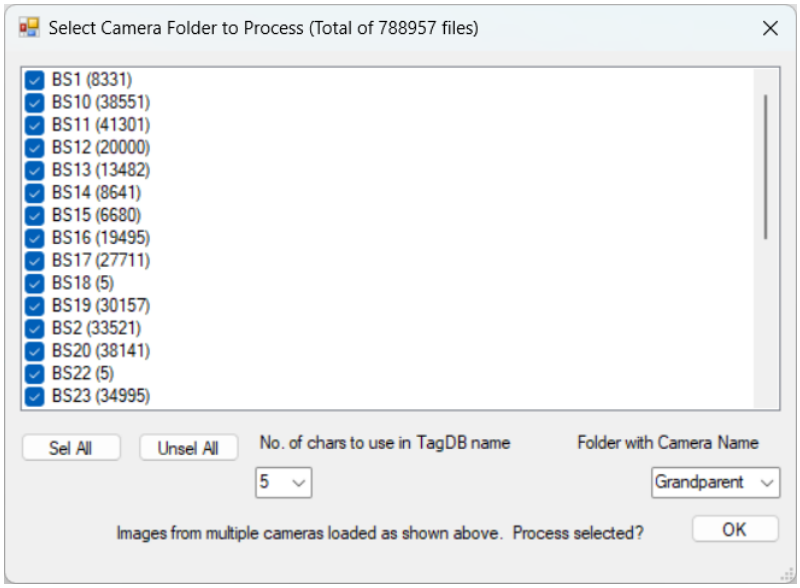


Figure 29 Multiple camera selection screen.

The bracketed number after the camera name is the number of files in the folder. This is only shown if the sorted order of loaded files is Folder->Modified. The name of the TagDB database created in the selected folder includes the data site\epoch, and the first n characters of the selected camera folder names, as specified in the No. of chars to use in TagDB name combo box. If more than one camera is selected, camera names are separated by commas. The option to change the camera name folder between Parent and Grandparent is shown. If OK is selected, data from the each of the selected camera data folders will be loaded into CamTrap Pro ordered by Modified Date within each camera name folder, where camera name folders are sorted alphabetically.

Selecting Analysis->Count vs Time, shows profiles for each camera separately as a stack as shown below:

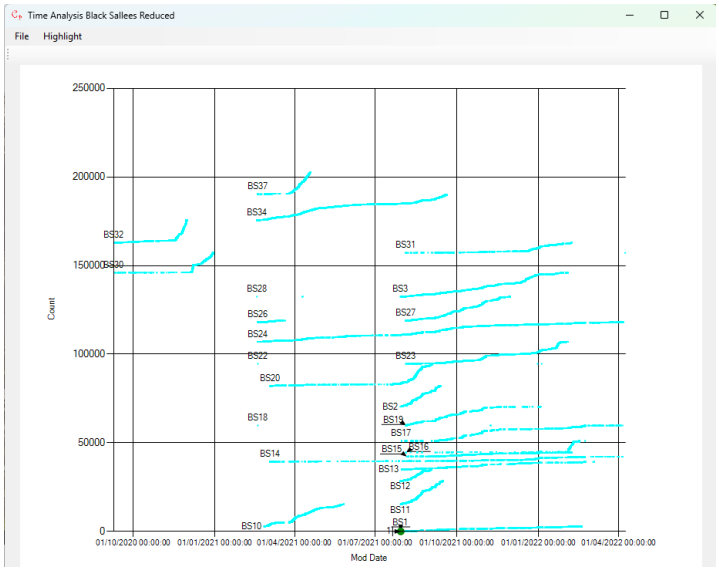


Figure 30 Count vs Time Profile of Data from Multiple Cameras

The name of the camera for each profile can be shown by moving the cursor over a non-horizontal part of the line profile.

After loading JSON data, each animal detection within the default detection range (currently 0.4 to 1.0) is marked as a blue highlight dot:

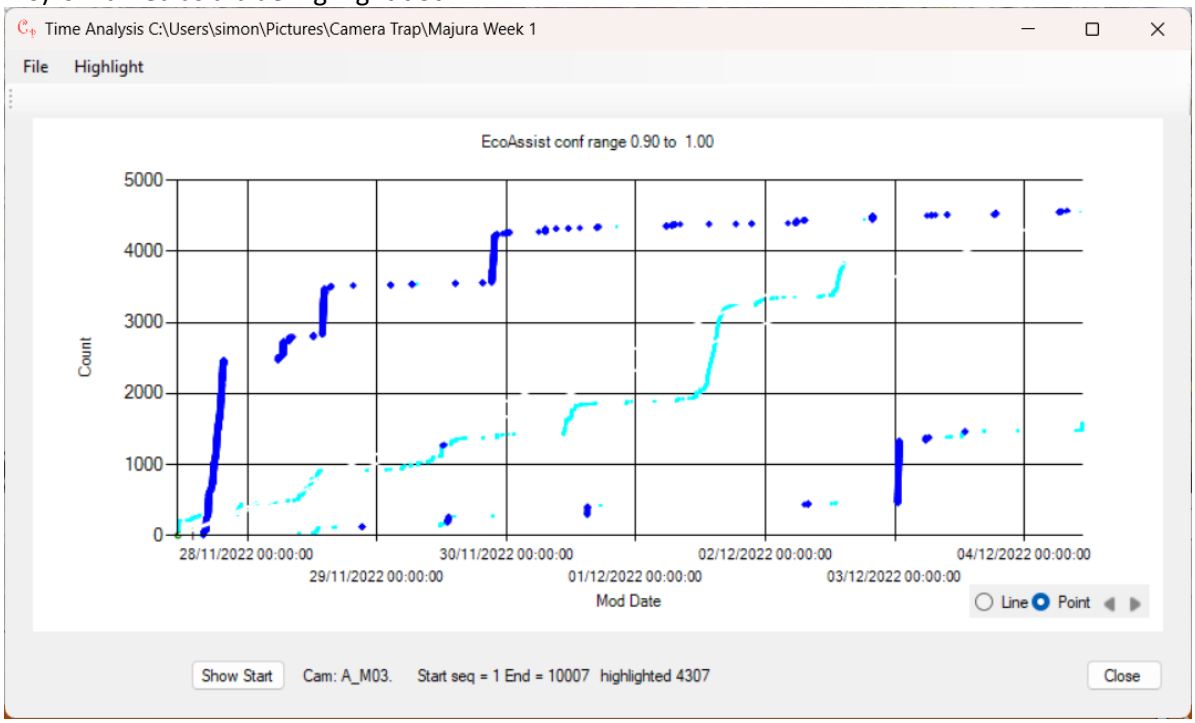
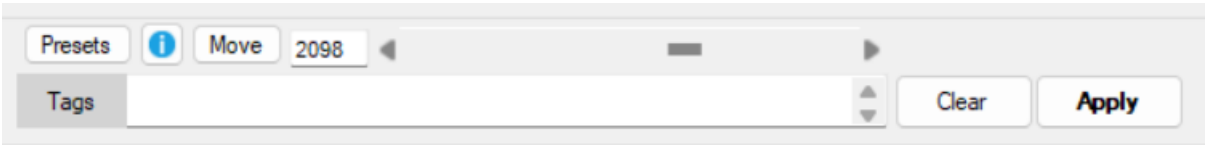


Figure 31 Multiple camera count vs time with animal detections highlighted

Selecting Highlight->Megadetector->Copy copies all highlighted images to sub-folders of the Highlighted folder, where the sub-folder names are the names of the multiple cameras. This data can then be loaded into CamTrap Pro for tagging and summary generation. Highlighted images can either be ordered within the camera folders they came from or collectively.

Tagging by Visual Inspection

Once the files are loaded, tags may be applied by visual inspection of each image using the Slideshow->Play option, which shows all the loaded images in the order selected in the Options screen. (For the Camera Trap options, this is Date Taken.) Ctrl-P toggles the slideshow between playing and pausing. The time between image displays can be selected in the Options screen or via Slideshow->Interval and should generally be 250 msec. If an image takes more than 250 msec to load, as can happen for large images, the time interval will be increased to the first multiple of 250 msec greater than the load time. If an animal appears in an image, the slideshow should be paused and moved backwards if required using the left arrow key. Tags selected from the Presets menu (shown by clicking the Presets button as shown below) can then be added to the image, or entered directly if allowed.



If the same tag is to be applied to multiple files (as will often be the case), this can done via the Time Analysis screen as described in Processing Multiple Images.

Viewing Data

The Start screen for CamTrap Pro is shown below:

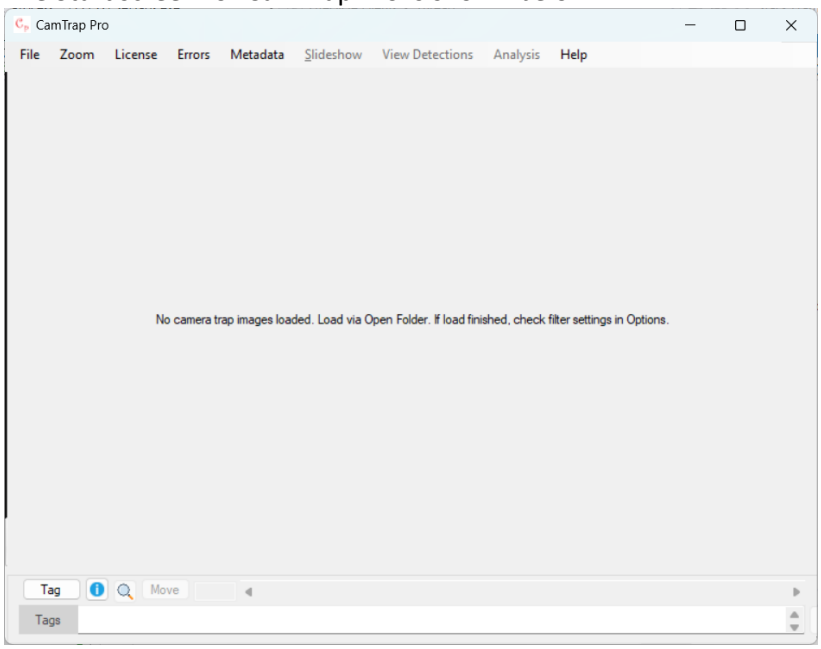


Figure 32 Main Screen after starting CamTrap Pro

Input data is loaded via the File->Folder option. For single-camera data, the selected folder should be the parent or grandparent folder of the image files. For multiple camera data, the selected folder should be above the folder containing all the individual camera data sets. The images must be 1 or 2 levels below the folder identifying the camera as shown in Figure 6.

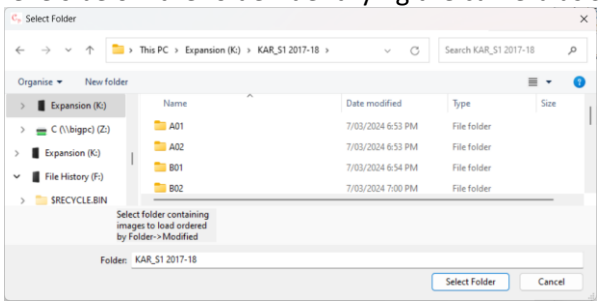


Figure 33 Folder Browse screen showing sort order

The sort order can be changed via the Options screen. Modified or Folder->Modified order gives faster operation than Date Taken. If Modified Date is not the same as Date Taken it can be updated from Date Taken in the Options screen. After loading the data, the Move and Find buttons are enabled:

Figure 34 Main screen after loading data

Zooming

Preset zoom factors of 100%, 150% and 200% can be applied via the Zoom menu items. Holding the Shift key and pressing the Up key zooms the image by a small amount, and Shift-Down un-zooms it. Any tags which have been applied to the loaded data are shown in the box to the right of the Tags label. The Move button displays the image with sequence number shown in the box to the right of it.

Find

The Find button ( ) shows the screen below:

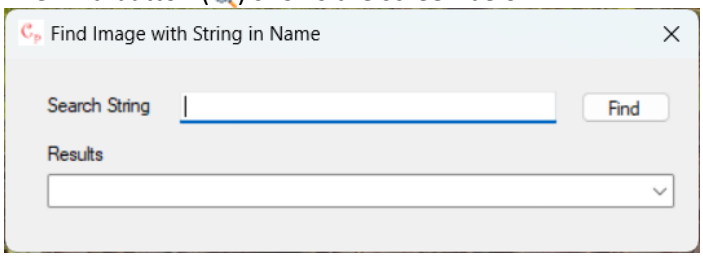


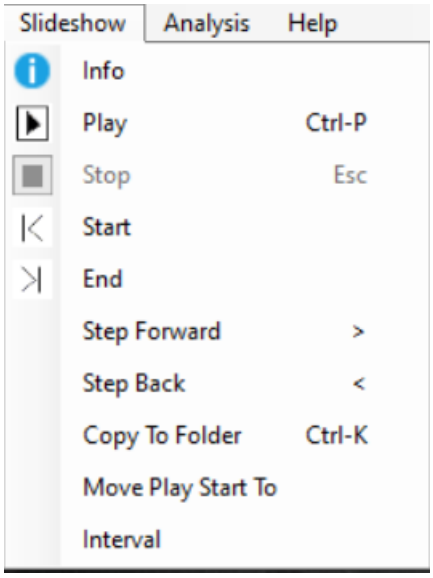
Figure 35 Find Image Screen

Entering a string in the Search String box shows the first loaded file whose path contains the string (often the numeric part of the file name). Other matches are shown in the results combo box. These can be shown by selecting them.

Slideshow

SlideShow->Info displays this section of the help file.

Slideshow->Play displays all images starting from the first one at a time interval selected from the Slideshow->Interval menu item. The keyboard shortcut for this menu item is Ctrl-P. Other slideshow options are as shown below:



Clicking the Play menu item or Ctrl-P on the keyboard displays each item sequentially from the sequence number defined by Move Play Start To for a period defined by the Interval menu option, and the menu item name changes to Pause. The Stop menu item (with keyboard shortcut esc) is now enabled, and clicking it returns to caption entry mode. After clicking Stop, clicking Play resumes playback from the stopped sequence number. Clicking the menu item now named Pause (or clicking Ctrl-P again) stops slideshow playback. Clicking this (or Ctrl-P) resumes playback. The position at which playback is resumed is controlled by the Move Play Start To menu option, which is shown in the screen below:

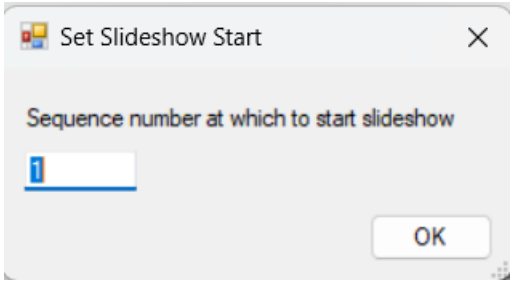
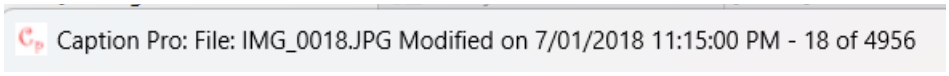


Figure 36 Move To screen

The Step Forward and Step Back controls move to the next or previous item in the slideshow. The left and right arrow controls provide the same functionality is no caption or sub-caption text is present. The sequence number of an item is shown at the top left of the screen as shown below with sequence number 18:



The Pause On Change option n sets parameters to allow the slideshow to automatically pause if there is a change between the currently displayed image and its predecessor. It is only used if showing camera trap data as a slideshow. More details in the help document Processing Camera Trap data

Copy To Folder (or Ctrl-K) allows copying of the current image (and optionally images ahead or behind the current image via the Images Ahead and Images Behind combo boxes) to a folder, the default value of which is My Pictures/Camera Trap Images via the screen below:

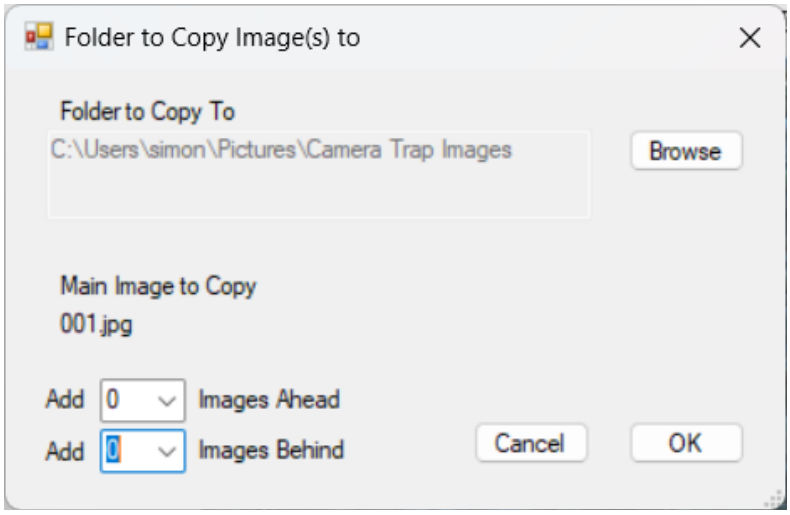


Figure 37 Copy to Folder screen

A different folder can be selected via the Browse button. If an image file with the name shown above already exists in the folder, the saved file name has an integer appended to the file name before the file extension (eg IMG_0048(1).jpg).

Start and End change the current item to the first or last loaded item.

Interval sets the time period of the timer displaying image files via the screen below:

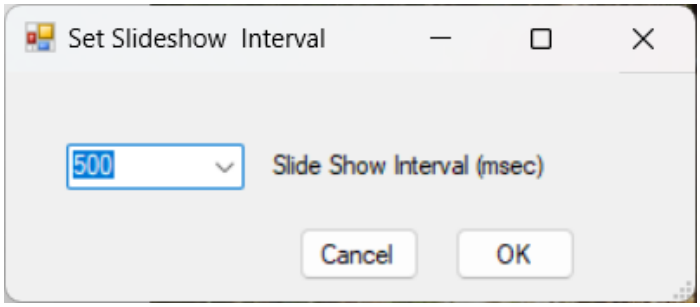


Figure 38 Setting slideshow interval

If the time period is shorter than the time taken to load the image (as may happen for large images, a short period, or a slow computer), the image is displayed on the next tick of the timer, so the actual period between displays will whichever integer multiple of selected period is greater than the time taken to load the image. The actual speed of the slideshow depends on the size of the images, the storage access speed and the speed of the computer being used. Using a 3.5 Ghz, 6-core computer with 2688x 1504 pixel images processing images on an external USB drive, a speed of 4 images/sec was obtained.

Metadata

Metadata for the currently viewed file can be shown by clicking the Metadata top-level menu item. Metadata from the Windows filesystem is shown first, then image-specific metadata. There may be hundreds of fields present. ICC Profile entries for red, green and blue are not shown as they are very long. An example of camera trap image metadata is shown below

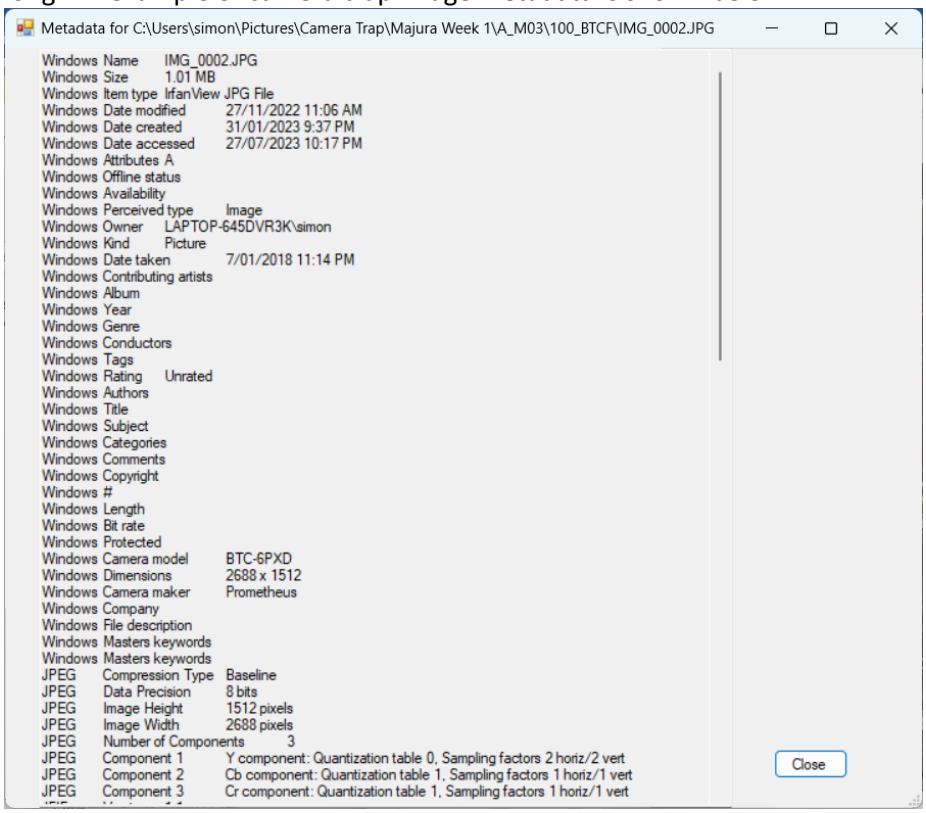


Figure 39 Metadata (part) of camera trap image

Errors

Errors generated in the course of CamTrap Pro operation can be viewed by clicking the top-level Errors menu item as shown below:

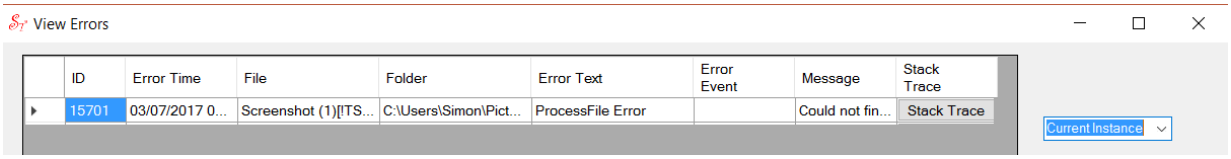


Figure 40 Errors from Current Instance

The default option is to show only errors which have occurred during the current run, (Current Instance in the combo box to the right of the error display) but errors from all runs can also be displayed:

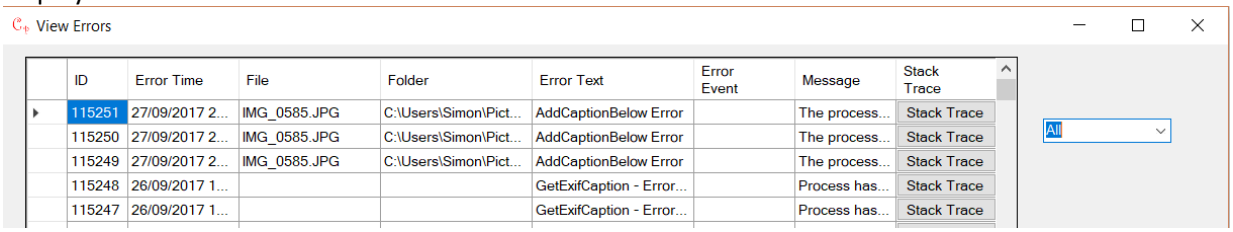


Figure 41 Display of All Errors

Adding Tags Manually

If single camera trap images are to be tagged, text may be typed in directly to the Tags Box and applied either by tapping the Enter key or by clicking the Apply button.

Semicolons should not be used in tag names. Tag Information can be displayed in Windows Explorer using Details view:

RCNX5653.JPG	8/12/2022 6:17 AM	IrfanView JPG File	918 KB	Kangaroo	8/12/2022 6:17 AM
RCNX5659.JPG	8/12/2022 7:06 PM	IrfanView JPG File	945 KB	Raven	8/12/2022 7:06 PM
RCNX5660.JPG	8/12/2022 7:06 PM	IrfanView JPG File	949 KB	Raven	8/12/2022 7:06 PM
RCNX5661.JPG	9/12/2022 6:32 PM	IrfanView JPG File	729 KB	Kangaroo	9/12/2022 6:32 PM
RCNX5662.JPG	9/12/2022 6:32 PM	IrfanView JPG File	860 KB	Kangaroo	9/12/2022 6:32 PM

Figure 42 Windows Explorer details view showing tags

Using Pre-set Values for Tags

If users wish to select tag values from a list rather than typing them in, this can be achieved via the Tag button on the main screen which shows the screen below. If Presets Only on the Advanced tab of the Options screen is checked, tags can only be added via this screen.

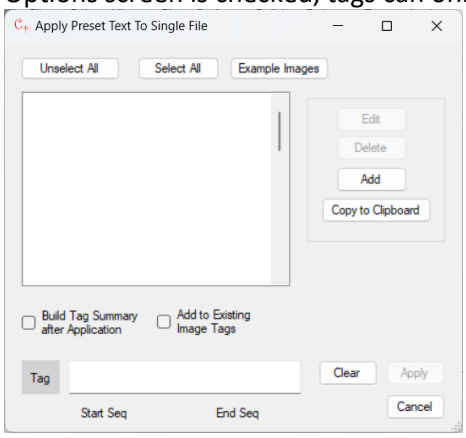


Figure 43 Preset Tag Screen When no Files Loaded

As there are no pre-defined pre-set text options, only the Add and Close buttons are enabled, Clicking Add shows the screen below, which allows definition of one or more pre-set texts.

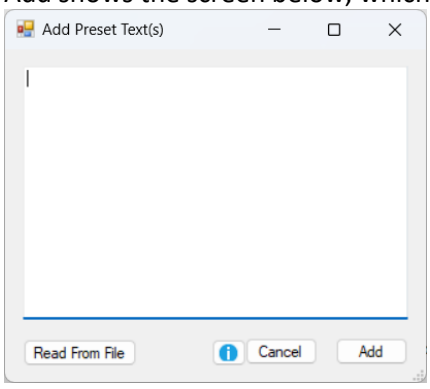


Figure 44 Screen for Adding Preset Texts

Multiple strings (the names of animal expected to appear) can be loaded from a text file in which each string is on a new line using the Read From File button or they can be pasted using one line per name. After clicking Add and then Cancel, the texts added appear in the main Tag screen as shown below:

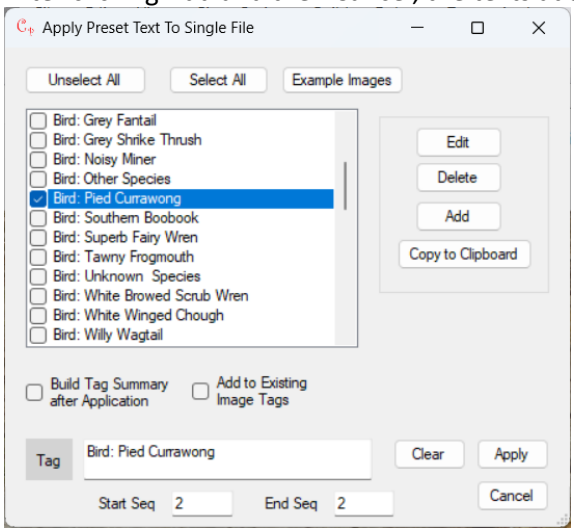


Figure 45 After Adding Pre-set Texts with one Item Selected

If example images for the expected animals are available, these can be placed in a URL and specified in the Advanced tab of the Options screen and viewed via the Example Images button.

Clicking Apply adds the tag to the image.

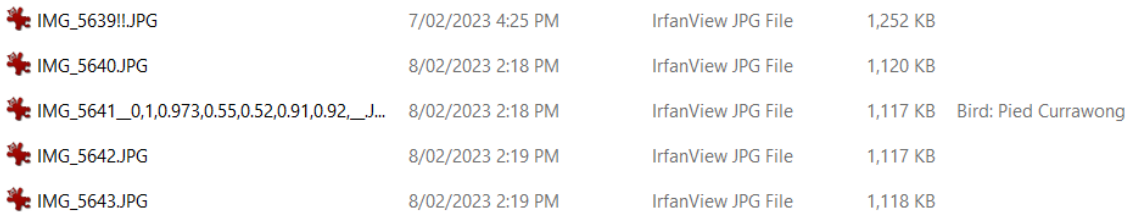


Figure 46 After applying tag

Tags can be removed by clicking Clear and then Apply. If multiple tags are checked, they are separated by semicolons in the Tags box.

One or more checked texts can be deleted via the Delete button (after confirmation) and if a single text is checked, its value can be edited via the Edit button.

Processing Multiple Images

Adding tags to a sequential group of images is performed via Tag Multiple button the Analysis-> Count vs Time screen which shows the Show Tags or Highlights screen. The Show Highlighted, Show Tagged by CamTrap Pro and Show Tag on Count vs Time options should be checked as shown below.

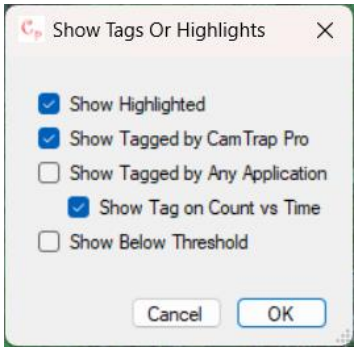


Figure 47 Show Tags or Highlights

With the options shown above, Count vs Time points will appear as shown below if no highlights have been generated via loading of the JSON file from machine learning analysis.

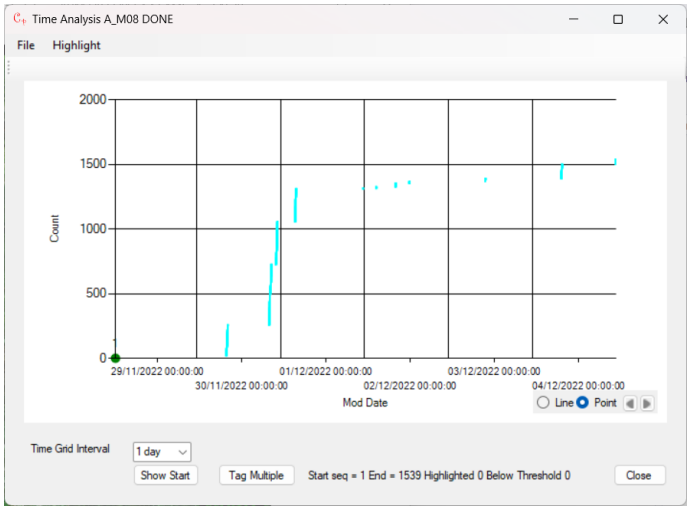


Figure 48 Count vs Time screen with no highlights or tags created

If highlights have been created for images, these are shown as below:

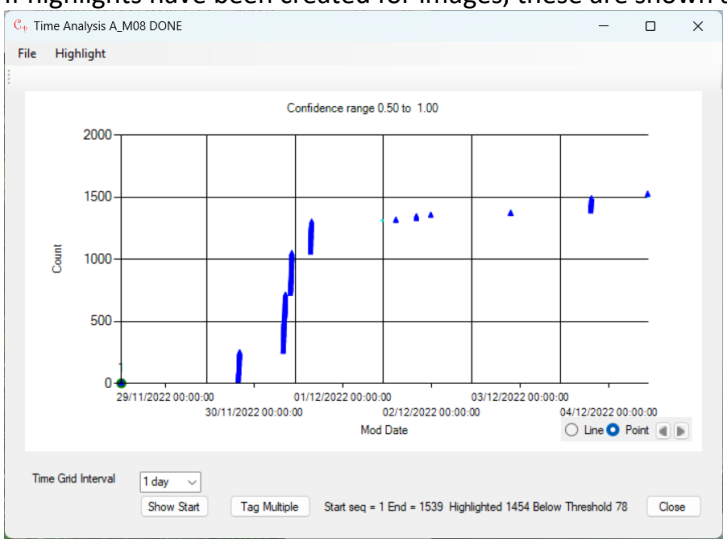


Figure 49 Count vs Time showing Highlights on almost all files

The sequence numbers of the first and last images displayed and the number of images with detections above and below the threshold value are shown below the chart.

Tag Multiple

Clicking the Tag Multiple button shows the screen below, which extends the functionality of the screen shown in Figure 43.

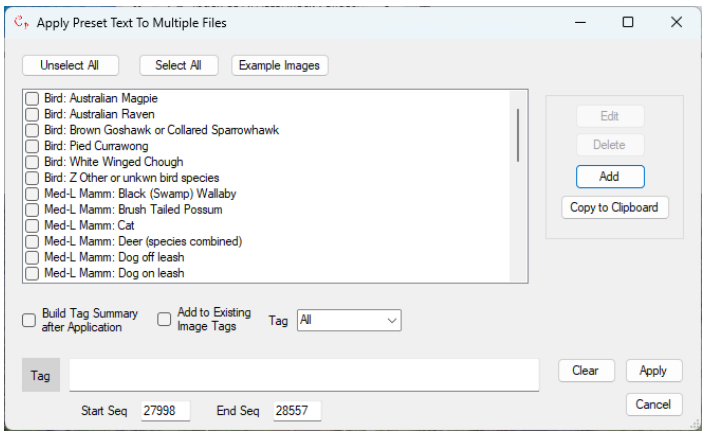


Figure 50 Tag Multiple screen

Once the image has been inspected and the species present identified, one or more tags can be selected from this screen. Example images for different species expected to be present can be viewed via the Example Images button.

If Build Tag Summary after Application is checked, the Tag Summary is refreshed after tags have been applied. If Add to Existing Image Tags is checked, tags selected are added to those already existing. The Tag combo box All options applies tags to all files visible on the Count vs Time screen. Tag application may be slow if the same animal appears in a large number of images. The 1st in Det Event option only applies selected tags to the first image in a detection event, the duration of which is specified in Options. This option is useful if there are a large number of images of the same animal, for example, a carrion-eater attempting to eat a bait. If this option is used, the number of images in the tag summary will always be 1 for each detection event, and the duration will be zero

View Image

If a filter has been applied when loading files (for example to show only highlighted files), species recognition may be improved by viewing zoomed images, images rejected by the filter or images existing at a higher resolution in another folder using Windows Photo Viewer. This facility is accessed via the View Images button on the Time Analysis screen. Clicking it shows the screen below:

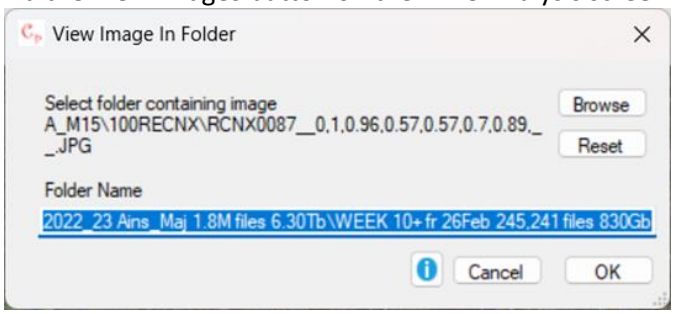


Figure 51 View Image in Folder Screen

The default is to search for the file in the loaded folder. If a copy of the loaded folder (perhaps containing images at higher resolution) is available, this can be selected via the Browse buttonThe default folder to search in can be restored via the Reset button. If the file exists in the selected folder, clicking OK shows it in Windows Photo Viewer as below:

Figure 52 Selected Image Viewed in Windows Photo Viewer

The image displayed can be zoomed, or the displayed file can be moved backwards or forwards in the selected folder via the or button. Viewing other images than those highlighted may assist with species identification, as may using the zoom button to show a zoom slider:

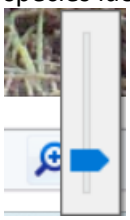


Figure 53 Windows Photo Viewer Zoom Slider

If an image is viewed in Windows Photo Viewer, closing it will also close the View Image in Folder screen shown in Figure 51. While the image is shown, the View Image in Folder screen is disabled and cannot be closed.

Adding Tags

Selecting a tag copies it to the Tag text box. If more than one tag is selected, all selected tags are copied separated by a semicolon. The Clear button clears the tag box and unselects all preset values. Applying an empty string removes any existing tags if Add to Existing is not checked. If Add to Existing is checked, any existing tags will have the selected tag (or tags) appended to the tag string with each tag separated by a semicolon. If Build Tag Summary on Completion is checked, a Tag Summary will be generated which can be viewed via the Analysis->Summarise Tags menu item and clicking No at the prompt below:

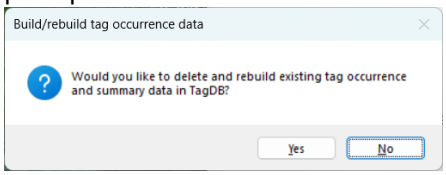


Figure 54 Screen to optionally rebuild tag occurrence and summary data

The start and end values are the sequence numbers of the first and last images displayed in the Count vs Time screen, which can be changed by zooming the display. By selecting a region of the Count vs

Time display showing a sequence of images captured over a short time (as below), multiple images of the same animal can be tagged.

If Build Tag Summary on Completion is checked, a tag summary is generated automatically on completion, and added tags can be displayed on the count vs time profile as below:

Figure 55 After applying a tag to multiple images

Tag text is added where the is a space of more than 5 pixels between tagged points.

Clicking Analysis-> Summarise Tags prompts the use to choose between rebuilding the summary or displaying one already created. If the option to Rebuild Tag Summary on Completion has been selected on the Tag Multiple screen (shown in Figure 50), No should be selected.

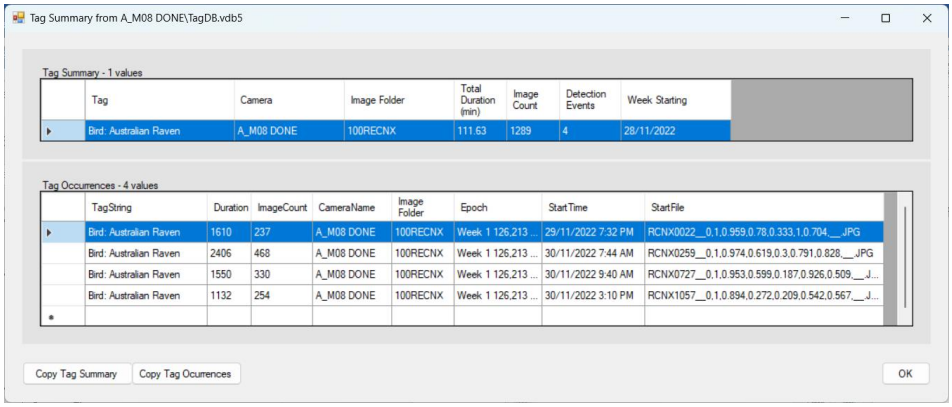


Figure 56 Tag Summary Screen

The Tag Summary screen is discussed in more detail on page 64

Editing Tags

Existing tags are shown below the image on the main screen when the image is loaded. These can be edited and reapplied via the Apply button. If identification of individual animals is required tags can be changed to include a unique identifier.

Deleting Tags

Tags on individual images can be deleted using the Clear button at the lower right of the main CamTrap Pro screen. To remove tags from multiple images, any text should be deleted from the Tag box and the batch operation should be run using the batch button. To remove tags from all images, click the Tags button in the Clear box in the Pre/Post Processing screen.

Adding Tags Automatically

Tags can be generated automatically by loading a JSON file produced by the Megadetector classifier, optionally refined. Detections of categories without the Use column checked in the Machine Learning Categories grid will be ignored. The default settings show Megadetector categories and only use Animal detections. If the Show All is selected, all detections within the specified range in a single image will be highlighted. Tags can be generated as well as highlights by checking the Name as Tag option for the category. Whenever detection confidence falls within the defined limits, a tag corresponding to the category name will be applied, and a red square will be shown on the count vs time profile if Show Tag on Count vs Time is checked when Count vs Time is loaded as shown in Figure 60.

Refining Megadetector Results

Auxiliary programs such as EcoAssist allow Megadetector results to be refined to identify particular species as shown below:

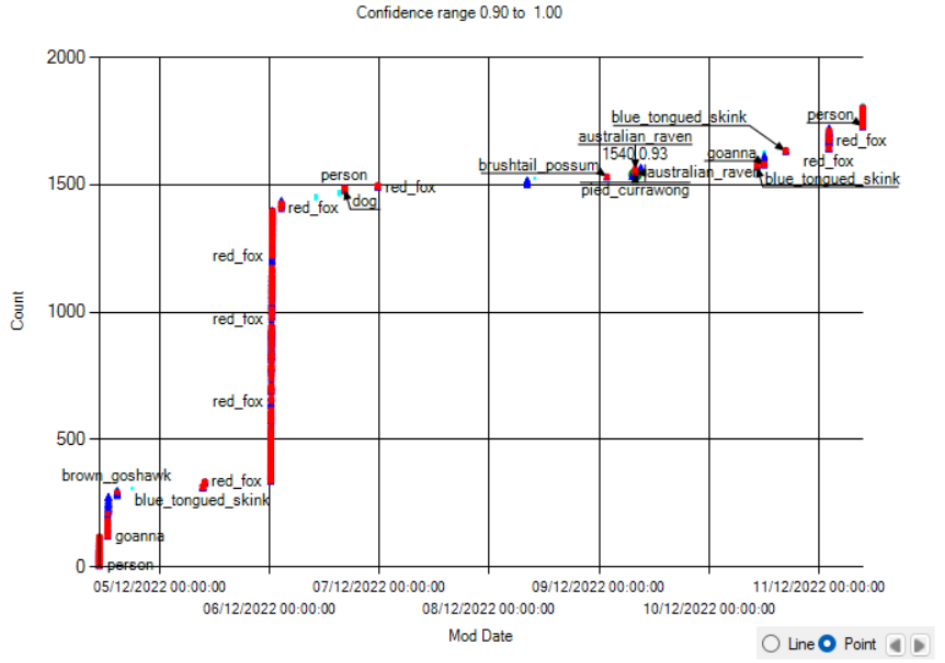


Figure 57 Automatically generated tags using refined Megadetector results

When a refining classifier is used with EcoAssist, two JSON files are produced. The file 'image_recognition_file.json' should be selected. The red squares indicate where the refined classification confidence exceeds the classification limit, dark blue triangles where an animal has been detected, but the refined classification does not exceed the classification limit, and light blue dots where no animal was detected with a confidence greater than the detection limit. Limits are defined in the Advanced screen of EcoAssist as described on page 80.

If individual images are shown by right-clicking on a red square or dark blue triangle, the bounding box of the detection will be shown, but the category name will only be shown if the classification limit has been exceeded.

The Highlight->Copy to Folder option will copy highlighted files and tagged files to the selected destination.

Previously Tagged Data

Images with tags previously created by other means can be loaded and viewed in the same way as untagged data, and analysed in the same way as if the images have been tagged within CamTrap Pro However, no data on the minimum and maximum number of animals appearing in a tag occurrence will be available.

Checking Name as Tag will apply tags corresponding to category names as well as creating highlights giving results as shown below for a dataset collected from a road with significant vehicle traffic.

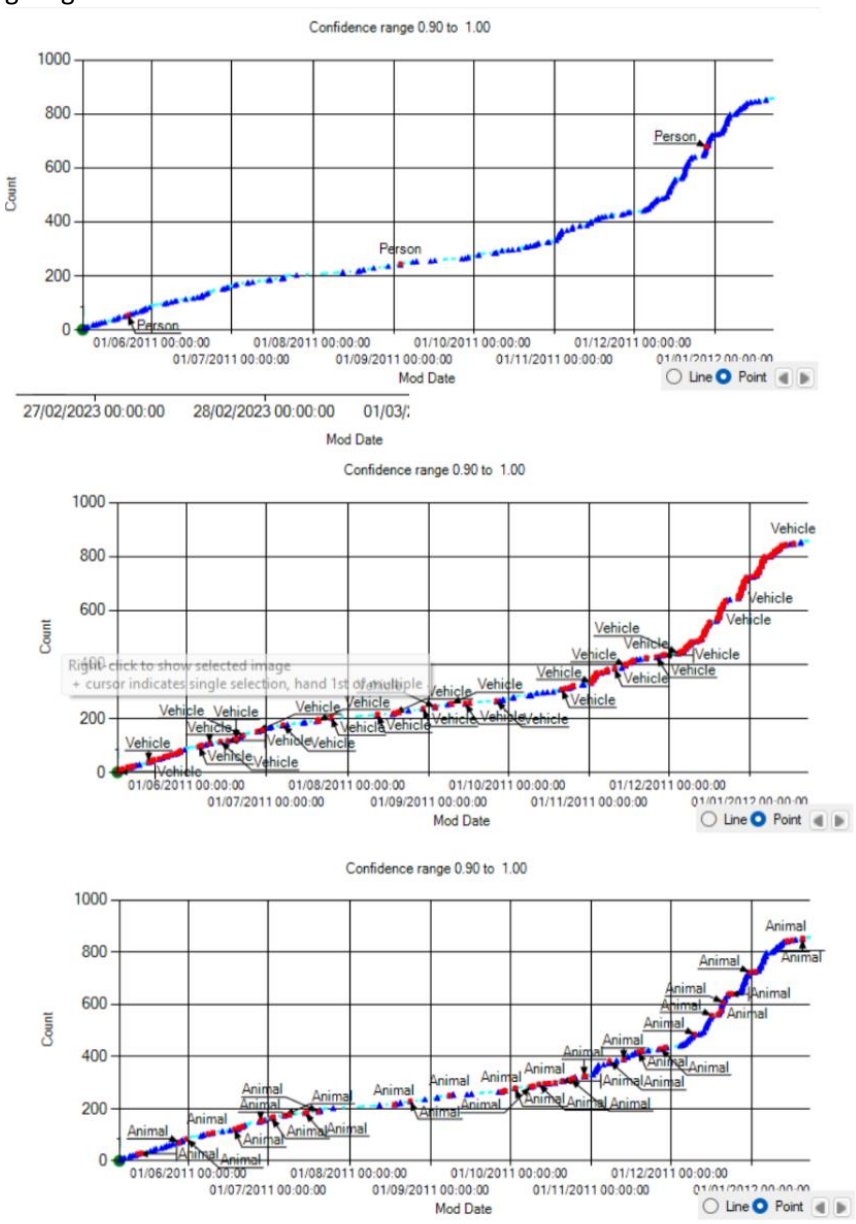


Figure 58 Results of setting Name As Tag for 3 different categories of automatic classification

Points shown in red are detections with the displayed category. From this data it can be seen that the increase in detections after 1/11/2011 is largely due to vehicles.

Analysis

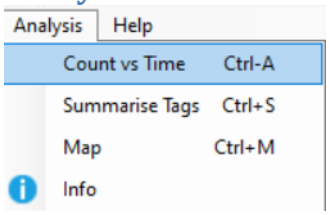


Figure 59 Analysis Options

These options analyse the camera trap image collections.

Count vs Time

This option shows a cumulative count vs time profile of the images similar to those shown on pages 14-15. An option to show generated highlights, tags created by the current instance of CamTrap Pro, tags retrieved from file metadata, or below-threshold detections is shown as below. Checking Show Tags from File Metadata option will be slow display of the count vs time profile.

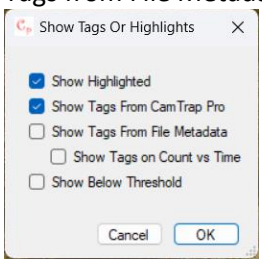


Figure 60 Show Tags or Highlights Options

Files with highlights created by machine learning are shown in blue (by default) and tagged files in red (by default) if the corresponding boxes are checked. Tag names are added if Show Tag on Count vs Time is checked. Files with detections with confidence below the lower threshold are shown in orange (by default). Default colours can be changed in the Options Advanced tab. The current file shown on the main screen is shown as a green circle.

For a multi-camera data set using Folder>Modified ordering, individual camera profiles are stacked and labelled as shown below. Note that the input data must be reloaded to manifest changes in ordering.

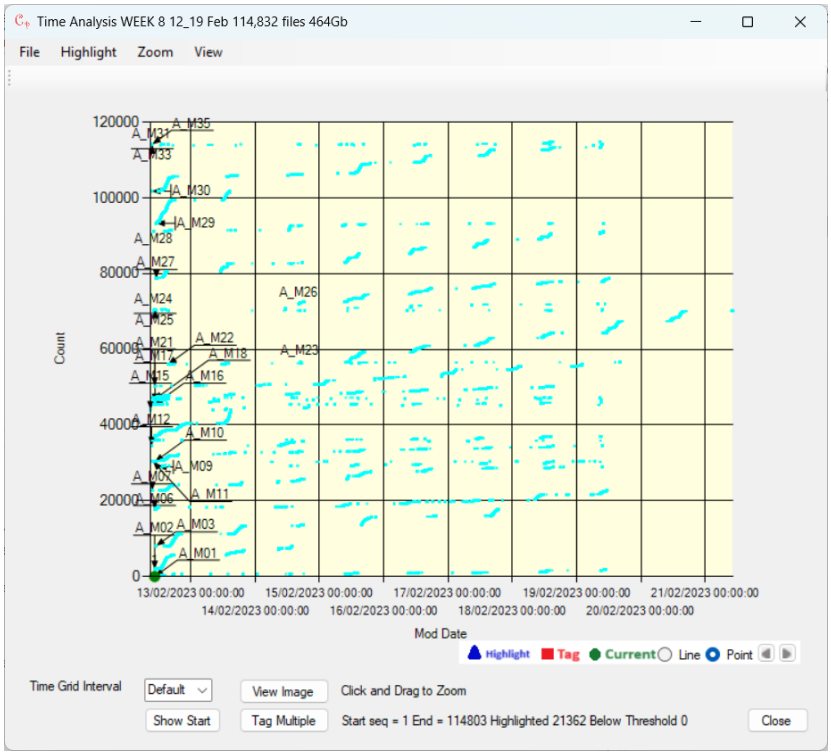
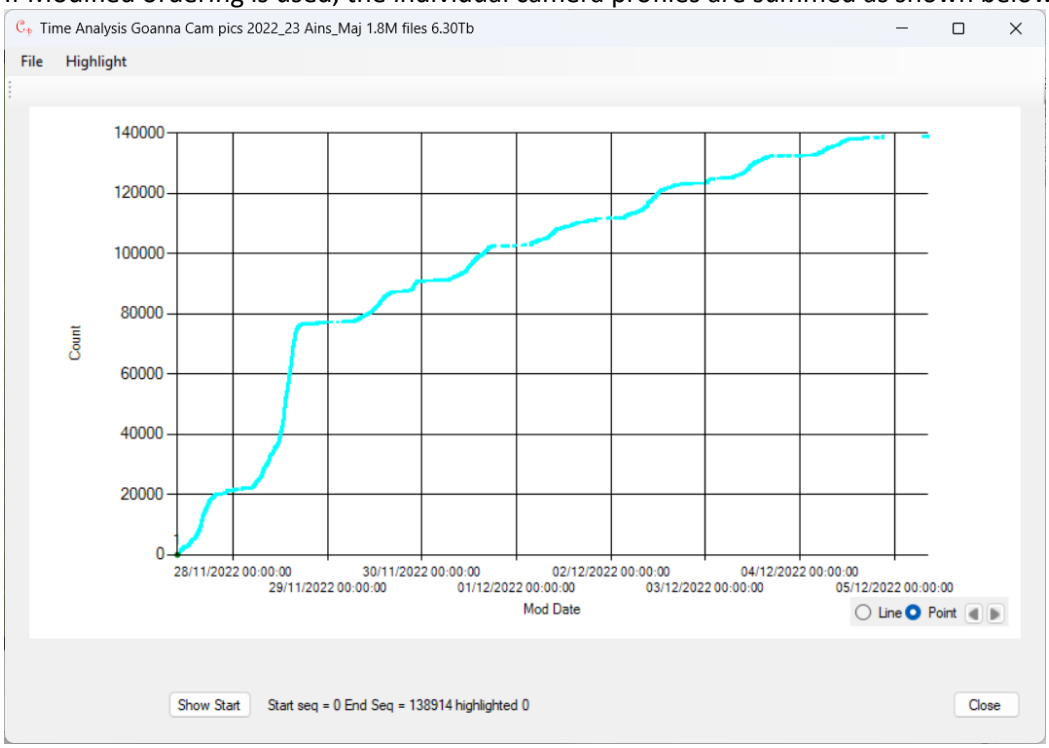


Figure 61 Count vs Time profile using Folder->Modified ordering

Show Start shows the first file loaded. Time Grid Interval allows selection of the time interval between vertical lines on the profile. The function of the View Image button is described on page 43, and that of Tag Multiple on page 32.

If Modified ordering is used, the individual camera profiles are summed as shown below:



Labelling of data from individual cameras is not shown in this case.

If Show Tagged is checked, applied tags are shown as below in a colour specified in Options:

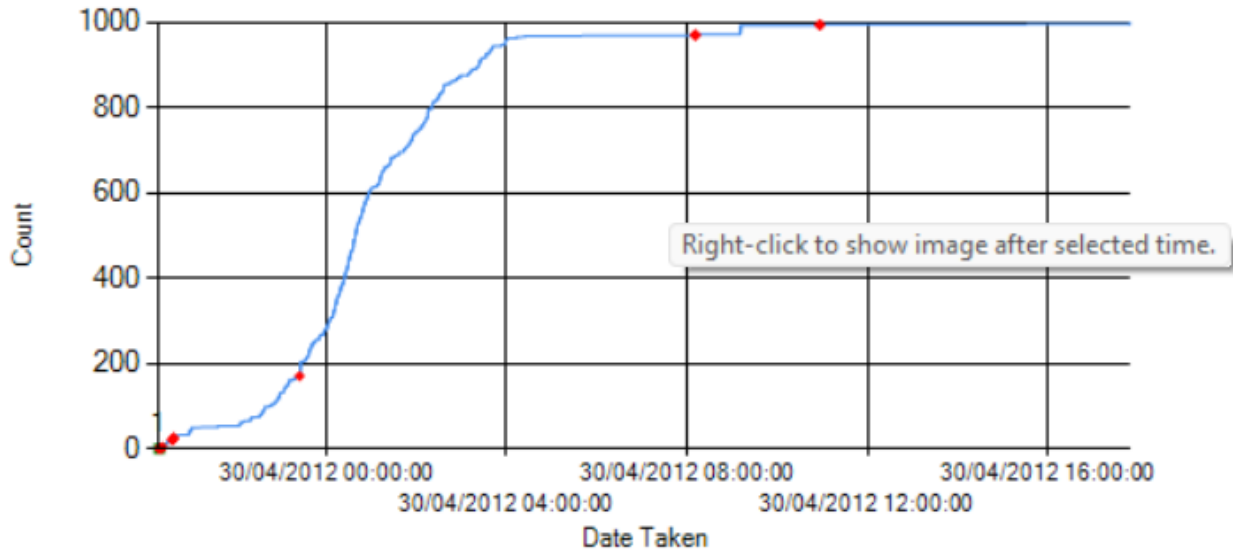


Figure 62 Count vs Time with Tags Images shown

If Show Highlighted is checked, highlighted images are shown as dots in a colour specified in Options:

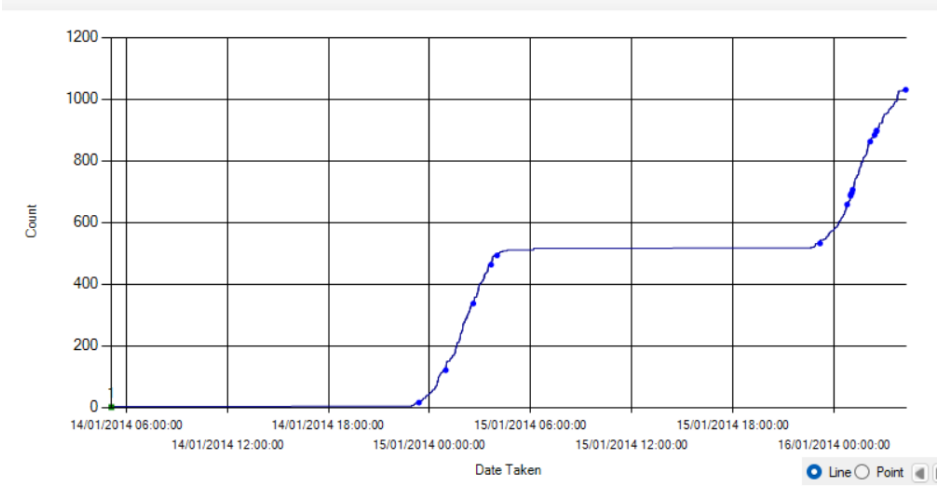


Figure 63 Count vs Time with Highlighted Images Shown

Profiles can be displayed as either lines or points (coloured light blue) as specified with radio buttons at the bottom right. The arrow buttons to the right of the radio buttons move the selected point left or right along the sequence.

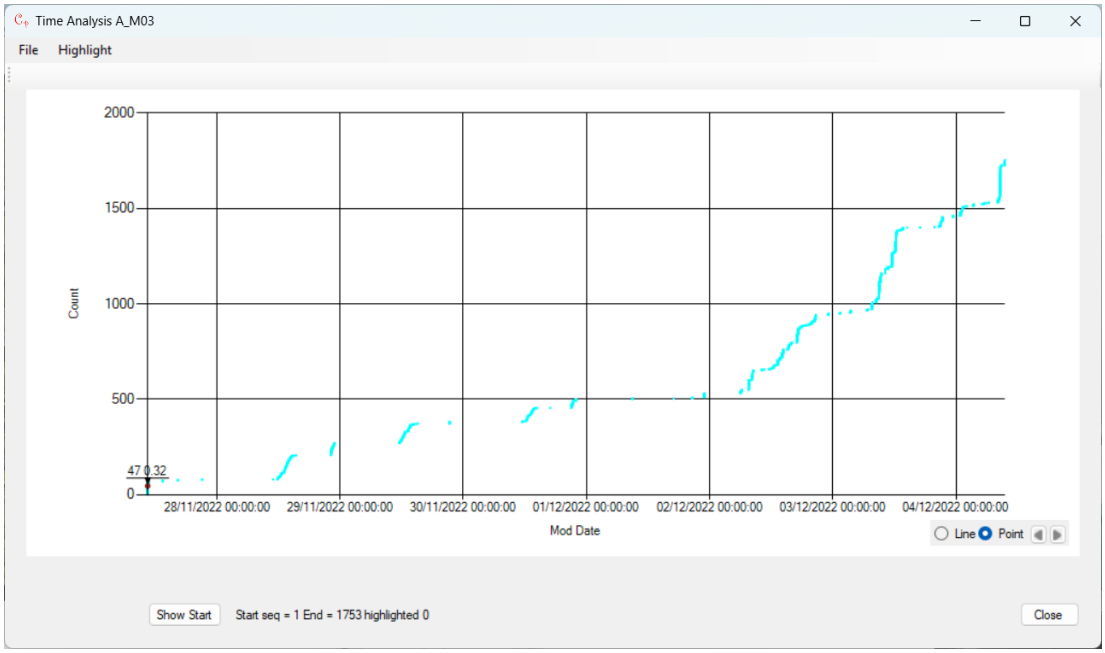


Figure 64 Count vs Time in Point mode

If the profile contains a number of large sharp steps as shown in Figure 48, this indicates that animals are moving in the viewed scene for some time and that tags need to be applied in bulk. This can be done manually in CamTrap Pro, or using the Exif Pro application, which allows application and removal of tags to a subset of loaded images. Megadetector uses machine learning to automatically detect animals in images and can be accessed from CamTrap Pro and applications such as EcoAssist. Output from this process can be loaded into CamTrap Pro.

The appearance of large step in the Count vs Time profile (as shown in Figure 48) indicates that an animal moving in front of the camera is triggering it more often than the more random false triggerings from moving shadows or vegetation. The profile can be zoomed by clicking and dragging to create a box around the area of interest (near the origin) as shown below left. The zoomed display is shown below right.

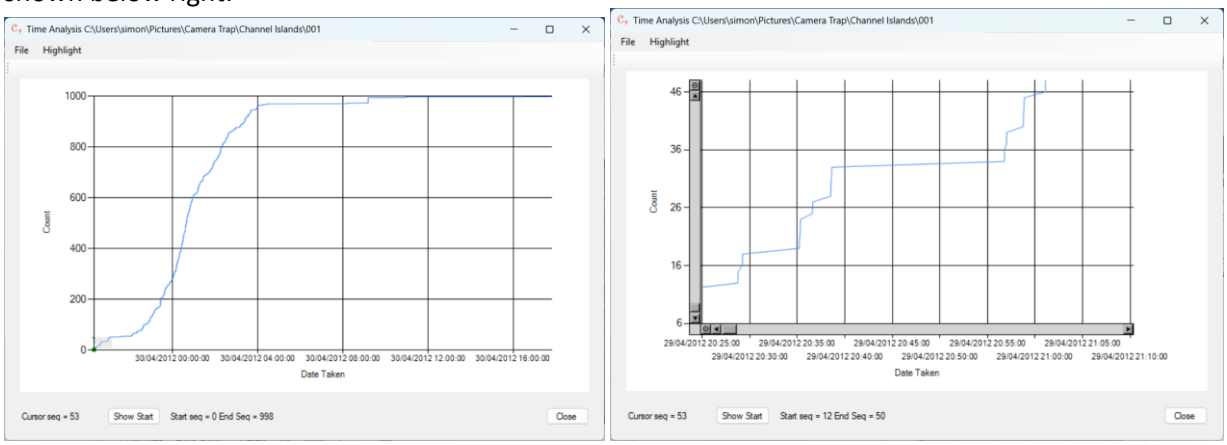


Figure 65 Zoom box defined on Count vs Time profile (left) and zoomed display (right)

The sequence number of the image corresponding the cursor x location is shown in the lower left-hand corner when the cursor is within the profile area.

The Show Start button shows the first image after the start of the displayed region, and right-clicking on the display near a time-count point shows the image. If only a single time/count point is within 5 pixels of the cursor, the cursor changes to a + and right-clicking shows the image. If more than one

point is close to the cursor, the cursor changes to a hand, and right-clicking shows the image with the lowest sequence number. The selected image point is shown in green, together with the sequence number as shown below. The average gradient at this point of the profile is shown to the right of the sequence number

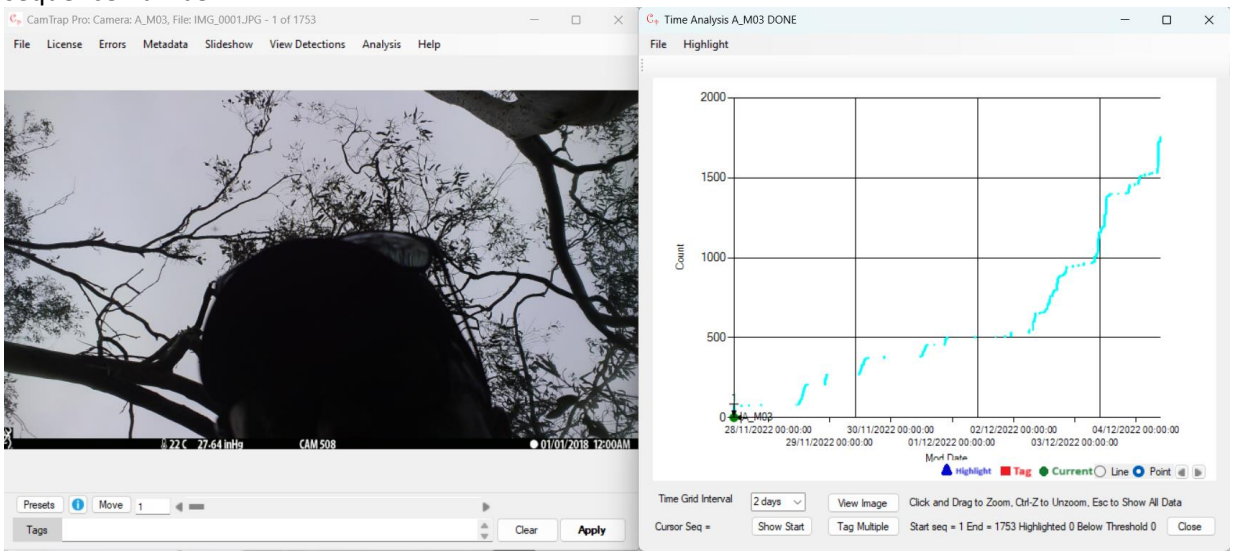


Figure 66 Display after right-clicking near graph point

The image sequence number (510) is shown in both the Count vs Time Profile and in the title area of the main CamTrap Pro window. Changing the displayed image with in the main CamTrap Pro window (via the > and < controls at lower left or the left (or down) or right (or up) arrow keys on the keypad), changes the point shown in the Count vs Time profile, allowing graphical viewing of the time interval between images. The displayed image can also be changed by arrow buttons to the right of the line/point selection buttons. Clicking View Image displays the selected image in Windows Photo Viewer, which permits display of neighbouring images which are not necessarily loaded, or higher resolution images which have not been loaded at all.

Highlight

An image highlight indicates that an image may contain an entity of interest. Highlighting options are accessed via the Time Analysis Menu as shown below:

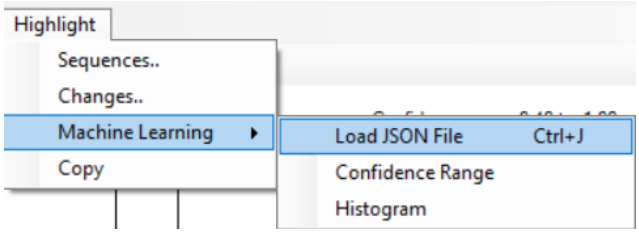


Figure 67 Highlight Options

Sequences.. highlights groups of images appearing in a rapid sequence. Cameras are frequently configured to record 3 images spaced by 1 second after triggering, so Sequence count should be greater than this in this case. Changes ... highlights images which differ from their predecessor or an average of their predecessors in hue or luminance. Images are resampled to a much smaller size before comparison. Both may detect the presence of animals in images but both suffer from false positive and negative detections. The Megadetector->Load Output options allows loading of the JSON file produced by Megadetector and detections with a confidence within the confidence range are highlighted. Megadetector->Confidence Range sets the confidence range for highlighting. Images where there is at least one detection below the lower confidence limit and no detections over the limit are highlighted in orange (by default). The colour of highlights and below-threshold detections can be changed in the Advanced tab of the Options screen.

The options are discussed in more detail below. Highlight and below-threshold results can be quickly inspected by right-clicking on the blue triangles or orange squares created by the process to show the image at the highlighted time. When a highlighted image is shown on the main screen the form (and taskbar) icon changes to a red background as shown below:

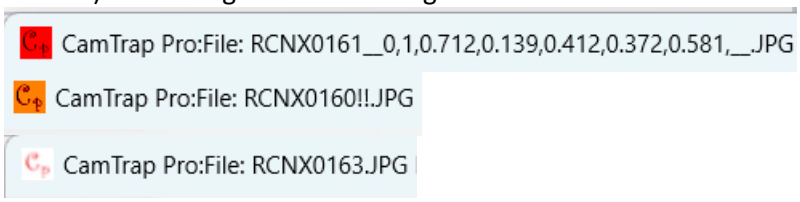


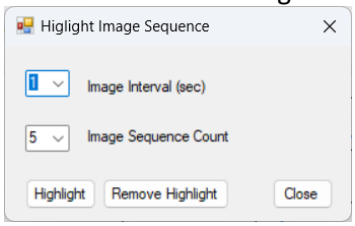
Figure 68 Highlighted image (top), Image with below-lower-threshold confidence(middle) and non-highlighted image (bottom)

If highlight metadata is stored in the file name, images with highlights contain a string defining the detection confidence and the positions of the corners of the bounding box between the strings __0, and ,__ before the file extension. Images with at least one detection below the lower limit of the confidence range have the string !! added in the file name before the file extension.

Inspecting the results of applying the filter defined in Options to show only below-threshold detections allows the effectiveness of the confidence range defined to be tested. If animals of interest are found in the displayed images after filtering (which can be quickly examined via a slideshow), the lower limit of the confidence range should be decreased. However, this will result in an increased number of false detections.

Sequences

As an animal may only appear for in a few images out of several thousand, the step in the Count vs Time profile caused by its appearance may not be perceptible. The Highlight->Sequnces option allows highlighting of points on profiles where the time interval is less than or equal to a number of seconds, over a number of contiguous images as shown below:



Clicking highlight shows blue points at images where this condition is satisfied:

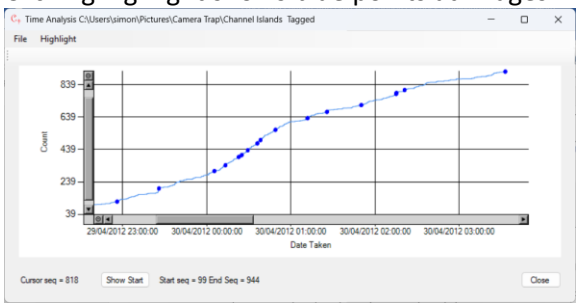


Figure 69 Highlighted points on Count vs Time profile

Clicking on highlighted points shows the image in order to see if the sequence is caused by the presence of an animal.

Changes

The Changes option places a highlight of selected colour on a time profile if a number of pixels in an image which differ in Hue, Luminance (or a combination of them) from their predecessors or an average of them. It can be used to detect the presence or movement of an animal in an image, or if the shadow pattern in an image changes. If the animal hue and luminance are similar to that of the background, no detection will occur will occur. Change detection is most useful where there are a large number of false triggerings from vegetation or shadow movement.

The screen which appears when selecting this menu item from a Time Analysis profile is shown below:

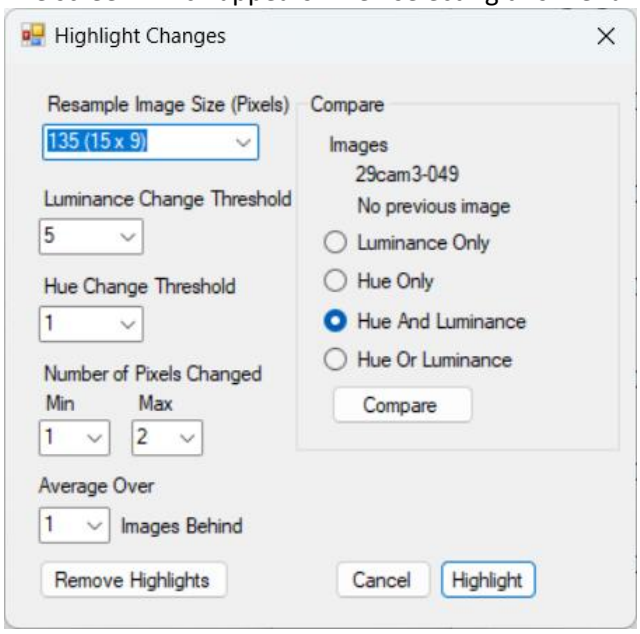


Figure 70 Change detection screen

A time profile point is highlighted when an image differs from its predecessor or an average of its predecessors. Images are first resampled down to dimensions selected from the Resample Image Size options, which are between 15 and 960 pixels with a 5:3 aspect ratio. Each pixel is then compared to the corresponding pixel of its predecessor or an average of a number of predecessors (as defined by the Average Over using the criteria shown below:

Comparison Mode	Highlighted When
Luminance Only	Luminance change exceeds threshold and number of pixels changed between Min and Max
Hue Only	Hue change exceeds threshold and number of pixels changed between Min and Max
Hue and Luminance	Hue Change and Luminance change exceed thresholds and number of pixels changed between Min and Max
Hue or Luminance	Hue Change or Luminance change exceed thresholds and number of pixels changed between Min and Max

The currently selected image can be compared with its predecessor (or an average of its predecessors) via the Compare button, which shows a screen as below:

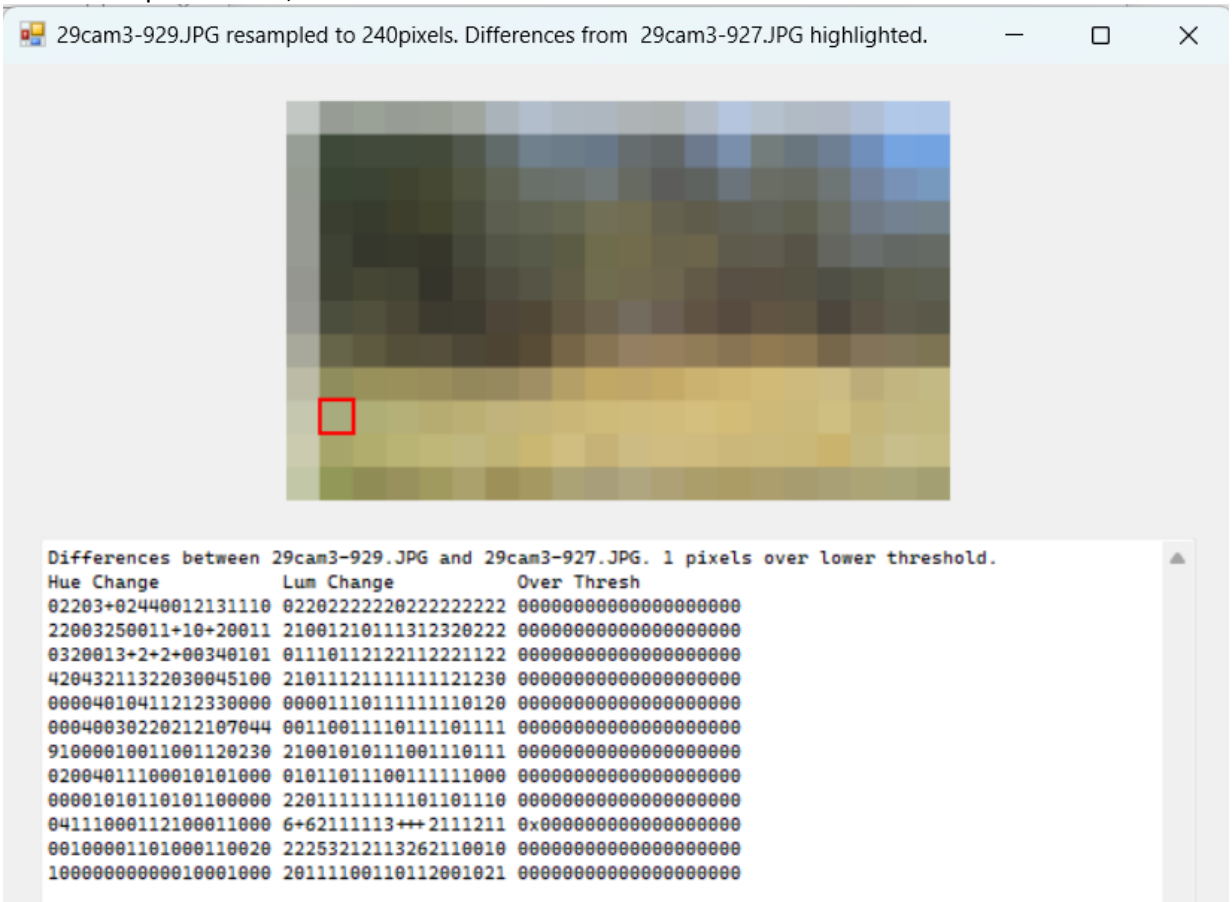


Figure 71 Comparison of Selected with Preceding Image

The resampled image is shown, with any pixel meeting the threshold criteria framed in red shown at the top. The line of pixels at the top and left-hand side are not correct. Hue and Luminance changes for each pixel are shown below, with change values greater than 9 replaced by a + in order to maintain a compact grid structure. Over threshold pixels are marked with x rather than 0. The original pixels within the image are also enclosed a red box as shown below:

Figure 72 Pixels within original image showing above-threshold change.

Change detection does not match human or machine learning performance in animal detection in an image. Its advantages over computer vision facilities such as Megadetector are that it is fast, and does not require access to training data or powerful computing resources. However, its performance is highly dependent on the correct choice of parameters, and the optimum parameters for any data set will depend on the nature of the scenes shown in the images, and the expected size and colour contrast of the animal to be detected. The ideal method of setting parameters is to find an image containing an animal preceding one or more images which do not contain the animal. The pixel size should then be adjusted so that the animal is contained in the majority of a single resampled pixel.

Change threshold values should then adjusted so that the pixel containing the animal is the only one meeting threshold criteria. The Minimum number of pixels changed should be set to 1 in this case, and the maximum to the largest number of resampled pixels containing the animal. Detection should then be tested over a number of images, including one containing the animal. Setting the Average Over value to a value >1 may improve precision and recall of detection.

Parameter values used will depend strongly on the number of pixels changed by the presence of an animal and the degree of contrast between the animal and the background. Some experimentation will always be required.

The Highlight button applies the change algorithm to all loaded images and highlights those which meet the criteria. These images can be copied to a separate folder for tagging.

Remove Highlights removes all highlight data from loaded images.

Machine Learning

The Machine Learning options allow reading of JSON files created by auxiliary applications such as EcoAssist. Internal application of Megadetector is not currently implemented. A histogram of the maximum confidence value for any detected entity for all loaded images can be generated, or images with values within a defined range can be highlighted in the time profile. The Megadetector options are shown below:

Figure 73 Machine Learning options

After processing, images with any animal detection with confidence between the upper and lower bounds will be highlighted as shown below:

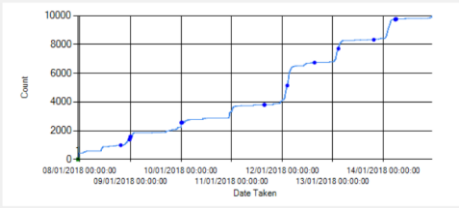


Figure 74 Megadetector detections highlighted

Selecting the Copy option after highlights have been shown allows each detection to be analysed visually and appropriately tagged.

Machine learning processing uses a neural network to classify images on the basis of training sets, which need to be quite large to obtain reliable results. The Megadetector model has been trained on a large number of images and is very accurate for large mammals, but works less well for reptiles. However, the detection of similarity may rely on completely different features from those perceived by humans, giving rise to false negative and positive detections, especially when large numbers of

training images are not available or where there is little contrast between the animal and the background. Some examples of false positive and negative detections of a lizard are shown below:

Figure 75 False positive and negative detections using Megadetector

The top image shows two false positive detections (albeit with low confidence) and one correct detection of a lizard. The bottom image shows a false positive and a false negative detection – the lizard is present at the bottom right of the image but has not been detected.

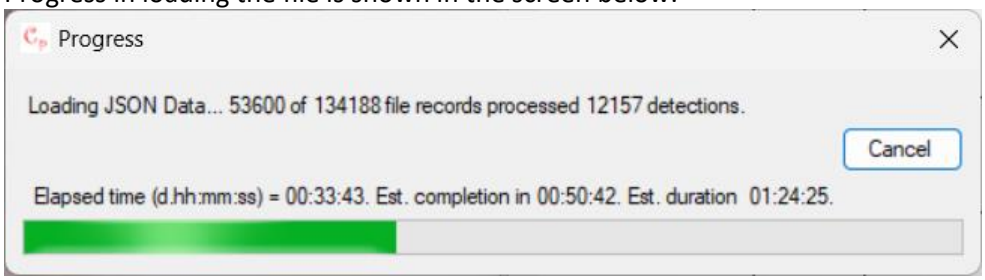
Load JSON File

The Load JSON File option allows output from classifiers such as EcoAssist to be used to highlight images. This output is in the form of a JSON format file created in the selected folder of the classifier. If EcoAssist is run on a different machine from CamTrap Pro, the option Use Absolute Paths in the Advanced view of EcoAssist should be unchecked. The folder selected in CamTrap Pro should be the same as that selected in EcoAssist.

Selecting a file on the Count vs Time profile highlights images on the time profile where the maximum detection confidence of an animal is within a range defined by the Confidence Range menu item and the file path in the JSON file matches the path of the loaded file, or the file name matches that of the loaded file depending on the Options setting. The default confidence range is 0.5-1.0. The progress bar for loading JSON data moves at a highly variable speed depending on the confidence range selected, so estimated completion times will generally not be accurate.

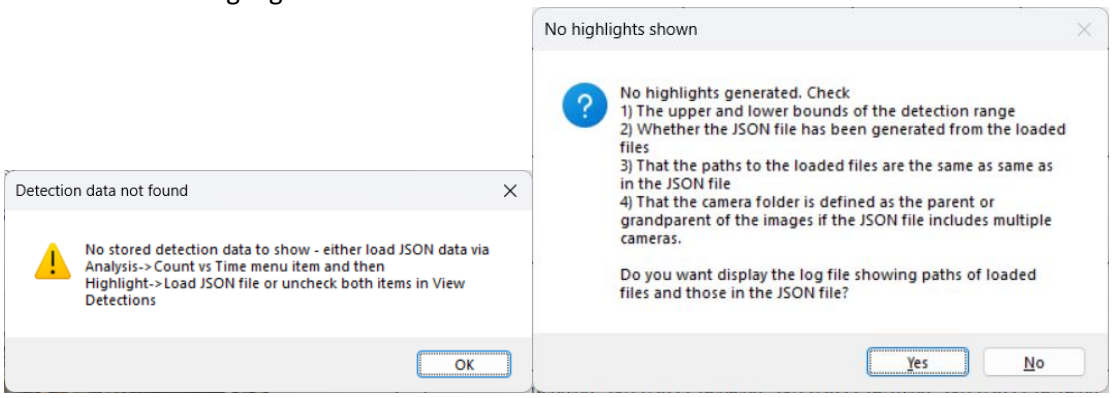
If metadata is added to the file name (via the Store in File Metadata option in the Highlights box), the path length may exceed the Windows limit of 260 characters, especially if multiple animals are detected in the same image and detection data is stored in the file name. In this case and option to remove detections until the path length is less than the Windows limit, or to Use Only Highest Confidence detection in each image. Note that multiple animals will still appear in Tag Occurrences even if this option is checked.

Progress in loading the file is shown in the screen below:



The Estimated Duration will generally change during loading, being more reliable as a greater proportion of the file is processed. Loading is faster is Store Detections is unchecked in the Options Advanced screen, but the loading process still takes many hours if hundreds of thousands of files have been loaded.

If the paths created from the JSON data do not match the loaded paths, the following screens are shown. The “No Highlights Shown” screen is also shown in the circumstances shown on the screen.



If Yes is selected, the paths extracted from the JSON file can be compared with those stored by CamTrap Pro. If any highlights are created and the option to store highlight metadata in the file name is selected the file name will be changed to include the detection confidence and bounding box co-ordinates where detection confidence exceeds the threshold value. The option to reload data with changed metadata, optionally showing only highlights as below is then presented.

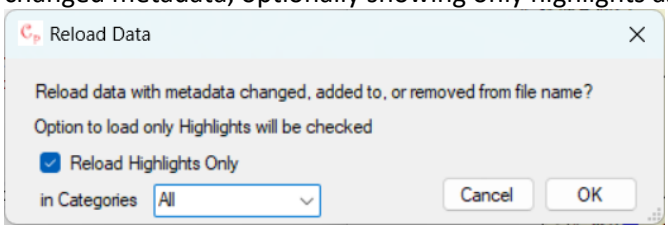


Figure 76 Reload option after loading JSON file.

If Reload Highlights Only is checked, the default is to reload all highlight categories. Highlights with selected categories can be reloaded via the Categories dropdown box. If metadata is stored in the Authors field, file names are unchanged.

Above threshold detection bounding boxes are shown in white (by default) and below-threshold bounding boxes in blue (by default), with the confidence value in white if both of the View Detections menu options are checked as shown below:

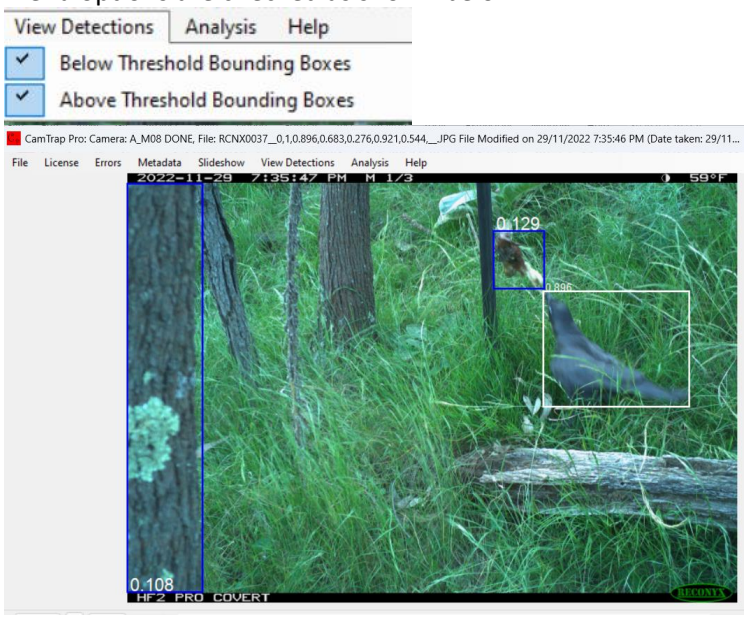


Figure 77 Above and Below Threshold Bounding Boxes (bottom) and Box Selection Options (top)

The icon at the top left changes from a white to a red background if an over-threshold detection is present. If there is at least one detection below the lower limit of the specified range and no detections above it, the icon changes to orange as shown below.

Figure 78 Image with at least one below-threshold detection

If a JSON file is available which was not created by scanning the locally stored data, the locally stored data should mirror the structure of the data used to create the JSON file. For example if the JSON file contains an element as shown below, the locally stored data should use the same folder structure, with only the drive letter (D:) changed.

```
{
 "file": "D:\\Goanna Cam pics 2022_23 Ains_Maj 1.8M files 6.30Tb\\Week 1
  126,213 images 411 Gb 27Nov_4Dec2022\\A_M12 DONE\\100RECNX\\RCNX0001.JPG",
 "detections": [
  {
   "category": "2",
   "conf": 0.907,
   "bbox": [
    0.0004882,
    0.02152,
    0.7187,
    0.9548
   ]
  }
 ]
},
```


After loading has completed, the option to reload the data is presented as shown below.

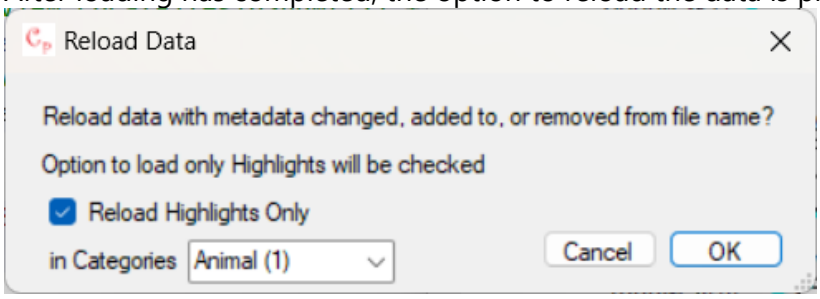


Figure 79 Reload data after loading JSON file

OK should be selected if detection metadata has been stored in the file name. A highlights-only filter can optionally be applied, with the highlight category selected.

Confidence Range

This option set the upper and lower bounds for the maximum detected confidence level for any entity appearing the Megadetector output via the screen below. For the default model MegaDetector 5A used by EcoAssist, the only entities detected are animals, vehicles and people, but models can be built in EcoAssist to identify particular species. However, very large numbers of training images (10,000 per species) are required for reliable detection.

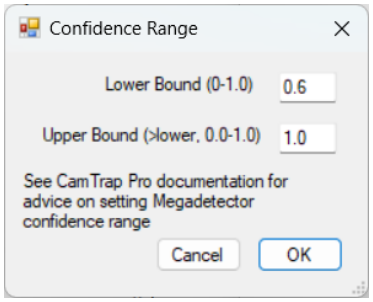


Figure 80 Megadetector Confidence Range screen

If the upper bound is set to the default value of 1.0, the value of the lower bound used determines the compromise made between false negative and false positive detections, and should be set after examination of the histogram of confidence levels. The default lower bound is 0.6. High values will tend to include only high confidence detections, but will result in false negative detections if animals do not have strong visual contrast with their surroundings, or if parts of them are occluded. This advice can be viewed via the Info button.

An example of a false negative detection is shown below:

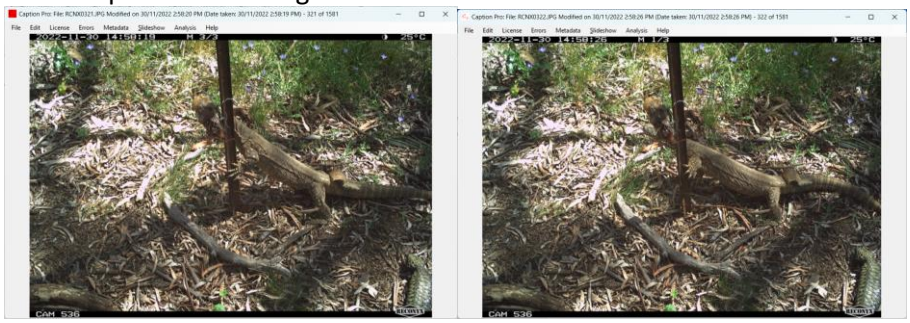


Figure 81 Example of correct (left) and false negative (right) detection

The two successive images (taken 7 secs apart) have maximum detection confidences of 0.82 and 0.46 respectively, despite them being visually very similar. Using a lower confidence bound of 0.8, only the first will register as a detection. The confidence level setting trades off between precision and recall. A low confidence level bound will have fewer false negative detections but will include more false positive ones. Low confidence detections are usually false, but may not be.

The nature of detections can be explored by setting the upper bound to a value of less than 1.0 and examining the images with maximum confidence values in this range, either by right-clicking on highlights or by copying all highlighted images to a new folder and examining them.

After setting a confidence range, highlighted images can be copied to a separate folder and analysed separately. The smaller number of images allows more reliable human detection of animals and determination of their species.

If different detection bounds are required after a run, these can be changed via the Confidence Range screen.

Histogram

The histogram option shows the distribution of maximum confidence values over the set of images. The distribution is highly variable, as the examples below show:

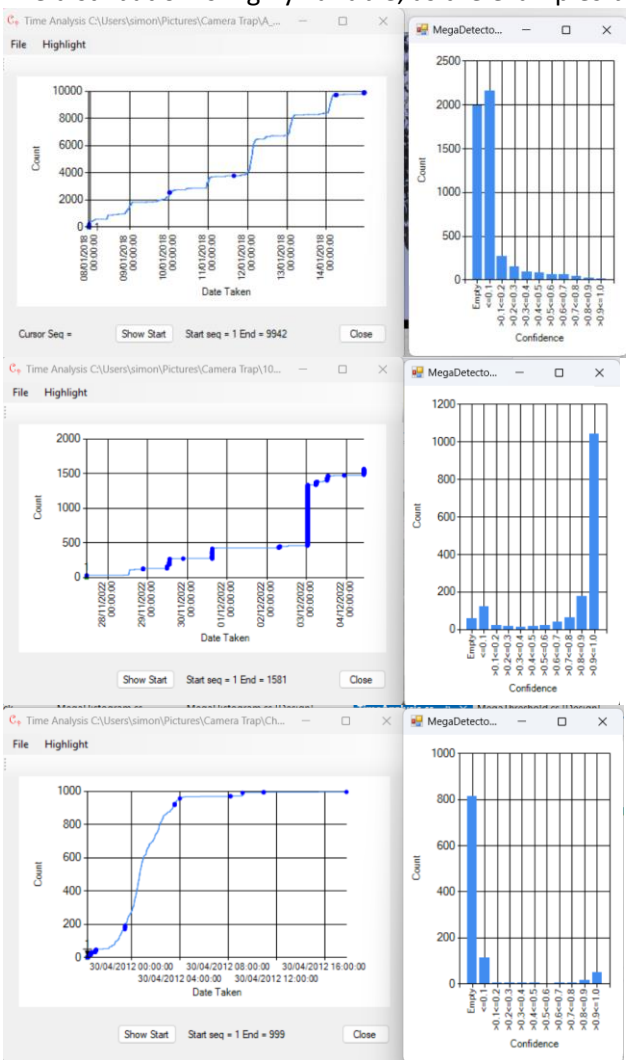


Figure 82 Confidence value histograms and count vs time profiles for 3 datasets. A confidence range of 0.85-1.0 is used to define highlights.

The top dataset above is from a baited camera trap running for 7 days, where the bait did not attract any animals. The small number of animal detections come from animals crossing the camera scene. The count vs time profile shows fewer triggers at night but no sharp steps. There are a very large number of false triggering images which Megadetector interprets as containing animals but with low confidence.

The middle dataset is from another baited trap running for 7 days which attracted a large number of animals, resulting in many high-confidence detections and large, sharp steps in the profile where animals move within the camera scene for periods of a few minutes.

The lower dataset is from a non-baited trap running over a single day. The absence of steps indicates that animals did not spend long within the camera scene, but there were a significant number of high-confidence detections of animals briefly present.

Showing the Histogram as a cumulative percentage plot allows selection of the appropriate confidence range values:

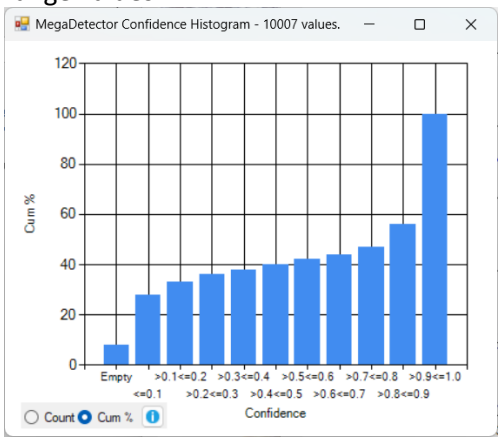


Figure 83 Cumulative Percentage Histogram Plot

The lower bound of the first category above 80% represents a reasonable compromise between false positive and false negative detections. In the example above this will be 0.9.

Copy

The Highlight Copy option images highlighted using Megadetector or other algorithms to a selected folder. If the Changes algorithm is used, only images which differ from their predecessor will be copied and these may not include all those showing animals. The default destination folder is a sub-folder with the name Highlighted in the user's Pictures folder. This folder is created if it does not already exist, and cleared of any existing content if it does. The highlight path is added to that of the selected folder, with the drive information removed.

An option to load the content into CamTrap Pro is presented to facilitate visual inspection and tagging. In the case where false triggerings dominate animal detections, analysing the content of this folder will reduce the effort of identifying animal species in images. The confidence range lower limit can be adjusted to ensure that all animals are detected in images.

Zoom

Menu options are listed below

Camera (ctrl-M)

The Camera screen is below:

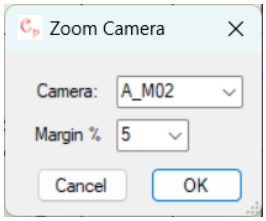


Figure 84 Camera zoom selection screen

The camera combo box lists all cameras in the loaded folder. Clicking OK sets the zoom region to include all images from the selected camera, plus a percentage margin specified in the Margin % combo box. This menu option is only shown if the folder sorted order is Folder->Modified.

Unzoom (ctrl-U)

This menu option undoes the last zoom operation. The keyboard shortcut is ctrl-U.

Show All (ctrl-A)

This menu option shows images from all cameras. The keyboard shortcut is ctrl-A.

View

Refresh Points

Clicking this menu options refreshes all points shown on chart according to the settings shown on page 49 when the Count vs Time chart was shown

Summarising Tags

A text and graphic summaries of tag data can be obtained via the Analysis-> Summarise Tags menu option. If no Tag Occurrence data is present in the tag database (which is stored in above the folder containing the images as TagDB_EpochName_CameraName_.vdb5), an option to create the tag summary will be presented as shown below.

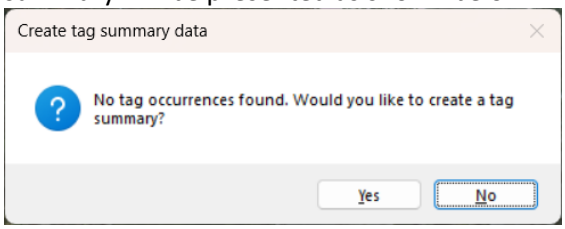
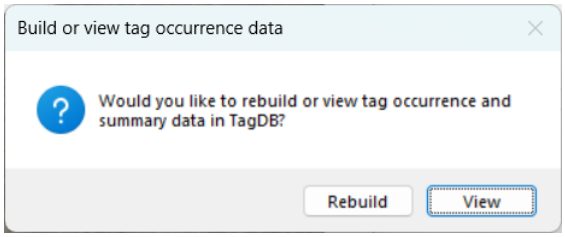
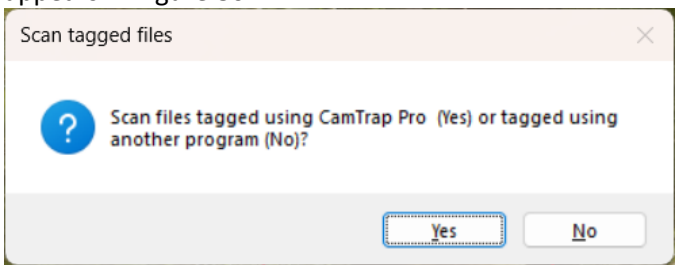


Figure 85 Screen for creating Tag Summary if none present

Yes should be selected unless a tag summary has been generated before and the tags are unchanged. No closes the dialog. If Tag Summary data already exists, the screen below is shown instead of the screen as shown above:



If Yes is selected from Figure 85, or the Rebuild option from screen above present, the option to detect and summarise tags one of two ways is then presented. Clicking View shows the summary as it appears in Figure 86.



If only a few files have been tagged manually, selecting Yes will greatly speed creation of the tag summary and this option should generally be selected. No should be selected if files have been tagged externally (for example by Exif Pro or directly from Windows). The progress screen for this operation will move at an irregular speed.

Tag summary screens for Week, Day and All times groupings of data are shown below.

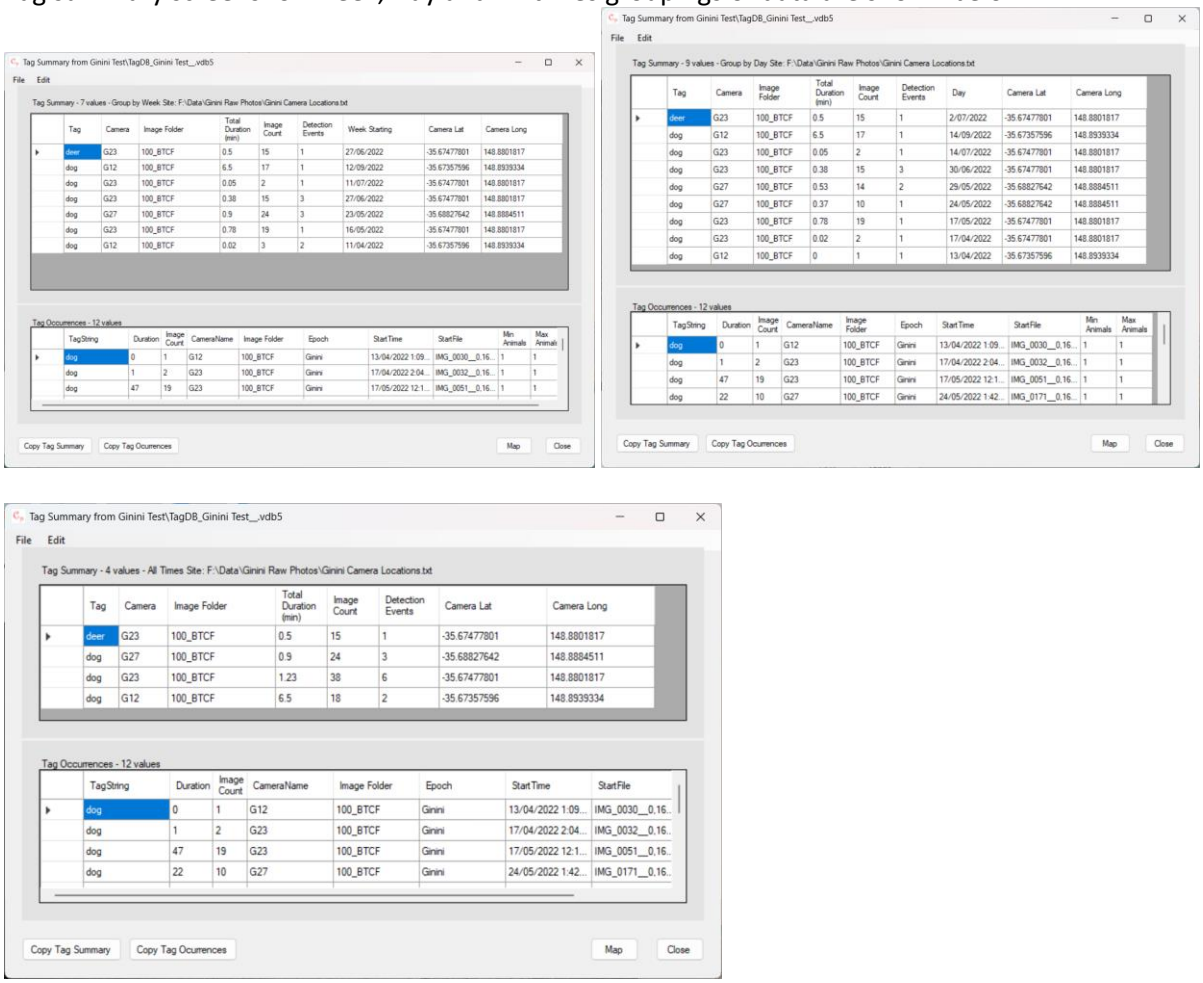


Figure 86 Tag Summary Screens grouped by week (top left), day (top right) and all times (bottom)

The All grouping option adds all the detections which occur for each camera. If this option is selected, Modified dates do not have to be accurate for all the camera data.

The Map button shows the summary as a map, with detections counts summed over all times. Map functionality is described in more detail on page 70.

The upper Tag Summary grid shows the sum of durations and image counts and the detection event count for each tag present for all the loaded files. A duration of zero indicates that the tag was only applied to a single isolated image. A detection event occurs when there is a sequence of one or more images where no pair of sequential images is separated by more than the time interval specified as Max Gap on the Advanced tab of the Options screen. The time interval commonly used is 10 minutes. Detection event count is used as a measure of species abundance.

The lower Tag Occurrences grid shows the tag, duration, image count, camera name, image folder (the name of the folder in which the file was found), the epoch of image collection (as defined in Options->General) start date/time and start file name of each group of files tagged. Min Animals and Max Animals show the minimum and maximum number of animal detections in the images comprising the occurrence.

The camera name is shown if multiple cameras are used. The content of each grid can be copied to the clipboard and pasted into a report.

If tracking of individual members of a species is required, distinctive tags can be applied (eg Goanna 1, Goanna 2).

Copying Summary Data

The Tag Summary data can be copied to the Clipboard and transformed into a form suitable for import into a GIS (Geographic Information System).

Summary Views

Count vs time, text and map summaries are shown below:

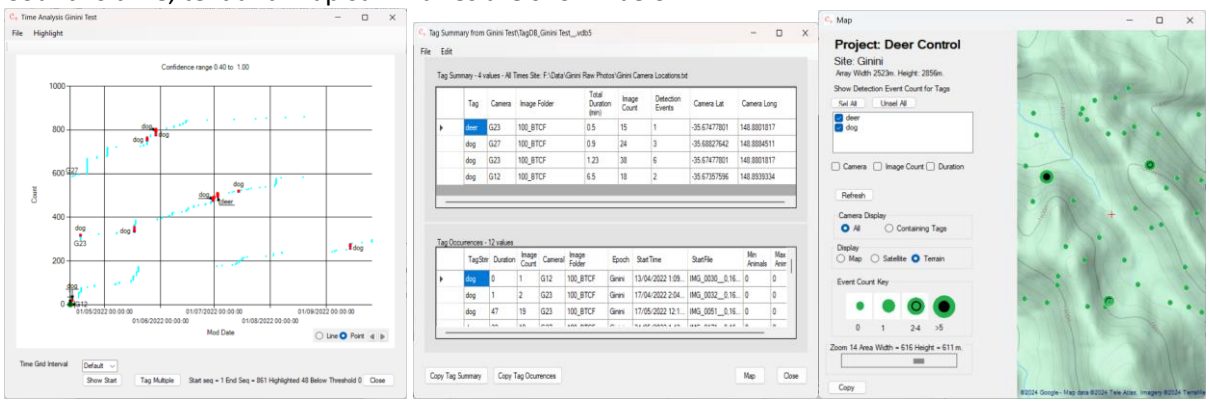


Figure 87 Summary Views of Tagged Data

Consolidating Summaries

A project will usually collect images from multiple cameras over multiple epochs in a particular region, and will generally require a report on the animal species recorded by the cameras. As projects may record data over dozens of epochs from tens or hundreds of cameras, millions of images are frequently created. If the analysis and tagging process operates on data grouped by epoch, a tag summary (and associated database) will be created for each epoch. If the data is grouped by camera, the summary is as shown below:

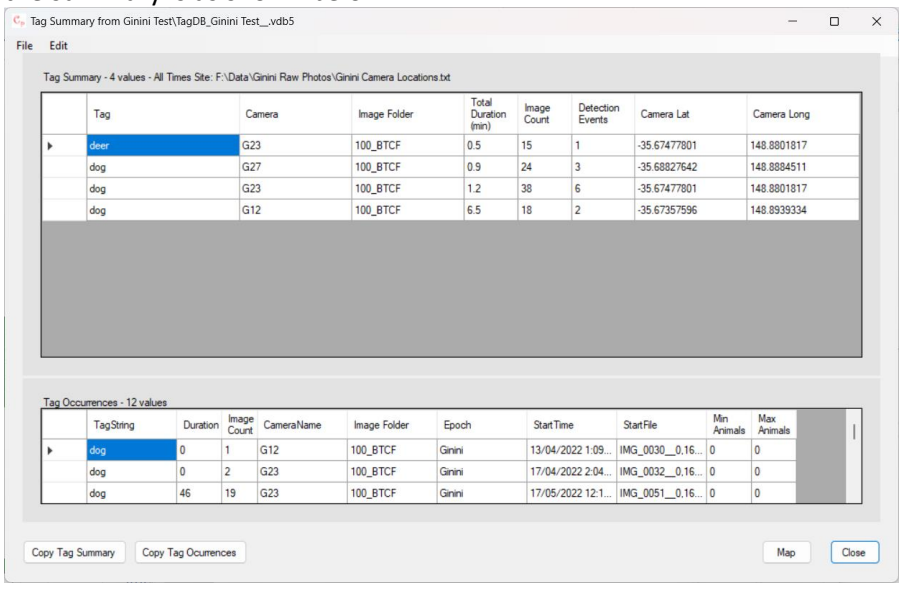
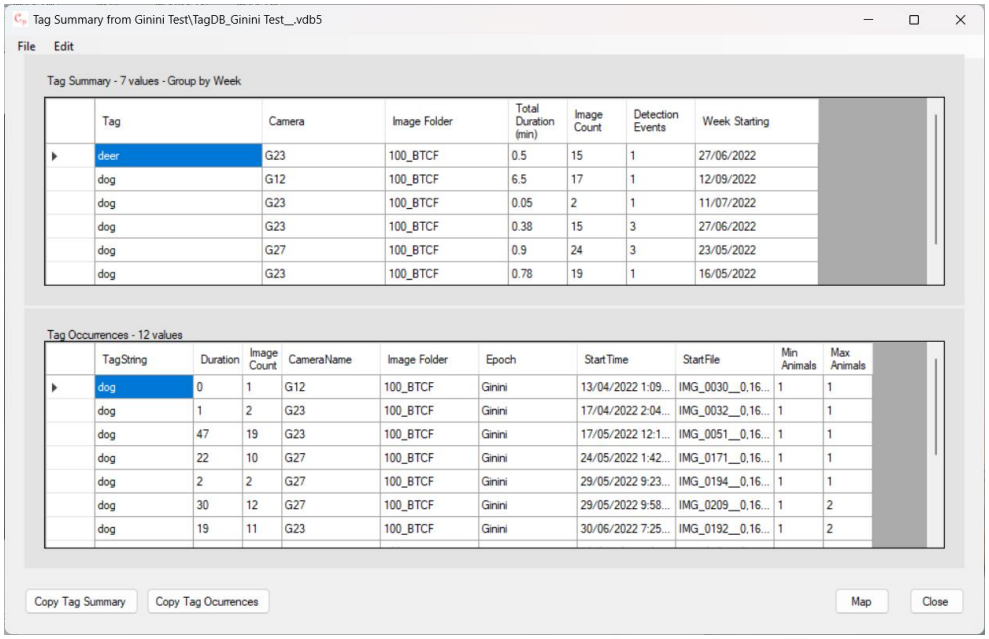


Figure 88 Tag Summaries from with camera location for all times

If the day or week option set in the General tab of Options



Summaries or individual epochs can be consolidated via the File->Consolidate TagDBs menu option. The Browse button allows selection of a folder below which to search for .vdb5 files whose name starts with TagDB to consolidate. The Consolidate button performs the consolidation. The Copy button copies displayed data to the clipboard, and Cancel closes the screen. Columns can be sorted by clicking in the header. After selecting a folder and consolidating and with Consolidate Cameras is checked, Summary image counts and durations from all cameras are consolidated as shown below. This mode is useful for summarising animal detections over the region where cameras were placed.

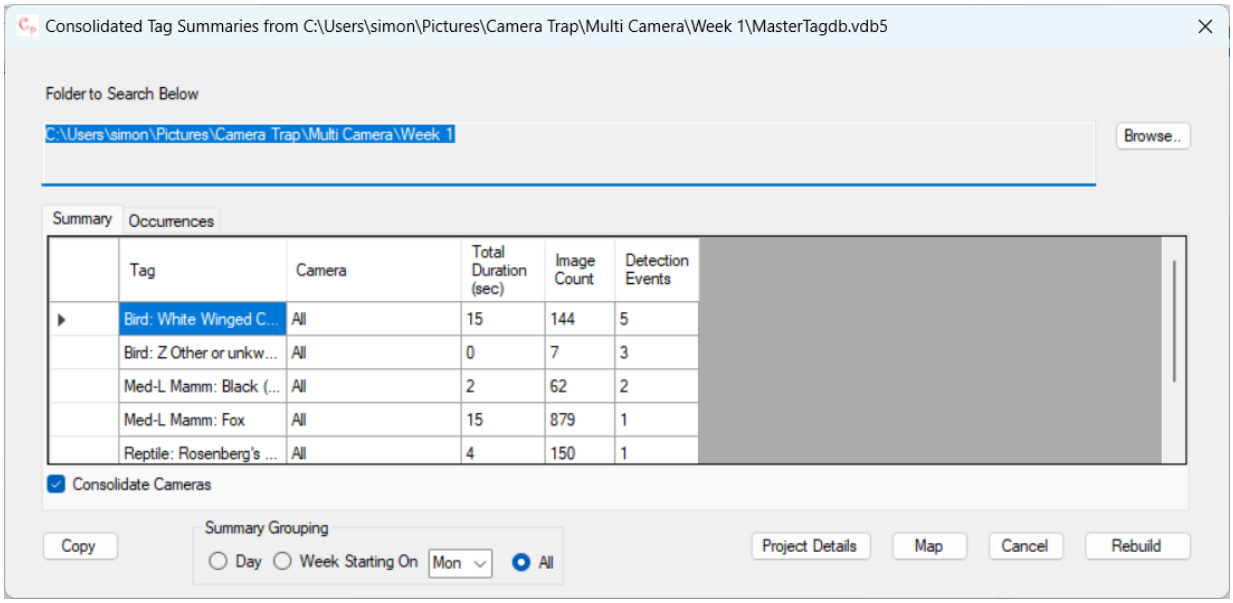


Figure 89 Consolidated Tag Summaries with Consolidated Camera data for All Times

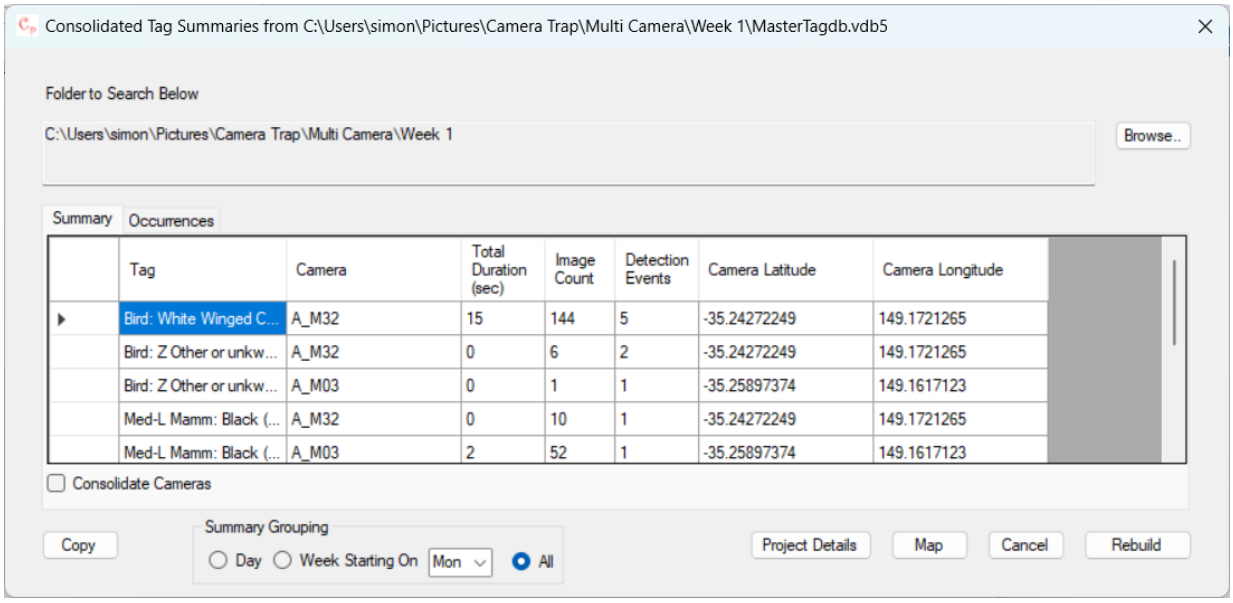


Figure 90 Consolidated Tag Summaries from IndividuaL Cameras for All Times

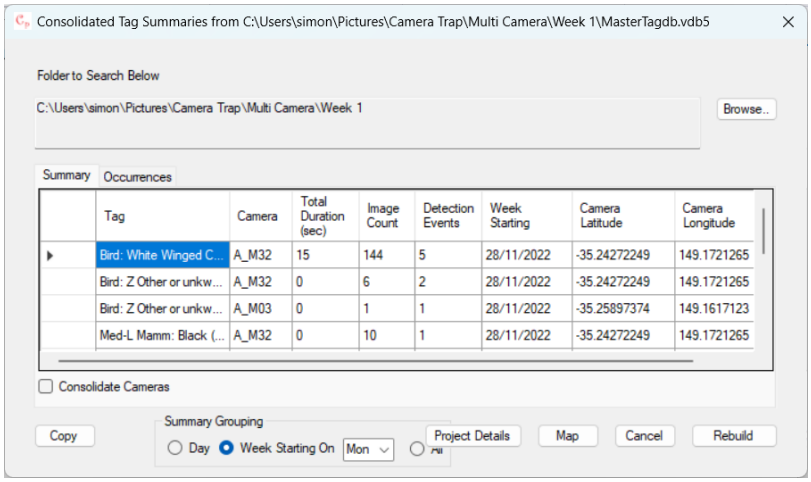


Figure 91 Consolidated Tag Summaries for Individual Cameras - Grouped by Week

The grouping interval can be set to day, week or all via the controls in the Summary Grouping box.
Camera Locations, Project and Site name can be set via the Project Details button
Clicking Map shows a map of camera locations with different icons for the number of Detection Events for selected tags (irrespective of whether Consolidate Cameras is checked or not):

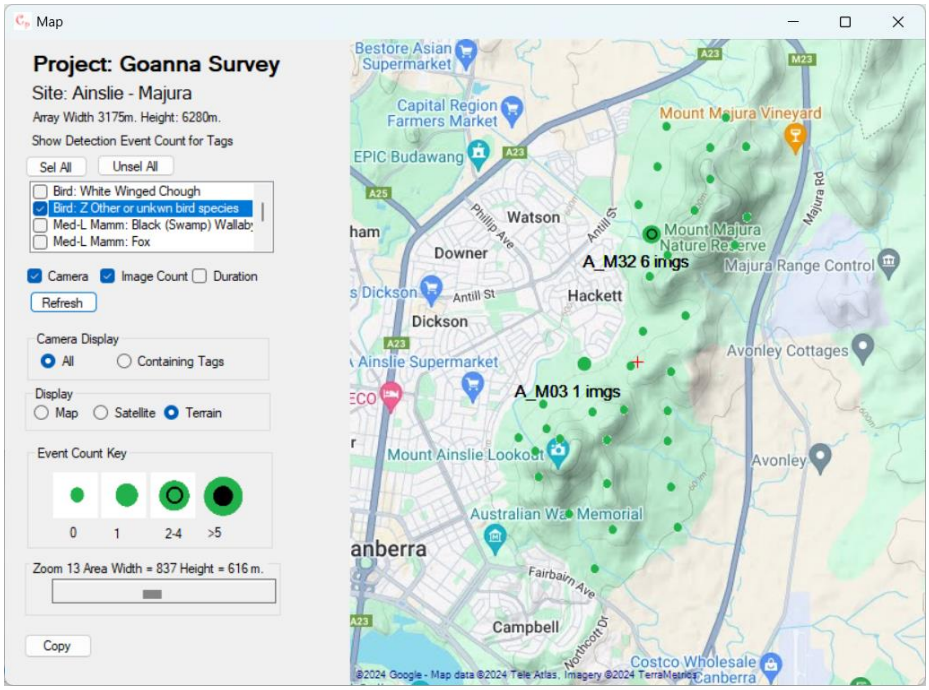


Figure 92 Map Display of Consolidated Data

Map

The Map button shows a map representation of data from the Tag Summary grid, summed over all times.

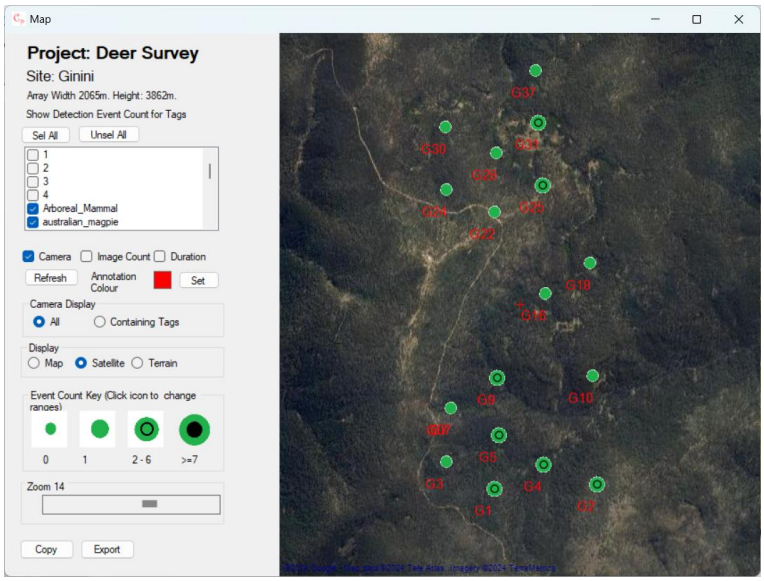


Figure 93 Map Representation of Summary

Camera locations are shown as symbols on map background, which can show terrain, a satellite view, or an urban style map. Different symbols are used for different values of Detection Event count for each camera. The Camera name, image count and duration (in minutes) can be displayed as text below the symbol. Displayed tags can be selected from the list displayed. These comprise those created or selected as Use in the Categories grid of the General tab of Options. Only cameras with tagged data can be displayed by selecting Containing Tags in the Camera Display box. The default is to display data from all cameras. Changes to the map style, or the tags selected for display are applied via the Refresh button. The colour of the annotations can be changed from the default of red via the Annotation Colour button. The display can be zoomed in or out and the size of the displayed region is shown above the scroll bar, together with the zoom factor, which is not continuous.

The entire image can be copied to the clipboard using the Copy button, and pasted into a report.

The range values assigned to the various key icons can be set by clicking on the icon or the text below it to show the Event Count Values screen.

Event Count Key Values

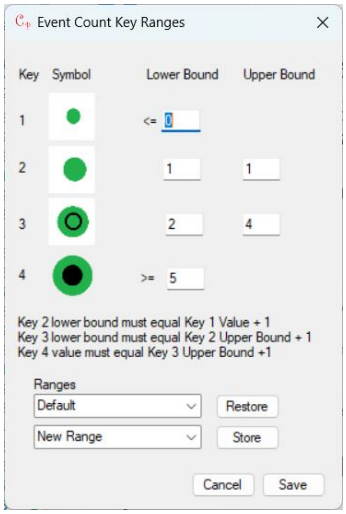


Figure 94 Event Count Values screen showing default values

The values for Detection Count corresponding to the 4 different icons shown on the Map at camera locations can be defined above. If values do not conform to the rules shown, an error describing the non-conformance is shown on clicking Save and the screen does not close. If the values do conform, the screen closes and the map display is refreshed with the new values.

Sets of values (or ranges) for the 4 icons can be saved and restored using the Restore and Save buttons. The Default range is as shown above. This range cannot be changed.

The Export button exports camera location and detection counts into a CSV file which can be loaded into a web-based GIS to give a map as shown below, to which other layers can be added if required.

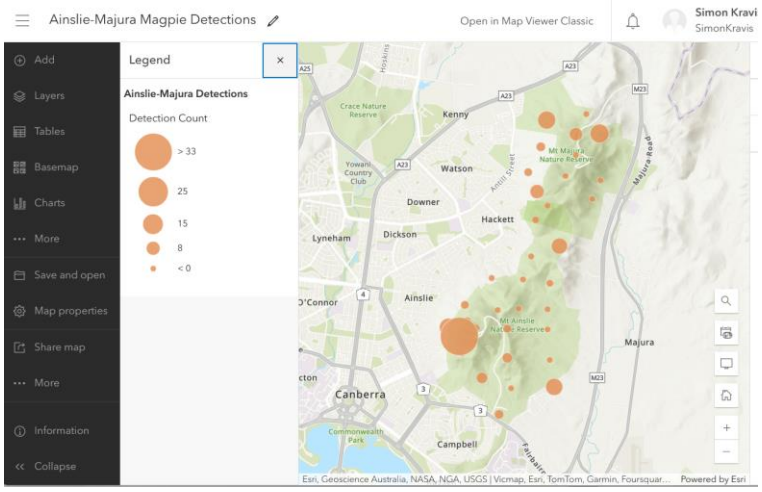


Figure 95 Display of Detection Counts in ArcSoft GIS

Detections

Machine vision (AI or machine learning) image analysis algorithms may identify inanimate, stationary objects such as bait, rocks or vegetation as animals with high confidence as shown below.

Figure 96 Examples of non-animal detections

Such detections may be identified as their boundaries remain fairly constant over a number of images, which is seldom the case for animal detections. Such detections can be shown via the detections screen, which shows the number of images in which detection boxes with areas within the specified tolerance (selected from Area % Tolerance combo box) and width of median values occur within a region of the image. Low tolerance value show fewer detections, but may miss some inanimate objects as detection box size and width may vary between images.

The number of regions defined on images is specified by the Size parameter, with a default value of 20, giving 400 regions. Counts of detections found in regions are colour coded as a heat map, as well as being shown within the image region. Hovering over a cell shows the count and a variation score defined as the detection box area variation over the mean detection box area. High counts and low variation scores indicate a high probability of the detection being of a stationary (i.e. inanimate) object.

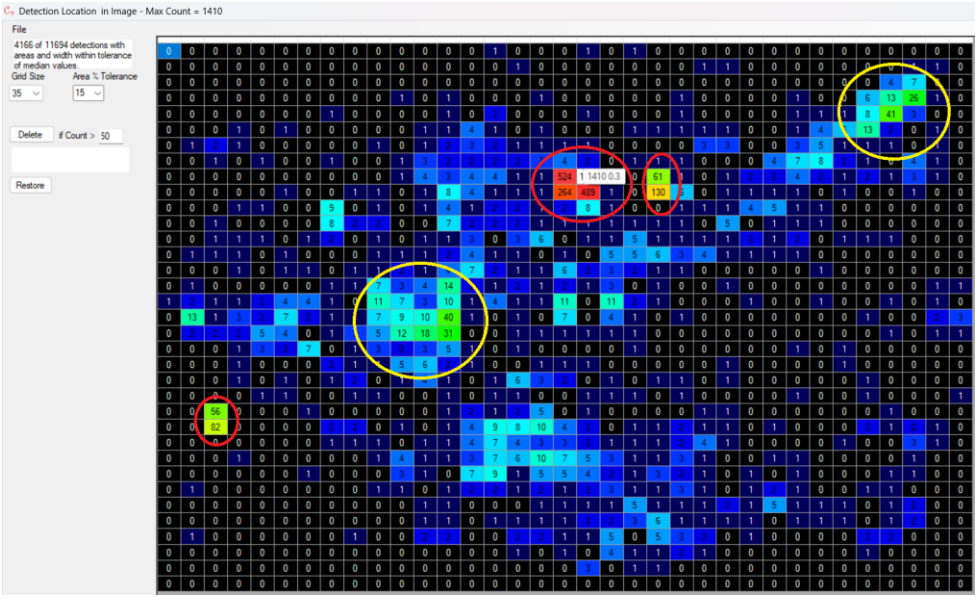


Figure 97 Detection location information using grid of 35x35 regions. Detections of inanimate objects are circled in red and those of stationary animals in yellow

The heatmap used to colour regions is black (0)-blue-green-yellow-red-white, with white being the region with the highest count. Hovering over a cell shows the count and the proportionate area variation. Detections of inanimate objects (circled in red) often have counts much higher than those of neighbouring regions, whereas detections of animals which do not move much (circled in yellow) are typically broader.

The Time vs Count plot for another data set are shown below:

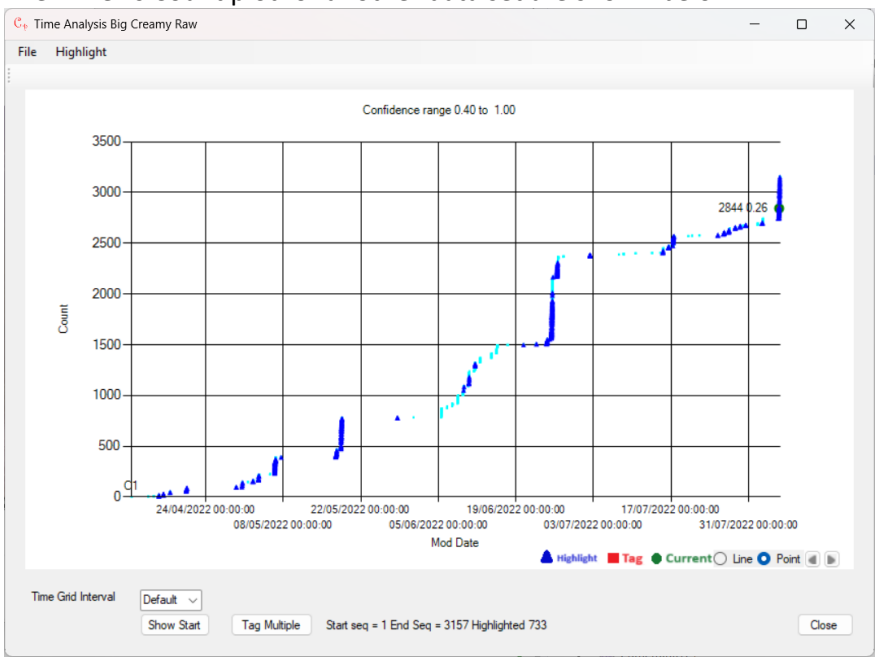


Figure 98 Count vs Time profile with Highlights

This data set contains detections with confidence >0.4 for 733 of 3157 files. The Detections map is shown below:

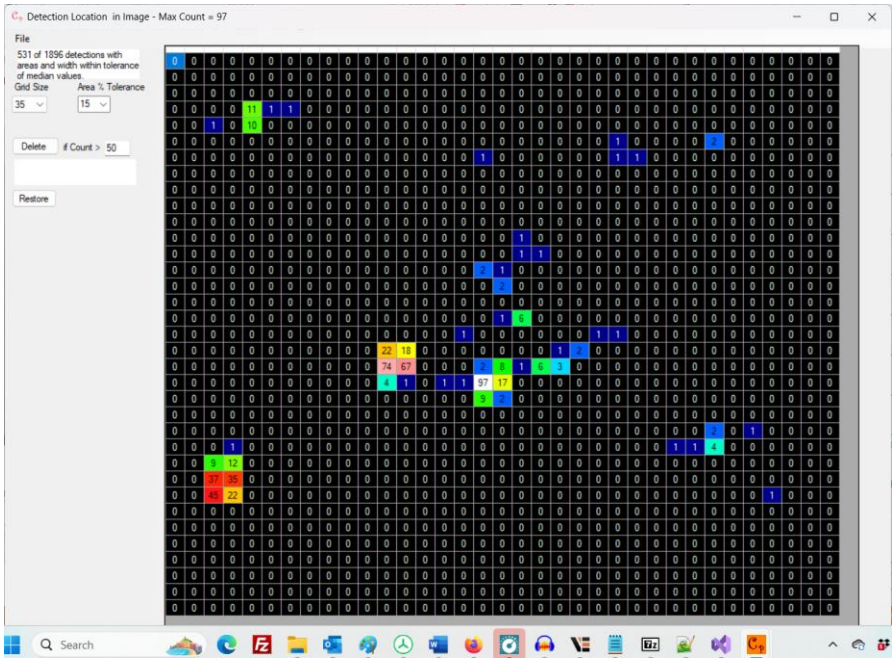


Figure 99 Detections map showing only a few groups of files with similar area and location

The detections map shows a few groups of files with similar areas and locations probably arising from detections of stationary, inanimate objects. Inspection of images containing these detections (by right-clicking twice on a region and selecting Show Images with Detections) confirms that these are detections of rocks:

Figure 100 Image containing 1st of 67 detections

After deleting all detections with a count of more than 5 in a region, the Count vs Time profile is as shown below:

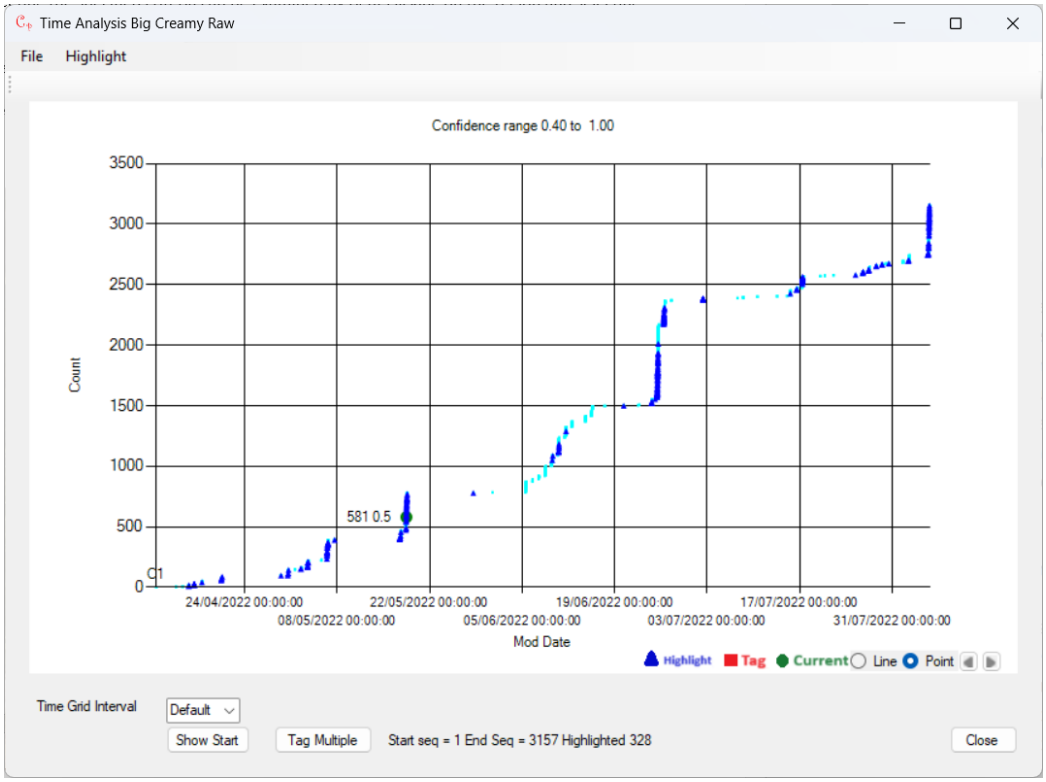


Figure 101 Count vs Time after deleting detections with count >5 in a region

Although the number of images with detections has been reduced from 733 to 328, many detections of stationary objects remain, principally because the detection areas and widths vary by more than 15%.

Detections meeting the specified criteria can be examined by right clicking on the region and selecting Show Images. This loads the images containing the detections into the main screen, where they can be examined to see if the object detected is inanimate or not. Detections can then be deleted by right-clicking and selecting Delete Detections. All detections in regions with counts exceeding a specified threshold can also be deleted via the Delete button. Deletions can be restored via the Restore button. Deletion of detections is most useful when analysis is fully automated using a refining classifier to detect animal species. If semi-automated analysis is used, sequences of images containing detections are inspected before tags are applied and inanimate object can be excluded at this point.

Licensing

As downloaded, CamTrap Pro comes with a free Demo license which allows unrestricted operation for 30 days after installation or until 25 tags or 5000 images have been applied, and a nag screen is shown each time CamTrap Pro is started. If these limits are insufficient, a permanent basic license allows loading of up to 20,000 images and application of up to 1,000,000 tags can be purchased. Other permanent licenses for loading up to 50,000 or unlimited images and application of 1,000,000 tags can also be purchased. All licenses are available for purchase from here. Fixed-term licenses can be obtained at a reduced unit cost. Contact Aleka Consulting for a quote

License key installation is done by clicking on the License top-level menu to show the following screen:

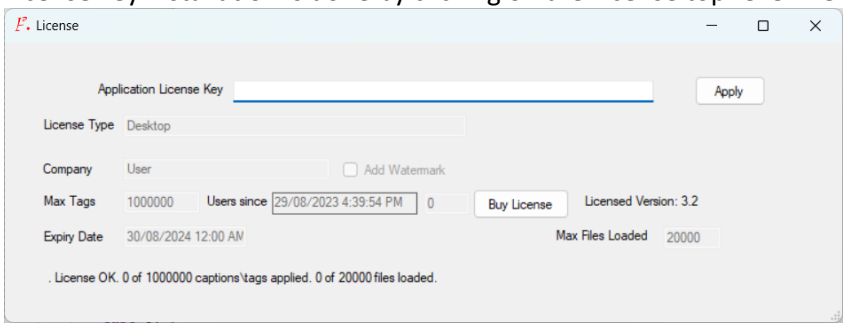


Figure 102 Licensing screen after basic license purchase

The screen shows License OK at the bottom left of the screen if the license is valid and indicates the license type. If the license is not OK, the reason is shown. The screen also provides a link to purchase a permanent license from the Aleka Consulting web site via PayPal by clicking the Buy License button. A license may be used on up to 2 computers.

Support

Clicking Help->Support and then the Create Support Data Zip File button creates a support zip file with data about the current instance of CamTrap Pro. Answer Yes to any prompts asking if you want to allow Registry Editor to make changes to the device. If the support zip file is then emailed to support@alekaconsulting.com.au this will provide valuable information for dealing with operational problems and bugs.

Appendix 1 - Auxiliary Programs

A number of programs may be used in conjunction with CamTrap Pro as follows:

Exif Pro 2.1

Exif Pro is a mature, ex-commercial product intended for photographers which allows the addition of multiple Windows tags to photos. After selecting the folder containing the images, selecting a group of thumbnails below the main image and right-clicking allows tags to be added or deleted as shown below.

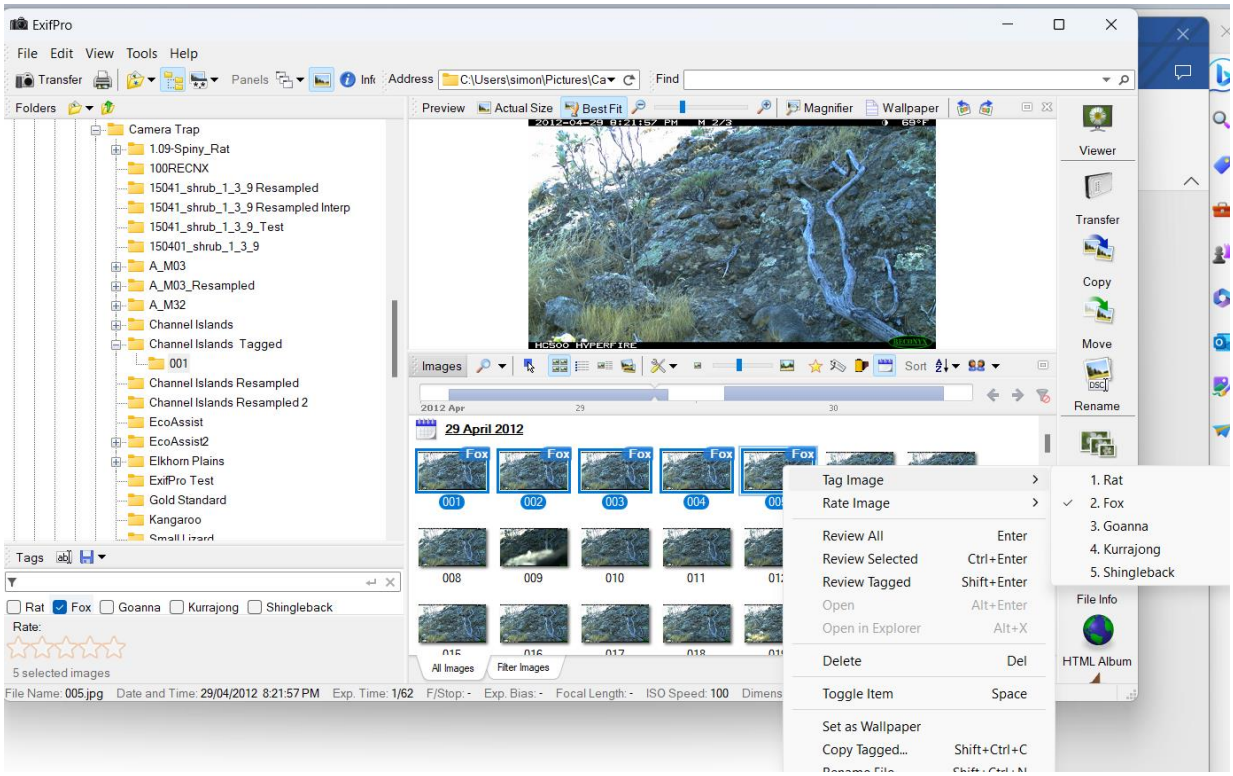


Figure 103 Exif Pro

Tags can be defined via the button at the lower left. Tagged files can be loaded into CamTrap Pro for further analysis in the same way as if the tags had been created in CamTrap Pro.

Exif Pro 2.1 can be downloaded from a number of software libraries including CNet and Softonic. Source code is available at https://github.com/mikekov/ExifPro.

EcoAssist

EcoAssist is a Python application which can run on any platform (including Windows) from Netherlands ecologist and data scientist Peter van Lunteren. It requires the use of the Anaconda Python data science distribution (download a light version for Windows from here), and Git for Windows. These must be installed before attempting to install EcoAssist. Installation error messages are difficult to understand unless you have substantial knowledge of Windows. EcoAssist uses the Megadetector computer vision model. EcoAssist is best run on a machine with an Nvidia Graphics Processing Unit (GPU). It will run if this is not present, but much more slowly.

EcoAssist is installed via an install.bat file, which may take over an hour to run. As it is downloaded from another computer it raises a Windows warning about harming your computer when run unless it is unblocked via the Properties tab. Once it is installed, a command window appears immediately, but the application screen (as shown below) takes some time to appear.

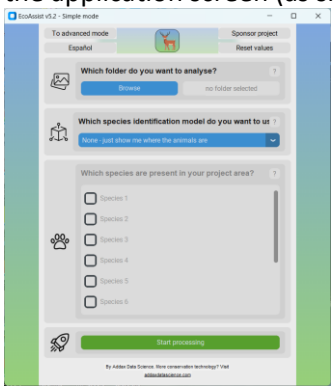


Figure 104 EcoAssist Start Screen (Simple Mode)

Click 'To Advanced Mode' and select the folder containing the images to show the screen as below:

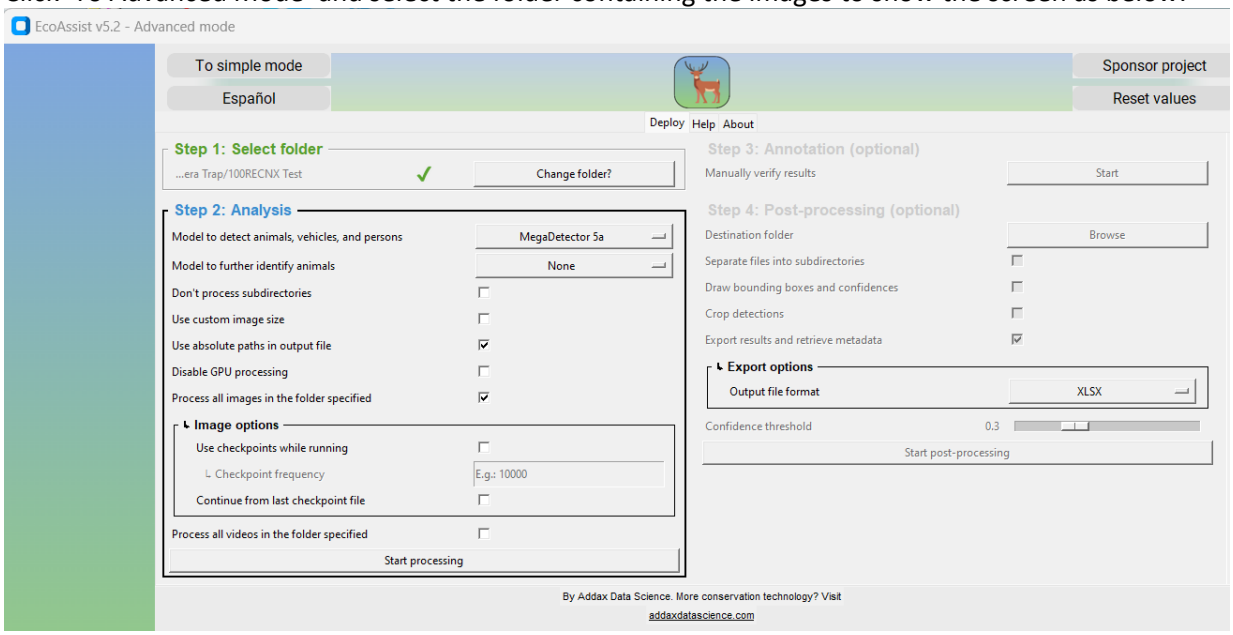


Figure 105 EcoAssist Advanced Mode screen

The default checkpoint frequency of 500 should be used so that processing can be resumed in the event of a crash. Checking 'Use custom image size' and reducing the image size from the default value of 1280 increases processing speed at the cost of failing to detect small animal images. Using a value of 640 increases speed by a factor of 4.

The default model (MegaDetector 5A) detects only animals, people and vehicles. It does not attempt to detect animal species. Process all images in the folder specified should be checked, and Deploy Model clicked. Once it is running a progress screen appears:

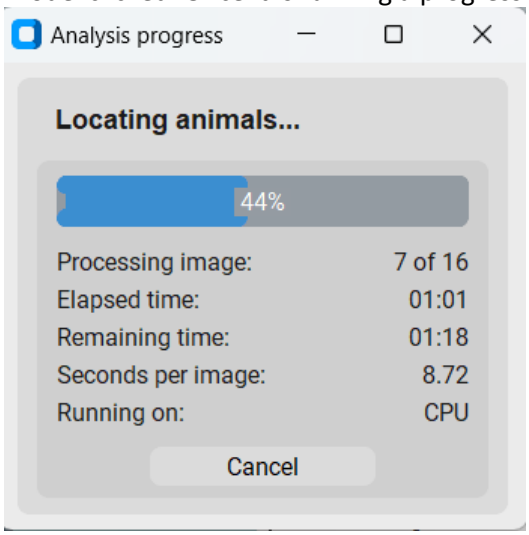


Figure 106 EcoAssist progress screen

Once processing is finished, a large tick is shown in the Analysis box:

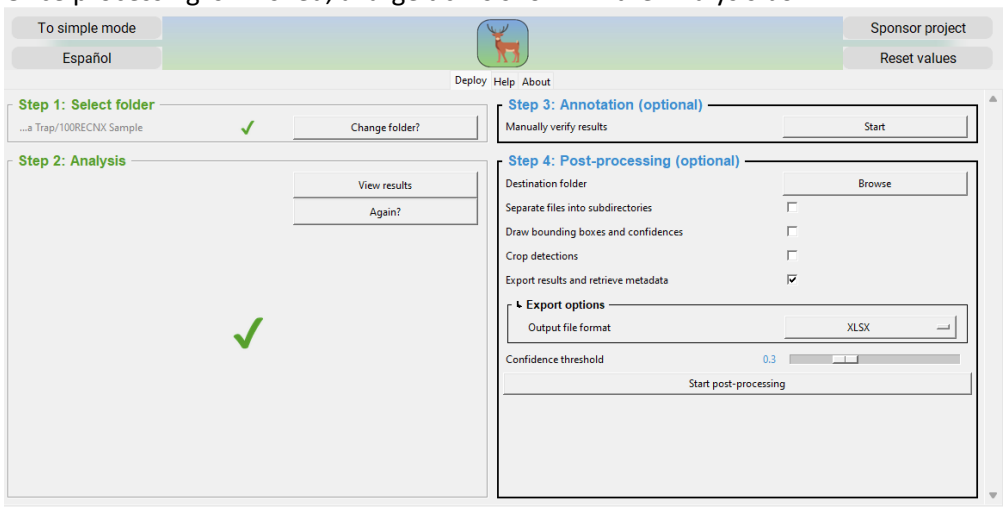


Figure 107 EcoAssist screen after completion of processing

The output JSON file is created in the analysis folder with the name Image_recognition_file.json. The file contains data on the file name and details of the detections. It has the format as shown below:

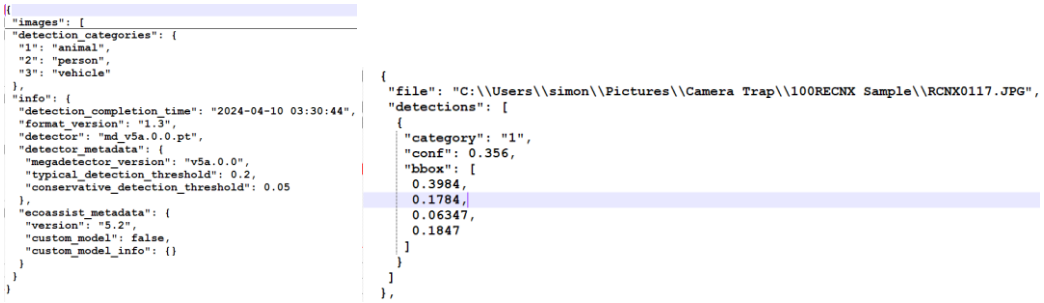


Figure 108 EcoAssist result file format (left) and a file node in the images node (right).

This file should be browsed for when loading data into CamTrap Pro via the Highlight->Megadetector->Load JSON file option.

Refining Megadetector Results

EcoAssist v 5.2 introduced the option to refine Megadetector results using pre-built species-specific classifiers to identify animal species. These are run after Megadetector and can be selected in Simple and Advanced mode as shown below:

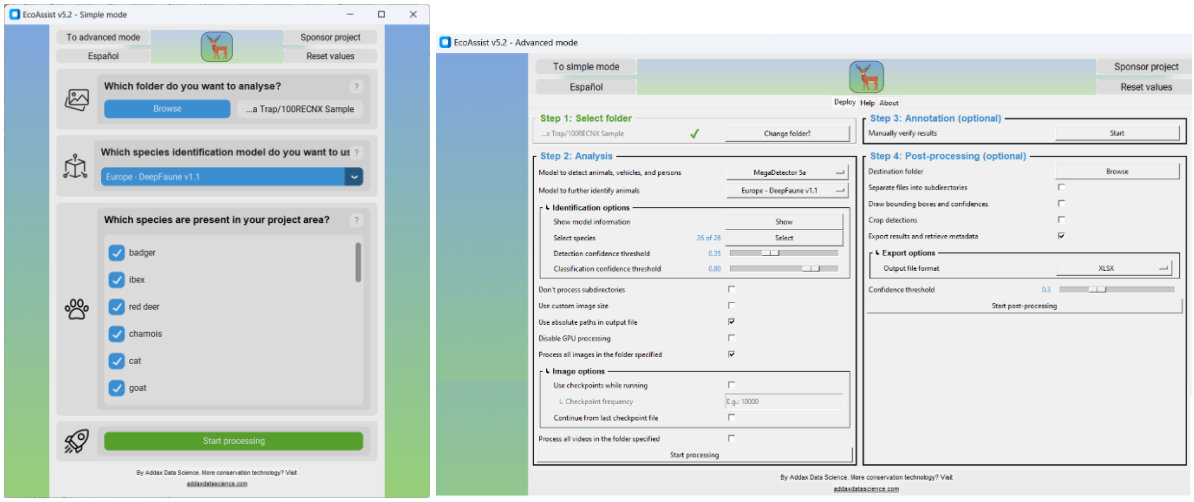


Figure 109 Simple (Left) and Advanced (Right) EcoAssist Modes Showing Refinement Options

Species to be detected can be selected from those specified in the model, and the threshold for species classification and detection can be set in advanced mode. When a refining classifier is used with EcoAssist , two JSON files are produced. The file 'image_recognition_file.json' should be selected. An example of the format of the JSON file in this case is as shown below:


```
file": "F:KAR_S1_A01_R1_IMAG00017.JPG",
  "detections": [
   {
    "category": "6",
    "conf": 0.99974,
    "bbox": [
     0.4652,
     0.5164,
     0.1921,
     0.171
    ],
    "classifications": [
     [
      "3",
      0.99974
     ],
     [
      "6",
      4e-05
     ],
     ....
     [
      "26",
      0.0
     ]
    ],
    "prev_conf": 0.942,
    "prev_category": "1"
   }
```

```
"detection_categories": {
 "2": "person",
 "3": "vehicle",
 "4": "aardwolf",
 "5": "african wild cat",
 "6": "baboon",
 "7": "bird",
 "8": "brown hyaena",
 "9": "caracal",
 "10": "cattle",
 "11": "cheetah",
 "12": "donkey",
 "13": "elephant",
 "14": "fox",
 "15": "gemsbok",
 "16": "genet",
 "17": "giraffe",
 "18": "hare",
 "19": "honey badger",
 "20": "hyrax",
 "21": "jackal",
 "22": "klipspringer",
 "23": "kudu",
 "24": "leopard",
 "25": "lion",
 "26": "mongoose",
 "27": "ostrich",
 "28": "porcupine",
 "29": "rhinoceros",
 "30": "spotted hyaena",
 "31": "springbok",
 "32": "steenbok",
 "33": "zebra",
 "1": "unidentified animal"
},
```

```
"classification_categories": {
 "1": "aardwolf",
 "2": "african wild cat",
 "3": "baboon",
 "4": "bird",
 "5": "brown hyaena",
 "6": "caracal",
 "7": "cattle",
 "8": "cheetah",
 "9": "donkey",
 "10": "elephant",
 "11": "fox",
 "12": "gemsbok",
 "13": "genet",
 "14": "giraffe",
 "15": "hare",
 "16": "honey badger",
 "17": "hyrax",
 "18": "jackal",
 "19": "klipspringer",
 "20": "kudu",
 "21": "leopard",
 "22": "lion",
 "23": "mongoose",
 "24": "ostrich",
 "25": "porcupine",
 "26": "rhinoceros",
 "27": "spotted hyaena",
 "28": "springbok",
 "29": "steenbok",
 "30": "zebra"
},
```


Figure 110 Example of JSON file Element, Detection_categories and Classification_categories Nodes Using Refinement

The refining classifier is only used when a Megadetector animal detection confidence exceeds the detection threshold specified in Figure 109. The confidence value for classification threshold for all the different custom classes (identified by category numbers) is then shown in the classification_categories node in descending order of confidence. If the classification confidence exceeds the threshold defined in in Figure 109 (Advanced mode) , the category number in the detection_categories node corresponding to the category shown in the classification_categories node. Refining classifiers are seldom highly accurate, as they have generally been built with much smaller numbers of training images than Megadetector.

Appendix 2 – Megadetector JSON File Format

The JSON file from EcoAssist has the format as shown below where only Megadetector is used (no refinement):

```
"images": [
  {
    "file": "path",
      "detections": [
        {
          "category": "x1",
          "conf": c1,
          "bbox": [
            x1,
            y1,
            width1,
            height1
          ]
        },
        {
          "category": "x2",
          "conf": c2,
          "bbox": [
            x2,
            y2,
            width,
            height2
          ]
        }
        <Repeat for other detections>
      ]
    },
  <Repeat for other files>
  }
  }
],
"detection_categories": {
  "1": "name1",
  "2": "name2",
  "3": "name3"
},
```

Figure 111 JSON File Format

Parameters are as follows:

Parameter	Description	Example
path	Full path to file with \ escaped	C:\\users\\simon\\pictures\\Test\\001.jpg
x	Integer code for category of detection. Megadetector uses 1 for animal, 2 for human, 3 for vehicle	1
c	Confidence value for detection (0 to 1.0)	0.954
x	X co-ordinate of top LH corner of detection bounding box as fraction of image width	0.64
y	Y co-ordinate of top LH corner of detection bounding box as fraction of image height	0.754
width	Width of detection bounding box as a fraction of image width	0.13
height	Height of detection bounding box as a fraction of image height	0.57

If there are no detections or a detection is to be skipped, m is zero (or negative) and the file entry is as below

```
{
    "file": "path",
    "detections": []
```

The detection_parameters node contains the category code (an integer) and the category name.

Appendix 3 – Recommended Processing Sequence

The first step is to examine the folder structure containing the all the camera trap images via the Folder Tree button on Pre/Post Process screen accessed via File->Pre/Post Process. This displays the folder structure below the selected folder and indicates if JPEG files are present in any of the folders. The structure should conform that shown in Folder Tree. Camera folders should be renamed appear in alphabetical order – this may require adding leading zeros before numbers appearing in folder names. Epoch folders (if present) should be treated in the same way

Processing via Visual Inspection

The simplest way to process camera trap data is to display all images for the selected data as a slideshow, stop when an image containing an animal of interest is shown and record the species of animal shown. Human vision is extremely good at identifying animals in images, but the number of images which can be examined is limited by fatigue. If the selected data contains a high proportion of images not containing any animals, fatigue effects will reduce the number of animal-containing images identified. As typical data sets may use dozens of cameras, recording over time periods of a month or more, data sets may comprise millions of images, making human inspection of all of them a daunting proposition.

Once one or more animals have been detected in an image, its species (and possibly the animal's identity) can be determined and the image tagged or a separate record made of the occurrence of that species or species/identity. If the time at which the image was taken is correctly recorded in image metadata, the Tag Summary option can be used to generate a report. The process for making the image Modified date to indicate the correct time of image capture is described in

Playing a slideshow of images after Highlights Only filtering (perhaps after using a refining classifier) allows visual detection of images showing a species of interest. If one is detected the slideshow can be stopped (via ctrl-P) and the Count vs Time Plot zoomed to show only those images, which can then be tagged. Using Highlights Only filtering reduces the number of images to be inspected and the detection boxes focus attention.
Setting Modified Dates.

Reducing Image Count

Camera traps may be configured to take a number of images in rapid succession after being triggered. These images may assist in species identification, but increase the number of images to be processed. If machine vision is being used to detect animals, the additional images may be redundant and can be filtered out in Options to reduce processing times. Removal of closely-spaced images will not affect detection event count, which is the ecologically significant measure most often used. Input images can also be decimated to achieve a similar result, although this will miss single-image detections. However, if animals detected are fast-moving (such as kangaroos), they may only be detected in a single member of a sequence, and if these detections are of interest, filtering may exclude significant data.

Automated methods of detecting images containing animals using machine vision are readily available. One the best known uses a machine vision model called Megadetector, whose development and support is funded by Microsoft. This model can detect images containing people, vehicles, and animals. This model has been incorporated into a number of free, open-source analysis products including EcoAssist and CamTrap Detector. These products can be used to create a JSON file listing detections in images, and to sort image according to whether they contain any of the recognised entities on the basis of a threshold confidence score assigned to all detections. There is an inverse relationship between the threshold confidence score and the number of false positive detections.

Running CamTrap Pro on all images in which Megadetector has detected animals with a confidence above a threshold value can greatly reduce the number of images to be inspected, but at the cost of false negative detections, which may occur if a species of interest is highly camouflaged and false positive detections from inanimate objects. The false positive count can be reduced via the Detections screen, which can remove detections occurring in the same location (see Detections). Access to a computer with an Nvidia GPU is also required to process large image collections within a reasonable time using an analysis product. CamTrap Pro can operate on JSON files recording detections from analysis, making it possible for people without GPU-enabled computers to analyse data. This makes CamTrap Pro particularly suited to Citizen Science projects.

Changing the threshold confidence value will trade off precision and recall for detections, and the optimum value may be different for different species. CamTrap Pro can generate a histogram of confidence values which can then be used to determine the optimum value for the confidence threshold. Using the Below Threshold Only filter allows examination of all images where there has been a detection, but with a confidence below the lower bound of the confidence range. If animals of interest are detected, the lower limit should be reduced. Once highlights have been generated in this way, only the highlighted images can be displayed via Options filtering.

Playing a slideshow of images after Highlights Only filtering (perhaps after using a refining classifier) allows visual detection of images showing a species of interest. If one is detected the slideshow can be stopped (via ctrl-P) and the Count vs Time Plot zoomed to show only those images, which can then be tagged. Using Highlights Only filtering reduces the number of images to be inspected and the detection boxes focus attention.

Setting Modified Dates

In order to use the Tag Summary facility of CamTrap Pro, the Modified dates of all images should be set to the actual dates and time on which they were recorded. This can be achieved as follows. The range of Modified dates for images from each camera should then be examined via the Camera Info button, and any images with inconsistent dates (such as those arising from camera date resetting after recording) can be deleted via the Edit By Time button. If dates are consistent but incorrect (for example if they correspond to camera default dates, which may be years before the actual date on which the image was recorded), they can be shifted via the Change Modified Date options in the Options screen. If OCR is used to obtain image dates, about 10% of dates will not be reset due to failures of conversion of the dates shown at the top or bottom of the image. If different start dates are required for different epochs, these can be applied via the Use Epochs checkbox on the Option screen after setting Epoch start dates via the Set Epochs button. Dates may also be incorrectly set. For example, the wrong year may be specified. Modified dates may also be reset if the files are read by some other applications. In this this case, the duration of a camera data set may be zero or a few minutes. In this case, the Modified date can be reset to the Date Taken in the Options screen, and then changed if necessary. Filtering by decimation may speed the evaluation of time data for large data sets.

Checking for Corrupt Files

The presence of corrupt image files can cause CamTrap Pro to crash. They can be identified via the Check for Corrupt file option on the Pre/Post Process screen, and optionally deleted. After opening the folder below which are the desired images either one or two levels below (as specified in the Parent/Grandparent options) , the first image is displayed as below:

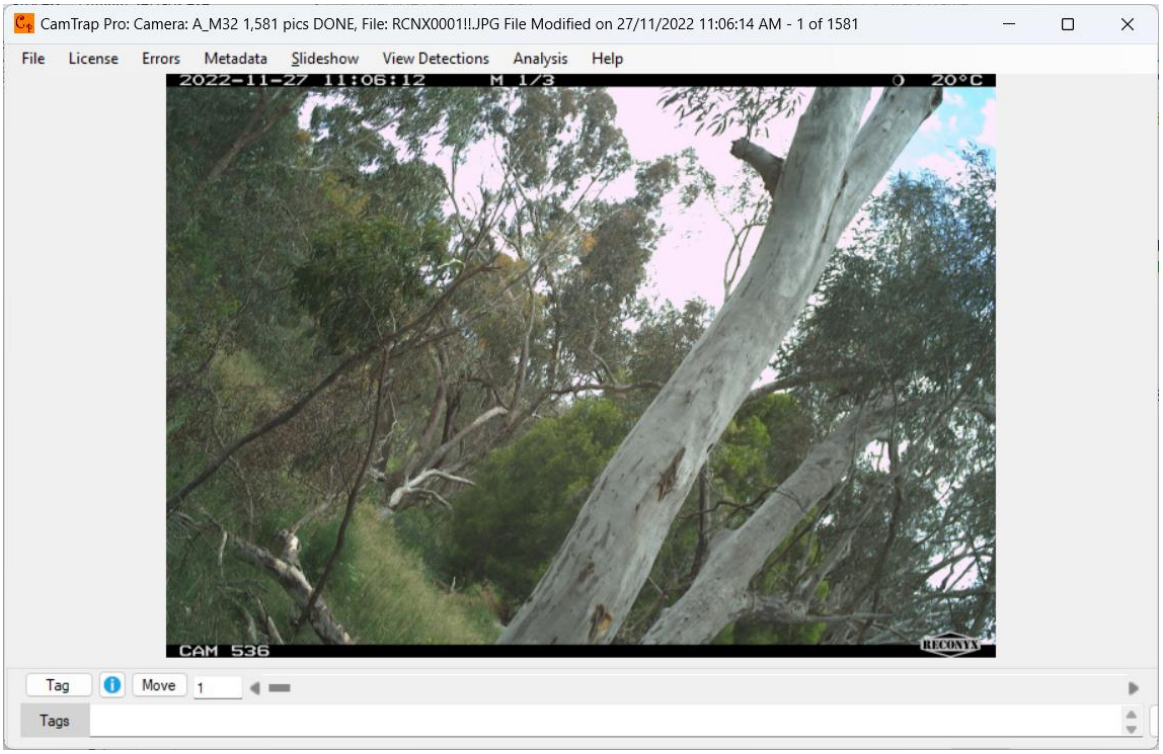


Figure 112 Display after loading camera data

Analysis Methods

An overview of the loaded data can be displayed via Analysis->Count vs Time. If the Modified dates of the loaded files do not reflect the actual dates on which the photos were taken, they can be set via the Options screen by various methods.

The time profiles may give a rapid indication of whether the camera was triggered by animals or not if a baited tarp is used. False triggerings occur when the infrared radiation from one half of the image differs from that from the other. This can arise from moving vegetation or shadow patterns as well as the appearance or movement of an animal or bird. False triggerings are less frequent at night as shown in the examples below:

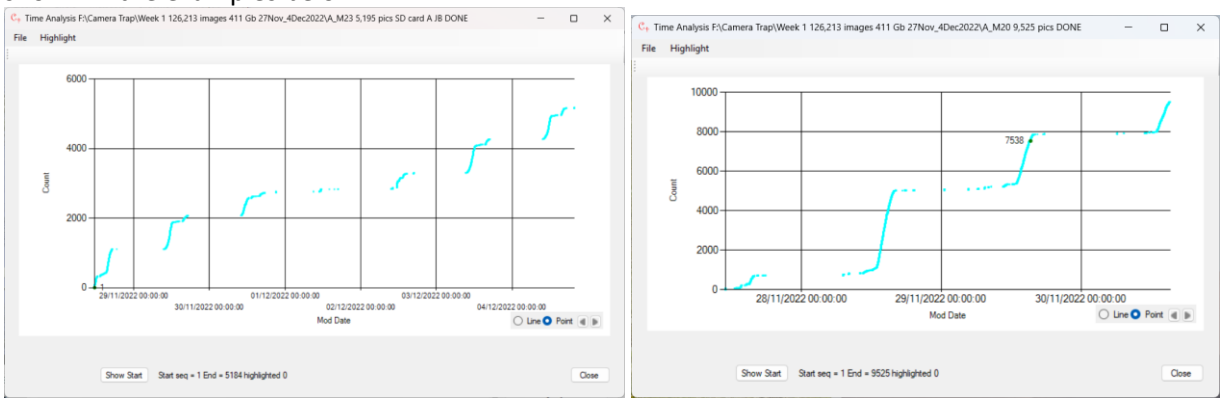


Figure 113 Examples of data with many non-animal triggerings

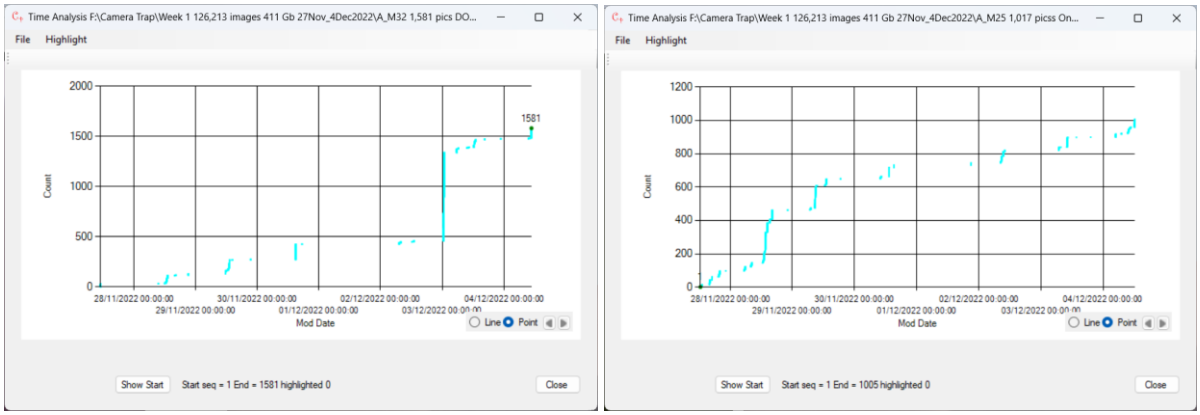


Figure 114 Examples of data with few non-animal triggerings

Where the majority of detections are of animals, clicking on a step in the count vs time profile is often sufficient to show the animal and allow tagging of image with the name of the animal appearing. Where this is not the case, CamTrap Pro provides three methods of automatically detecting images containing animals.

Sequences

This option highlights groups of images where a specified number of images occur within a specified time period as described on page 54. It exploits that fact that animals will move often rapidly around a baited trap, creating a large number of images over a short time period. Processing is very fast, and various combinations of image count and time period can be specified, but the process is not highly effective in discriminating between false and animal triggerings. Animal appearances may be very brief with non-baited traps and sequence analysis may miss these, as they do not produce a step.

Changes

This option resamples the input image to a specified size and looks for changes in hue and/or luminance over a number of pixels between adjacent images or the current image and an average of a number of previous images as specified on page 55. The parameter space is extremely large and processing is slow, but there may be a substantial reduction in the number of images to be inspected visually.

Machine Vision

Machine Vision (or Machine Learning) is the most effective method of detecting images containing animals but requires the data to have been processed to generate a JSON file using a classifier built from a training set of labelled images. The Megadetector public-domain classifier (or model) has been trained on 2.5 million images but only detects animals, humans and vehicles. It is readily available and is built into a number of applications, including EcoAssist but requires a computer with an Nvidia GPU for fast processing. A gaming computer with an Nvidia GeForce 3060 8 Gb graphics card processed 12 MPixel images at a speed of 4-5 images per second. On a non-GPU 2.3 GHz machine, speed was about 7 seconds per image. EcoAssist also provides a number of species- specific classifiers which can be used to refine the animal category of Megadetector to identify particular species.

Using Megadetector to highlight images containing animals or birds with confidence > 0.5 for the data with many false triggerings shown in Figure 113 gives results as shown below. Highlighted images are shown in dark blue.

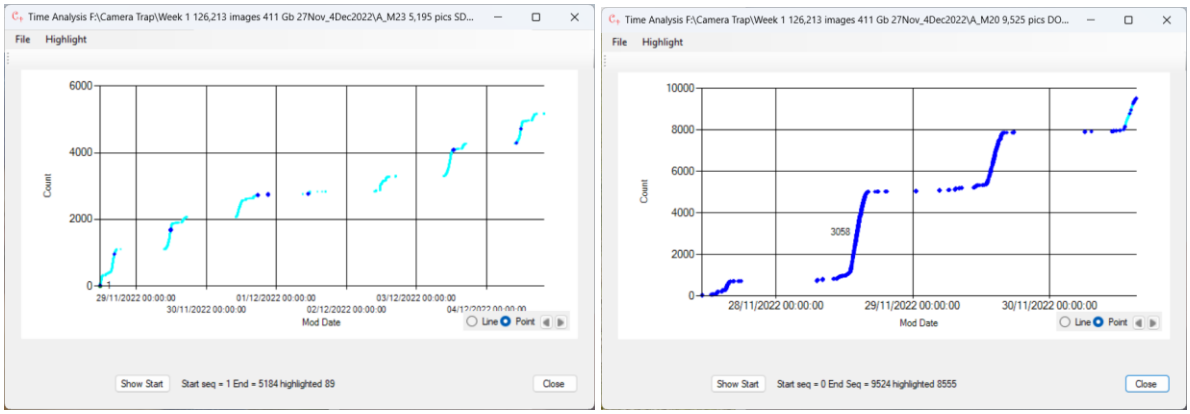


Figure 115 Data with many false triggerings analysed using Megadetector

In the data shown in the left panel, Megadetector finds 89 out of 5149 images contain animals, which is greatly reduces the number of images which have to be visually inspected by zooming into the Time Analysis display and right-clicking on highlighted values. However, in the data shown in the right panel, Megadetector finds that 8554 out of 9524 images contain images or animals or birds, which is not a useful level of data reduction. Clicking on one of the highlighted images, indicates that Megadetector is detecting the bait as an animal

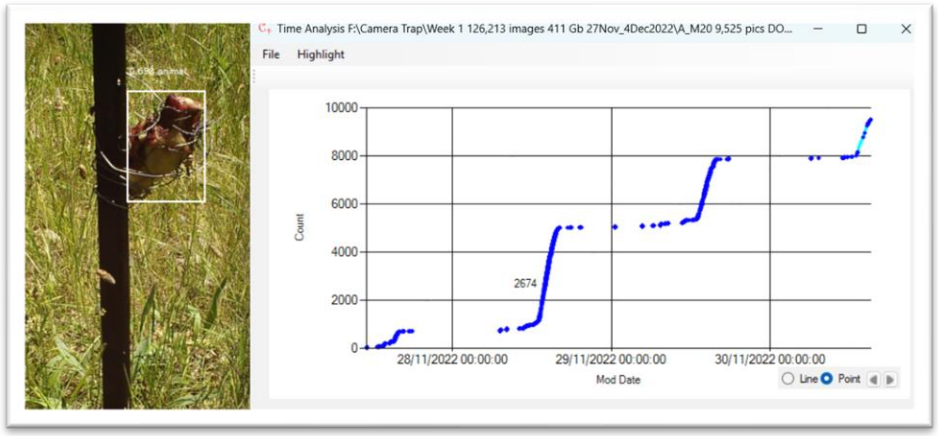


Figure 116 Megadetector detecting bait as an animal

Increasing the confidence threshold to 0.9 gives a greater reduction (to 322 images) and almost all of the highlighted images contain animals or birds. The highlighted images are all outside areas of rapid increase of count and were almost all taken at night.

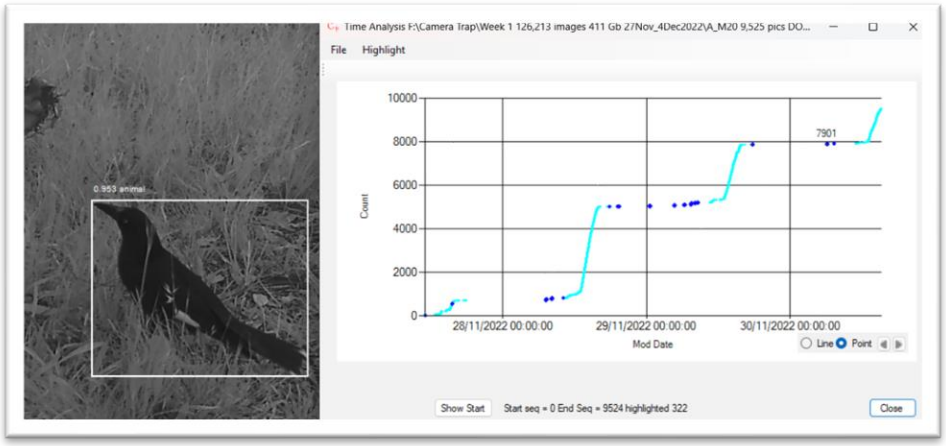


Figure 117 Example of night-time triggering

Tagging

Where highlights have been created via machine learning or change detection, bounding boxes are shown around any detections. After visual identification of the animal species, text can be added to the box below the image, and clicking Apply will store the text as a tag in the image file metadata as shown below:

Figure 118 Image with bounding box around detected animal

Text from a set of options can also be added to the text box (and optionally applied) via the Presets screen shown on page 40.

Zoom

Menu options are listed below

Camera (ctrl-M)

The Camera screen is below:

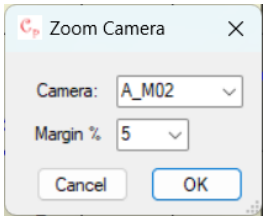


Figure 84 Camera zoom selection screen

The camera combo box lists all cameras in the loaded folder. Clicking OK sets the zoom region to include all images from the selected camera, plus a percentage margin specified in the Margin % combo box. This menu option is only shown if the folder sorted order is Folder->Modified.

Unzoom (ctrl-U)

This menu option undoes the last zoom operation. The keyboard shortcut is ctrl-U.

Show All (ctrl-A)
This menu option shows images from all cameras. The keyboard shortcut is ctrl-A.

View

Refresh Points
Clicking this menu options refreshes all points shown on chart according to the settings shown on page 49 when the Count vs Time chart was shown
Summarising Tags, the option Analysis->Summarise Tags should be selected. Tag data is stored in a separate database (Tag_<Epoch>_<CameraName>_.vdb5) created in the loaded folder. To consolidate tags from a multiple cameras or epochs, a folder should be selected above all the individual databases in the Consolidate Tags screen shown on page 67, and Consolidate clicked.

Fully Automated Processing
The availability of species-specific classifiers with acceptable performance makes fully automated processing a possibility, using the Name As Tag functionality described on page 20. Checking this option for categories displayed in the Options->General Tab automatically adds tags as well as highlights to files during processing of the JSON file from the classifier where the classification confidence falls within the range specified. Used in conjunction with the Map display, it is possible to create publicly usable results from a large survey involving dozens of cameras and hundreds of thousands of images in a single step. However, processing times may be several days and the following conditions apply:

1. All camera folders must be at the same level in the folder tree.
2. Camera folder names should be less than 10 characters long to avoid overlapping on the Map display.

Accuracy
Machine vision algorithms rely on similarity between images used for training and those being analysed. However, image comparison features are not the same as those used by humans and misleading results may be obtained. This can lead to incorrect identification as shown below:

Figure 119 Misidentified Animal

Inanimate objects such as rocks or vegetation may also be detected as animals as shown below.

Figure 120 Detection of rocks and vegetation as animals

If a pre-trained classifier based on species found in location distant from the images being analysed and not found in the analysis location is used, poor results may be obtained. For example, a classifier based on South African veldt wildlife (mainly large mammals) will not give sensible results when applied to Australian images – animals are detected as being in incorrect categories rather than being undetected.

Setting lower threshold confidence values allow a trade-off between precision and recall, but high confidence spurious detections may still occur. Highly camouflaged animals may only be detected with a very low confidence and using this value may result in a massive number of false positive detections. Such images are not suited to automated processing.

Figure 121 High-confidence spurious detection (left) and low-confidence detection of camouflaged lizard (right)

Photos recorded at night may have a much lower resolution than those recorded in daylight and this may affect detection accuracy. Classifiers may work well for some categories but poorly for others. Accurate and complete classification may not be critical for assessment of common, frequently detected species, but if the species of interest is rare or highly camouflaged, fully automated processing may not be appropriate. Fully automated species analysis will never achieve the accuracy of manual refinement of generic classifier results, but has the substantial advantage of requiring little human input.