CTmax Tracker

Version 1.2

User Manual

Generated May 2026

Multi-specimen Critical Thermal Maximum (CTmax) real-time tracking with USB DAQ hardware integration and internal temperature estimation (Newton's law)

For licensing, contact: jacob.l.johansen@gmail.com

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1. Overview

CTmax Tracker is a Windows desktop application for Critical Thermal Maximum (CTmax) experiments in aquatic ectotherms. It monitors real-time water temperature via a USB-1208LS Measurement Computing (MCC) DAQ device, controls a pump connected to a hot water sump and a pump connected to a cooling bath to ramp water temperature at a user-defined rate, and records the temperature at which each specimen reaches its CTmax (typically loss of equilibrium or righting response in fish). Up to 8 specimens can be tracked simultaneously in a single trial.

Key capabilities:

- Multi-specimen tank canvas — up to 8 colour-coded draggable/resizable specimen rectangles or ovals
- USB-1208LS DAQ integration for live water temperature monitoring
- Automated heating ramp with configurable rate (°C/min) and optional cooling return
- Maintenance phase — holds water at a pre-trial target temperature before ramping begins
- One-click CTmax recording per fish — logs ambient CTmax temperature, elapsed ramp time, and timestamp
- Internal / core body temperature estimation using Newton's law of cooling (Stevens & Sutterlin 1976)
- Live temperature chart — plots actual vs. target temperature in real time
- Structured CSV export — trial metadata, settings, fish measurements, CTmax results, and a second-by-second temperature log
- Notes system — timestamped free-text notes added during the trial
- Settings persistence via JSON file
- 7-day demo trial and licensed activation modes

2. System Requirements & Installation

Hardware Requirements

- Windows 10 or Windows 11 (64-bit)
- Measurement Computing USB-1208LS DAQ device with MCC InstaCal drivers installed
- Temperature probe(s) connected to analog input channels on the DAQ device
- Heating hardware connected to a digital output channel of the DAQ device
- (Optional) Cooling hardware connected to a second digital output channel

Installing CTmax Tracker

CTmax Tracker is distributed as a standalone Windows installer. No separate Python installation or additional software is required.

- Obtain the installer file: CTmaxTrackerV1Installer.zip from www.FishResilience.com / Softwares.
- Double-click the installer to launch the Setup Wizard

- Follow the on-screen prompts:
  - Review the information page and click Next
  - Choose the installation folder (default: Program Files(x86)\CTmax Tracker)
  - Optionally create a Desktop shortcut labelled 'CTmax Tracker v1.2' (recommended)
  - Click Install to complete installation
  - Optionally launch CTmax Tracker immediately when the installer finishes

DAQ Hardware Setup

To use the USB-1208LS device, install the MCC InstaCal software from www.mccdaq.com before launching CTmax Tracker. InstaCal must detect and configure the device (board number 0 by default). If no DAQ hardware is present, the software runs in simulation mode — all features except live temperature are available for testing.

3. License Activation & Demo Mode

Demo (Trial) Version

When launched without a valid license, , the software runs in 7-day demo mode:

- The title bar shows: CTmax Tracker v1.2 — DEMO (X days remaining, saving disabled)
- CSV export is disabled
- All other features (temperature monitoring, DAQ control, CTmax recording, internal temp estimation) are fully functional
- The 7-day trial is one-time and machine-locked; it cannot be reset

Licensed Version

With a valid license activated:

- The title bar shows only: CTmax Tracker v1.2
- CSV export is fully enabled
- The license is tied to your machine hardware and cannot be moved to another computer

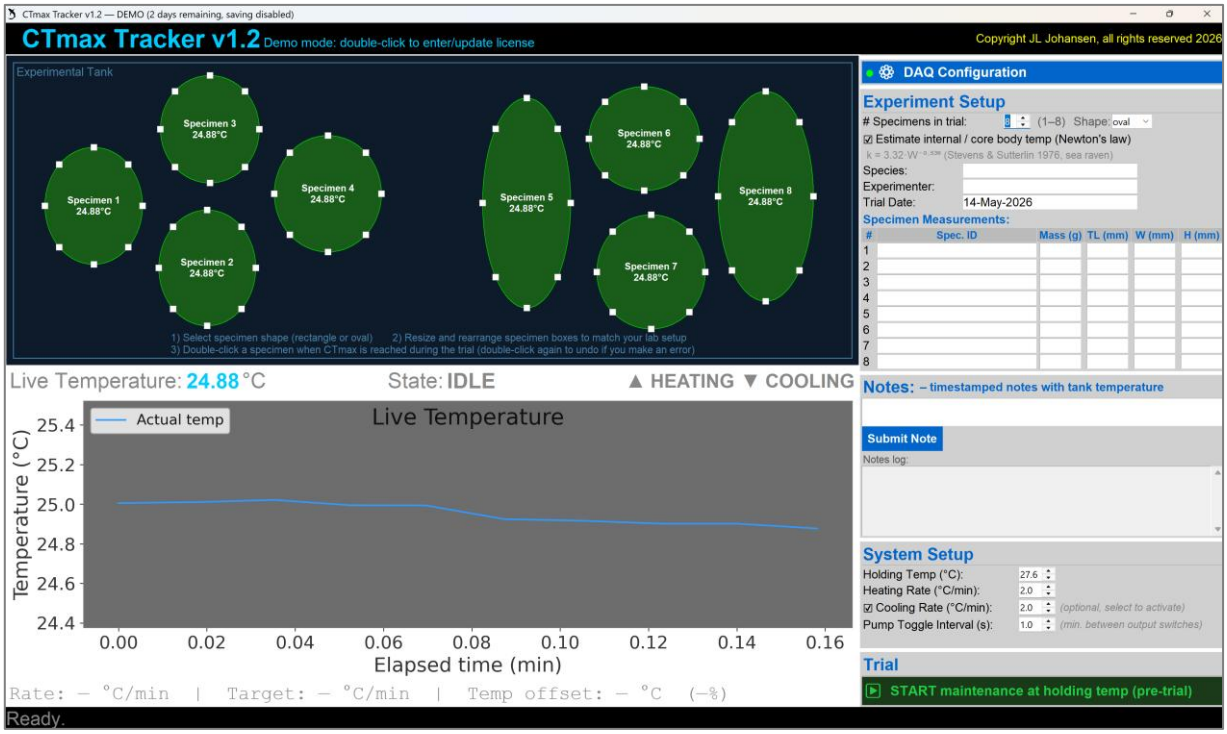
Activating a License

- On first launch, and during demo mode, the License Activation dialog opens automatically
- Copy your Machine ID using the Copy button
- Send your Machine ID to jacob.l.johansen@gmail.com to receive a license key
- Paste the license key into the Enter License Key field and click Activate License
- The application closes the dialog and launches in licensed mode

To acquire a license, contact:
Jacob L Johansen - jacob.l.johansen@gmail.com
Note, we aim to keep license fees to an absolute minimum, just enough to keep the software updated and website active. A student license lasts 3 years and cost US$35. A lab license doesn't expire and cost US$90.

4. Application Layout

The CTmax Tracker window is divided into three regions:



Region	Contents
Bottom Left panel	Live temperature chart showing actual vs. target temperature over time, with heating/cooling state indicators and a second-by-second discrepancy readout.
Top Left panel	Experimental Tank Canvas — a resizable canvas showing one draggable rectangle or oval per specimen, colour-coded by state (active, CTmax reached, disabled). Displays live ambient temperature, estimated internal temperature (if enabled), and CTmax values.
Right panel	Experiment Setup Panel — all controls: DAQ configuration, specimen count & shape, Internal temperature checkbox, fish measurements, notes, notes log, maintenance/ramping/cooling settings, and trial activation button.

The header bar at the top shows the application title and version. Double-click the demo mode in the header bar to enter license mode from within the program.

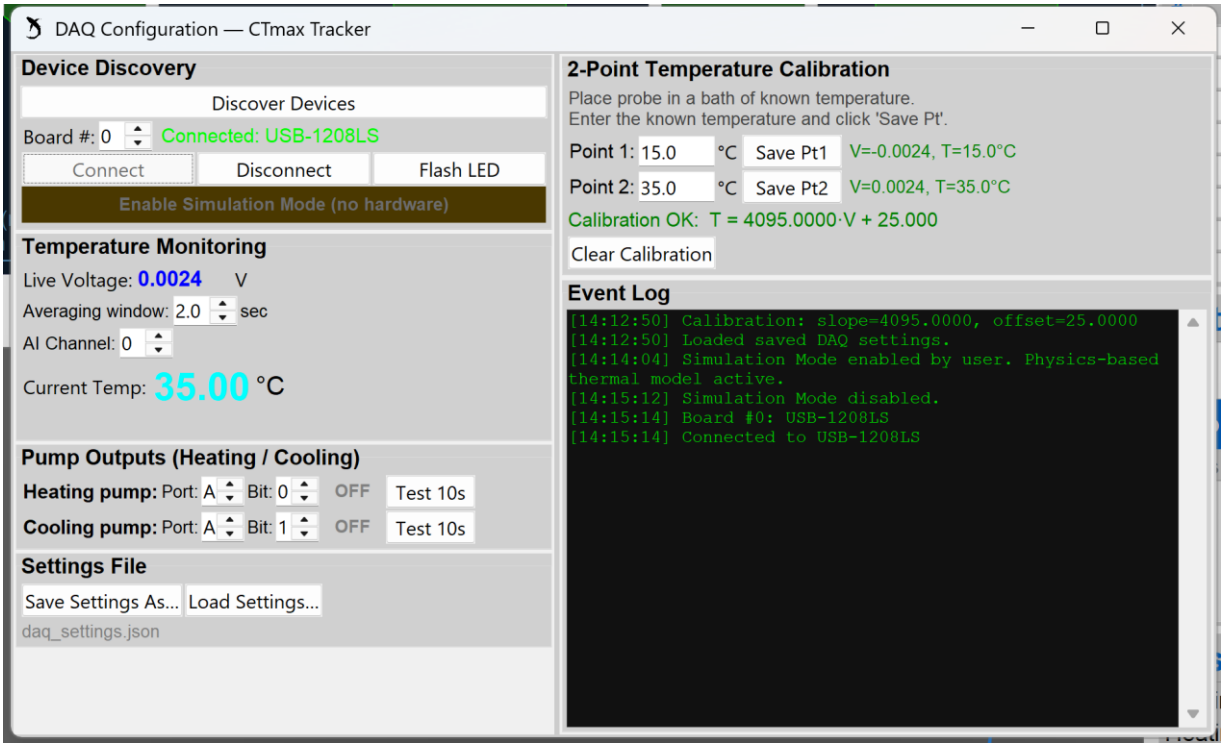
The status bar at the bottom of the right panel contains a scrollable event log recording all significant actions and state changes.

5. Getting Started — Step-by-Step Walkthrough

Follow these steps in order for a standard CTmax experiment. The right panel sections are arranged to match this workflow from top to bottom.

Step 1: Configure the DAQ

- Click the ⚙ DAQ Configuration button in the Experiment Setup panel
- The DAQ Controller window opens
- Select the “Discover Device” button and check the Event Log for board numbers
- Select the board number matching your USB-1208LS device (default: 0)
- Set the Analog Input channel for your temperature probe (default: 0)
- Set the Digital Output port and bit for your heating hardware
- Optionally configure a second digital output for active cooling hardware
- Verify the live temperature reading is sensible; adjust probe calibration if needed
- Close the DAQ Controller — all settings are saved automatically to settings.json
- Previously saved settings (including calibration values) can be recalled using the “load settings” functon



Step 2: Set Up Specimens on the Tank Canvas

- In the Experiment Setup section, set the Number of fish (1–8) using the spinbox
- Choose the shape for your Experimental Tank setup: Rect (rectangle) or Oval
- The tank canvas updates to show the selected number of specimen boxes
- Drag each specimen box to the corresponding fish position in the tank
- Resize boxes by dragging the corner handles to match each fish's position

Step 3: Enter Fish Data

- In the Fish Data entry section, enter the Species, Experimenter, and Trial Date
- For each specimen, enter: ID, Mass (g), Total Length (mm), Width (mm), Height (mm)
- Mass (g) is required for internal temperature estimation (**calibrated for fish only**)
- Specimen ID, Length, Width, and Height are recorded in the CSV but not required for temperature calculations

Step 4: Add Notes about your experiment as necessary

- Press "Submit Note" for each note you wish to save.

Step 5: Configure Maintenance Temperature

- Enter the Holding Temperature (°C) — the pre-trial target temperature
- Enter the Heating Rate (°C/min) — the rate at which temperature will ramp during the CTmax trial (allowed range 0.01 – 2.00 °C/min)
- Optionally enable Cooling Rate and set a return cooling rate for after the trial
- Set the Pump Toggle Interval (s) — minimum time between heating/cooling output switches (this is to avoid excessively fast activation/deactivation rates of heating and cooling hardware which may cause damage to the equipment (**User defined and user responsibility**).

Step 6: Start Maintenance

- Click ▶ START maintenance at holding temp (pre-trial)
- Unless in demo mode, a popup will ask you to Save Results as a CSV file
  - Choose a save location and filename — a suggested name and date is pre-filled
  - The CSV is written immediately; the chart is also saved as a PNG in the same folder
- The DAQ begins heating/cooling to reach and maintain the holding temperature
- The temperature chart starts plotting in real time
- Wait until the log confirms: 'Holding temperature X.XX °C reached — timer starts now'
- The system holds at the target temperature until you start the CTmax trial

Step 7: Start the CTmax Trial

- Click ▶ Stop maintenance, START CTmax Trial
- The system begins ramping temperature at the configured heating rate
- The chart switches to RAMPING state and plots the live ramp (heating and cooling icons will show the activity state of each element to meet the user defined ramping rate)
- Monitor fish behaviour closely — watch for loss of equilibrium (LOE) or righting response

Step 8: Record CTmax Events

- When a speciemn reaches its CTmax endpoint, double-click the CTmax button for that specimen on the tank canvas
- The CTmax temperature, timestamp, and elapsed ramp time are recorded immediately
- The specimen box on the canvas changes colour (red outline) and displays the CTmax temperature

- If internal temperature estimation is enabled, the estimated body temperature at CTmax is also shown and recorded
- If you make an error, double-click the Undo CTmax button for that fish to revert and re-record
- Repeat for each fish until all CTmax events are captured

Step 9: Stop the Trial and Save

- When all fish CTmax events are recorded (or you choose to stop early), click ■ STOP Experiment
- A dialog prompts: 'Stop CTmax trial and:' — choose:
  - 1) Return to maintenance — cools back to holding temperature at user set rate
  - 2) End trial — stops the experiment completely
  - 3) Cancel

Note: CSV saving is disabled in Demo Mode. Activate a license to enable full data export.

6. Feature Reference

6.1 Experiment Setup Panel (Right Panel)

The right-side panel is the primary control area. It is divided into labelled sections from top to bottom:

DAQ Configuration

- ⚙ DAQ Configuration button — opens the DAQ Controller window (see Section 6.2)
- A coloured indicator dot shows DAQ connection status: red = disconnected, green = connected

Experiment Setup

- **# Specimens (1–8):** Number of specimens in this trial. Updates the experimental tank canvas immediately.
- **Shape (Rect / Oval):** Display shape for each specimen box on the tank canvas.
- **Estimate internal temp:** Checkbox — enables Newton's law body temperature estimation (see Section 6.9).

Maintenance Settings

- **Holding Temp (°C):** Target temperature maintained before and after the CTmax ramp.
- **Heating Rate (°C/min):** Rate at which temperature rises during the CTmax ramp.
- **Cooling Rate (°C/min):** Rate for returning to holding temperature after the trial (enable with checkbox).
- **Pump Toggle Interval (s):** Minimum seconds between switching the heating/cooling output on or off. Prevents rapid relay switching.

Trial Controls

- ▶ **START maintenance:** Starts the pre-trial hold phase. DAQ begins heating/cooling to the Holding Temp.
- ▶ **START CTmax Trial:** Begins temperature ramp. Only available once maintenance holding temp is reached.
- ■ **STOP Experiment:** Stops the current phase. Presents options to return to maintenance or end the trial.
- **Save Results:** Opens a file dialog to export the trial CSV. Available after a trial has been run.

6.2 DAQ Configuration

The DAQ Controller window manages the connection to the USB-1208LS device and configures all hardware channels.

Device Discovery

- Discover Devices — all devices will show in the Event Log, including board numbers
- Select the appropriate Board Number, and press "Connect"
- Press "Flash LED" to flash the led of the USB1208 to visually verify connection is established
- If no USB1208 is available, you can press "Enable Simulation Mode" to run a simulated CTmax trial (e.g. for training purposes)

Temperature Monitoring

- Analog Input Channel — select which DAQ channel (0–7) the temperature probe is connected to
- Live temperature is displayed in large text in the main window header and on the chart
- Averaging Window — number of seconds of readings to average (smooths probe noise)

2-Point Temperature Calibration

Converts raw DAQ voltage to accurate temperature in °C using a linear fit:

- Place the probe in a bath at a known temperature. Enter the temperature and click Save Pt1.
- Move the probe to a second known temperature. Enter it and click Save Pt2.
- The calibration equation T = slope × V + offset is calculated and applied automatically.
- Click Clear Calibration to reset to defaults (slope = 1.0, offset = 0.0).

Pump Outputs (Heating / Cooling Control)

- Heating pump — port and bit number for the heating element relay
- Cooling pump — port and bit number for the active cooling relay (optional)
- Test buttons allow manually toggling each output to verify wiring (10sec activation)
- All port/bit settings are saved automatically to settings.json

Event Log

The bottom of the DAQ Controller shows a scrollable log of all hardware events: connection/disconnection, output state changes, calibration updates, and read errors.

Settings File

This section allows you to save or load DAQ configurations

6.3 Experimental Tank

The top left of the screen is a canvas representing the tank. Each specimen is shown as a labelled rectangle or oval.

- Drag any specimen box to position it to math your physical lab setup
- Drag corner handles to resize a box
- Boxes are colour-coded: blue outline = active (pre-CTmax), red fill = CTmax reached
- Each box displays the specimen number, current ambient water temperature, and (if enabled) estimated internal body temperature
- After CTmax is recorded, the box shows: CTmax (amb): X.XX°C and CTmax (int est): X.XX°C

6.4 Temperature Chart

The bottom left panel contains a live chart that plots temperature over elapsed time.

- Blue line — actual measured water temperature
- Orange dashed line — target temperature (ramp profile)
- State label — shows current state: IDLE / MAINTAINING / RAMPING / COOLING BACK / COMPLETE
- ▲ HEATING / ▼ COOLING indicators show which output is currently active
- Rate and discrepancy statistics are displayed above the chart
- The chart is automatically saved as a PNG when results are exported (alongside the data csv file

6.5 Fish Data Entry

Specimen metadata entered in the right panel is saved in the CSV export.

Field	Description
Species	Species name (e.g. Salmo salar). Applied to all fish in the trial.
Experimenter	Name or initials of the person running the trial.
Trial Date	Date of experiment (auto-populated with today's date).
Specimen ID	Individual identifier for each specimen (tag number, PIT tag, etc.).
Mass (g)	Body mass in grams. Required for internal temperature estimation.
Total Length, Width, Height (mm)	Dimensions of the specimen in millimetres.

6.6 Notes

The Notes section in the right panel allows you to record timestamped observations during a trial.

- Type a note in the text box and click Submit Note
- The note is stamped with the current time, elapsed ramp time, and water temperature
- All notes appear in the Notes log box and are saved in the CSV under the Notes section

6.7 Maintenance Phase

The maintenance phase holds the water at the Holding Temperature before and (optionally) after the CTmax ramp. This ensures fish are acclimated to a stable starting temperature.

- The DAQ heating output is toggled on/off to maintain the target temperature
- If a cooling output is configured, it assists in maintaining temperature from above
- The Pump Toggle Interval prevents rapid relay switching
- The event log records when the holding temperature is first reached
- The elapsed time between reaching holding temperature and starting the ramp is recorded in the CSV as pre_hold_duration_s

6.8 CTmax Trial Phase

During the CTmax trial, the water temperature is ramped at the configured heating rate. The ramp continues until all fish CTmax endpoints are recorded or the trial is manually stopped.

- The ramp starts from the current water temperature (the holding temperature)
- Target temperature increases linearly at Heating Rate °C/min
- The chart plots both actual and target temperature in real time
- Clicking the CTmax button for a fish freezes its canvas box and records: CTmax ambient temp, timestamp, elapsed ramp time (s and min)
- If all fish CTmax events are recorded before the trial is stopped, the log notes: 'All CTmax events recorded — experiment complete'
- After stopping, the system can optionally cool back to the holding temperature at the Cooling Rate

6.9 Internal / Body Temperature Estimation (works for FISH only)

When the Estimate internal temp checkbox is ticked, CTmax Tracker estimates the fish's core body temperature using Newton's law of cooling (Stevens & Sutterlin 1976):

$$T_b = T_a + (T_i - T_a) \times e^{-kt} \quad \text{where} \quad k = 3.32 \times W^{-0.536}$$

Symbol	Definition
Tb	Estimated fish body temperature (°C)
Ta	Current ambient water temperature (live sensor reading, °C)
Ti	Water temperature at the start of the ramp (°C)
k	Body-to-water heat transfer coefficient (min^{-1}), calculated from fish mass W (g)

- Tb is updated every second during the ramp and displayed on the specimen canvas box
- At the moment CTmax is recorded, the estimated body temperature is frozen and saved to the CSV as CTmax int est (°C)
- Fish mass (g) must be entered for each specimen — if mass is missing or zero, estimation is skipped for that fish
- The equation was derived for sea raven (Hemitripterus americanus, 12–3178 g, 4°C seawater) — treat estimates as indicative for other species (likely not an accurate estimate for all species)
- Ticking/unticking the checkbox mid-trial shows a warning dialog; unticking clears the displayed estimates

Note: Reference: Stevens E.D. & Sutterlin A.M. (1976). Heat transfer between fish and ambient water. Journal of Experimental Biology 65, 131–145.

7. Data Output (CSV)

The Save Results export creates a single structured CSV file with five sections. A chart PNG is saved automatically in the same folder.

Section	Contents
=== TRIAL INFO ===	Species, trial date, experimenter, number of fish, times for each phase (pre-ramp hold reached, ramp start, cooling back start, post-hold reached, trial end), and phase durations in seconds.
=== SETTINGS ===	Holding temperature, heating rate, cooling rate (if enabled), pump toggle interval, and DAQ configuration summary.
=== FISH DATA ===	One row per fish: Fish ID, Mass (g), Total Length (mm), Width (mm), Height (mm).
=== CTMAX RESULTS ===	One row per fish: Fish ID, CTmax amb (°C), CTmax int est (°C), timestamp, elapsed ramp time (s), elapsed ramp time (min). CTmax int est is blank if internal temperature estimation was not enabled.
=== NOTES ===	All manually submitted notes with timestamp, elapsed time, water temperature, and text.
=== TEMPERATURE LOG ===	One row per second throughout the entire experiment with the following columns: • **timestamp:** Wall-clock time (YYYY-MM-DD HH:MM:SS) • **elapsed_s:** Seconds since ramp start • **actual_temp:** Measured water temperature (°C) • **target_temp:** Target temperature at that moment (°C) • **temp_discrepancy:** actual_temp − target_temp • **actual_rate:** Instantaneous heating/cooling rate (°C/min) • **target_rate:** Configured ramp rate (°C/min) • **rate_discrepancy_pct:** Deviation of actual rate from

	target (%) • **state:** Experiment state: MAINTAINING / RAMPING / COOLING BACK / etc. • **heating:** 1 if heating output is ON, 0 if OFF • **cooling:** 1 if cooling output is ON, 0 if OFF

The CSV header section also includes computed ramp statistics: OLS slope of the ramp (°C/min), mean ramp rate, and standard deviation of ramp rate.

8. Troubleshooting

Symptom	Solution
Temperature reads 0.00 or does not update	Check that the DAQ device is connected and InstaCal detects it on board 0. Verify the analog input channel matches the probe wiring.
Heating output does not activate	Open DAQ Configuration and verify the correct port and bit are set for the heating output. Use the Test button to toggle it manually.
Temperature overshoots the holding target	Increase the Pump Toggle Interval to reduce relay switching frequency. Check that the heating element power is appropriate for the tank volume.
Internal temperature estimate not shown	Ensure the Estimate internal temp checkbox is ticked and that a valid Mass (g) > 0 is entered for the fish.
License dialog appears on every launch	The license file may have been deleted. Re-enter your license key or start a new demo trial.
Demo trial cannot be started	The 7-day demo is one-time. Contact jacob.l.johansen@gmail.com for a full license.
CSV file is empty or missing sections	Ensure the trial was fully started (maintenance + CTmax phases) before saving. Check the event log for auto-save errors.
Chart PNG not saved	The PNG is saved automatically alongside the CSV. Check the selected save folder for a file ending in _chart.png.

For other issues, contact support at Jacob.l.johansen@gmail.com

9. Changelog

Version 1.2 (May 2026)

- Internal / core body temperature estimation via Newton's law of cooling (Stevens & Sutterlin 1976)
- Machine-locked HMAC-SHA256 licensing with 7-day demo trial

- Demo mode: CSV saving disabled, days-remaining counter in title bar
- Text wrapping within specimen canvas rectangles and ovals
- Mid-trial warning when toggling internal temperature estimation
- Standalone Windows installer (PyInstaller + Inno Setup) with fish icon desktop shortcut

Version 1.0 / 1.1 (initial release)

- Multi-specimen tank canvas with draggable/resizable rectangle and oval shapes
- USB-1208LS DAQ integration for live temperature monitoring
- Configurable heating ramp rate and maintenance holding temperature
- One-click CTmax recording with undo functionality
- Live Matplotlib temperature chart with state indicators
- Structured CSV export (trial info, settings, fish data, CTmax results, notes, temperature log)
- 2-point DAQ temperature calibration
- Settings persistence via JSON
- Timestamped notes system

10. Contact & Licensing

For license keys, technical support, or feature requests, contact:

- Jacob L. Johansen, jacob.l.johansen@gmail.com

To obtain a license key:

- Open CTmax Tracker — the License Activation dialog shows your Machine ID
- Copy the Machine ID and send it by email with your license type request
- A license key tied to your machine will be provided

This software is provided for research purposes. The license is non-transferable and locked to the hardware fingerprint of the registered machine. Redistribution or modification of the software is not permitted without written consent.