



VERDALIS
Natural sound synthesis

InsectSwarm

Synthesised insects

Version 0.5.0

CLAP instrument for Linux and Windows

Part of the Verdalis Plugin Suite

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Introduction

InsectSwarm is a CLAP instrument that generates insects: a single bee, a hive, a wasp crossing the microphone, a mosquito that will not leave, a cicada chorus at noon, a field of crickets after dark. It contains no samples. Every wingbeat, every pass and every tymbal click is computed from phase accumulators, pulses, noise and filters while the plugin plays, so no two takes are alike and there is no loop point to find.

A bee is half noise

One number decides the whole design, and it is the first thing the reference library of 67 field recordings says.

HARMONIC-TO-NOISE RATIO	
Honeybee	6.6 dB
Mosquito	16.0 dB
a hive or a swarm	0 – 2 dB

A mosquito really is the thin whine it sounds like. A honeybee is very nearly as much turbulent air as tone — and that is why a stack of oscillators never sounds like one, however carefully its harmonics are set. It is not a missing harmonic. It is that most of what you are hearing is not harmonic at all.

So the engine generates turbulence alongside the wingbeat, and *Rasp* is the ratio between the two in dB, referenced to that measurement. At the centre of its travel each species reproduces its own figure.

Many insects are noise

The second finding is what makes the swarm work, and it means the plugin needed no ensemble stage, no chorus and no detune.

A single close insect measures 8 to 13 dB harmonic-to-noise. A hive measures 0 to 2. Nothing was added to the recording to make that happen: enough fundamentals, scattered widely enough, *are* noise. So *Count* and *Spread* are the whole mechanism, and rendering the engine back confirms it — twelve individuals at 150 cents apart come out at 1.7 dB, inside the measured hive figure.

At a *Count* of one, *Spread* correctly does nothing. One insect is one insect however wide the distribution it was drawn from.

The Doppler shift is real and inaudible

The third finding is a negative one, and it is worth knowing before you go looking for the control that must be broken.

Ten of the library's recordings are a single clean pass. They rise a median of **13.3 dB** over their own approach, over a **1.37 s** bump, at about **3.2 m/s**. At that speed the Doppler shift across the pass is **30 cents** — while the same insects' wingbeat rates wander by 43 to 103 cents on their own.

The pitch shift is buried in the wander. A flyby reads as movement because of its level, its filtering and its pan, not because of its pitch. InsectSwarm computes the Doppler anyway, because it is physically right and costs nothing, and *Speed* goes far past anything an insect can do for when you want it as an effect.

What is in this manual

The chapters below cover installing it, getting a first sound, how the model works and why it is built the way it is, the window, then a generated reference for every parameter and every factory preset. The last two chapters are honest about what does not fit yet and where the model comes from.

Installing

InsectSwarm is one self-contained `.clap` file plus its `presets` folder. There is no installer, no shared library to place and nothing to register.

Linux

CLAP hosts scan `~/ .clap`. Copy the plugin folder from the release archive into it so that you end up with:

```
~/ .clap/InsectSwarm/InsectSwarm.clap
~/ .clap/InsectSwarm/presets/
```

Then rescan plugins in your host. X11 and Cairo are the only external dependencies of the plugin window, and any Linux machine that can run a DAW has both.

Windows

CLAP hosts scan the common CLAP folder. Copy the plugin folder into:

```
C:\Program Files\Common Files\CLAP\InsectSwarm\
```

so that `InsectSwarm.clap` and `presets\` sit inside it, and rescan. There are no DLLs to install beside it — the window and its Cairo are linked in.

Keep the plugin and its presets together. The plugin finds its factory presets by looking for a `presets` directory next to its own binary. Moving the `.clap` file on its own leaves it with no factory presets at all.

Hosts

Tested with Bitwig Studio and Reaper. In Bitwig, `~/ .clap` is scanned by default; after installing, restart it or rescan under *Settings* → *Locations* → *Plug-in Locations*. InsectSwarm then appears as an instrument under the vendor *Ravetracer*, and the factory presets are indexed through CLAP’s preset discovery, so they show up in the host’s own browser as well as in the plugin window.

Your own presets

`SAVE` in the plugin window writes to a user preset folder, which is created on first use:

PLATFORM	LOCATION
Linux	<code>\$XDG_CONFIG_HOME/InsectSwarm/presets</code> , or <code>~/ .config/InsectSwarm/presets</code>
Windows	<code>%APPDATA%\InsectSwarm\presets</code>

User presets appear in the browser immediately, listed after the factory ones. They are plain text, so they can be copied between machines, kept in version control, or edited in any editor.

COLLECTIONS

A preset library is a shelf, and a long one is worth tidying. Your own presets are filed in **collections**: folders one level under the user preset directory. The browser lists the library down its left side — *All*, the factory presets, each of your collections, and *Unfiled* for presets saved into none — each with the number of presets in it. Clicking one lists just that one.

IN THE BROWSER	WHAT IT DOES
<code>NEW</code>	Makes a collection. It is listed at once, empty until something goes into it

RENAME	Renames the selected collection; its presets go with it
DELETE	Deletes the selected collection and every preset in it, after asking
Drag a preset onto a collection	Moves it there — or onto <i>Unfiled</i> to take it out of one
Right-click one of your presets	Renames it, changes its description, or deletes it

SAVE asks where a preset goes: pick a collection from the list — or *New collection...* to make one on the spot — then give the preset a name and, if you like, a **description**. The description is what the browser shows while the pointer is over the preset and what the help line shows while it is loaded: a sentence for whoever loads it next. Saving over one of your own presets offers its collection and its description again.

The factory presets are locked. They are part of the plugin, not files of yours, so they cannot be moved, renamed or deleted; to change one, load it, adjust it and save it as your own.

Collections are one level deep on purpose: a preset library is a shelf rather than a filesystem, and a tree deep enough to get lost in is one somebody will get lost in.

PRESET PACKS

A whole collection can be written out as a single file — a **preset pack**, extension `.insectswarmpack` — so a library can be handed to somebody else, or moved between machines, as one file rather than a directory.

With a collection selected in the browser:

BUTTON	WHAT IT DOES
EXPORT	Writes the selected collection — its presets and nothing else — as a pack into the <code>packs</code> directory beside <code>presets</code>
EXPORT AS...	The same, to a location you choose
IMPORT...	Lists the packs already in <code>packs</code> , plus <i>Other file...</i> for one from anywhere
REVEAL	Opens the folder the pack was just written to in the system's file browser

Importing adds the pack's presets to the library as a new collection named after the pack. Nothing is ever overwritten: importing the same pack twice gives two collections rather than a mixture of both versions in one.

A pack is the preset format again with a separator line between the presets, so it can be read, diffed and edited by hand like everything else here. It carries each preset's text verbatim rather than a re-serialised copy, which is what makes a round trip through a pack lossless.

EXPORT AS..., *Other file...* and **REVEAL** need the desktop's own file chooser — `zenity` or `kdiallog` on Linux, `xdg-open` to reveal, and the operating system's own on Windows. Where none is installed the buttons that need one are not drawn, and the plugin's own `packs` directory, which is where **EXPORT** writes, is enough on its own.

Building from source

The suite builds with a C++17 compiler and CMake 3.16 or newer. From the plugin folder:

```
./install.sh
```

That configures, builds, runs the self-test and installs to `~/.clap/InsectSwarm/`. `InsectSwarm_PREFIX=/some/where` `./install.sh` overrides the destination, and `-DCLAP_INCLUDE_DIR=/path/to/clap/include` points the build at a CLAP checkout it cannot find by itself.

A first sound

1. Load InsectSwarm on an instrument track.
2. Draw a long note — eight bars or more. The insects fly for as long as the note is held, and the release fades them out.
3. Open the preset browser by clicking the preset name in the window header and try **Single Bee**, then **Hive Wall**, then **Cicada Noon**.

Those three are the span of the instrument. The first is one insect, close enough to count its wingbeats. The second is sixty of them and no longer countable at all. The third is not a wingbeat in any sense.

Three things to try first

Change the species. *Species* selects one of seven measured insects, and they are not names someone invented for a menu: each carries the wingbeat rate measured across that species' recordings, the shelf and resonance fitted to its measured harmonic stack, and how harmonic its buzz is to begin with. A hornet beats at 85.7 Hz and a mosquito at 463.7, and everything between them is in the library.

Turn Count up. One becomes four becomes sixty. Watch the sound stop being a tone and start being a texture somewhere around eight, and note that nothing was switched on to make that happen — the individuals simply stopped agreeing with each other. If it stays too tonal, the control you want is *Spread*.

Move Rasp. At the centre each species sits at its measured harmonic-to-noise ratio. Turned down, a honeybee becomes the clean buzz it is usually drawn as and never is; turned up it becomes the rasp it actually measures as. This is the single knob with the most say over whether the result sounds like an insect or like a synthesiser imitating one.

How it works

A wingbeat is a pulse train, twice a cycle

A wing pushes air on the downstroke and again on the upstroke. Each push is a pressure pulse, and the tone you hear is that train — so the fundamental is the wingbeat rate and everything above it is a harmonic of it.

InsectSwarm generates the pulse as $(1 - u^2)^2$ over a width set by *Bite*. That shape was chosen for two reasons: its first derivative vanishes at both ends, so narrowing it brightens the buzz instead of adding a click, and its first two moments are closed forms, so the DC it would otherwise carry is removed exactly rather than filtered out afterwards.

Stroke is how unequal the two half-strokes are. At zero there is one pulse a cycle and every harmonic is present. Turned up, the second pulse grows until the two are equal — at which point the odd harmonics cancel completely and the buzz sits an octave above the wingbeat rate. Real insects are somewhere in between, and the measured stacks say so: a bumblebee's second harmonic is 11.7 dB *above* its fundamental and a hornet's 10.7 dB above, while a mosquito's is 0.3 dB below.

Where the species table comes from

Every species' measured harmonic stack turns out to have the same shape: a peak somewhere between 150 and 460 Hz, then a fall of 5 to 10 dB per octave. That is one resonance and one tilt, so four fitted numbers per species are enough — a one-pole shelf about 300 Hz and one resonant bandpass, crossfaded in.

The fit is against the discrete-time response of the very filters the engine runs, and against the excitation the engine actually generates, so what is shipped is a shape the plugin can make rather than one it approximates. Residuals run 1.5 to 4.0 dB RMS across stacks 25 dB deep, and rendering each species back out lands its wingbeat rate **within one cent** of the row it came from.

Tilt, *Formant* and *Resonance* move that fit rather than replacing it. At their centres you have the measurement.

Note that the resonance is an **absolute frequency**, not a multiple of the wingbeat rate. So raising *Rate* without touching *Formant* is what a real insect does when it flies harder: the beat changes and the body it radiates from does not.

The dragonfly row

One species is shipped as something that is barely a tone, and that is the measurement rather than a shortcut. Only **8 per cent** of the dragonfly recordings' frames are periodic at all, against 56 to 94 per cent for every other species, and they carry the highest crest factor in the library at 32.9 dB.

A dragonfly is a clatter of wings. Forcing it into a clean buzz would have been inventing a sound the recordings do not contain.

A swarm is only ever individuals

There is no ensemble stage in this plugin. *Count* spawns that many independent individuals; each gets its own rate drawn from a distribution *Spread* wide, its own place across the field, its own distance and its own slow rate wander. That is all.

Spread is the one default in the plugin that is calibrated rather than measured, and the reason is worth stating. The library cannot measure it: a hive recording yields one dominant pitch frame by frame, not sixty separate ones, so what comes out of it is how much *that* pitch moved — which is *Wander*, and is a different quantity. What the library does measure is where the scatter ends up, and 150 cents is the value that puts a dozen individuals inside the hive's measured 0 to 2 dB.

Wander itself is measured directly: every species drifts 10 to 24 cents from one 85 ms frame to the next. A rendered single bee at the default 18 cents measures 14 cents of frame-to-frame drift, which is what an 85 ms analysis window sees of a 3 Hz walk.

Roam is the same idea applied to level rather than rate. An insect is never a fixed distance from the microphone: it closes on it and backs off again, and close in, the inverse square law turns a few centimetres into several decibels. At a *Count* of one that is most of what separates a fly from a held tone; in a swarm of sixty the individual drifts are independent and largely cancel, so the same control reads as the crowd breathing rather than as one insect moving. That is why the factory presets carry 6 to 10 dB of it on the single insects and half a decibel on the hives.

The excursion is bounded and the compensation is set so that the loudest moments stay where *Swarm Level* put them. Turning *Roam* up adds the quieter moments rather than louder ones, so it cannot overload a patch that was in range without it; a solo insect gives up about 2 dB of average level at 8 dB of *Roam*, which is the insect spending time further away. *Roam* does not touch the flyby layer, which has a trajectory already.

A flyby is geometry, not an envelope

Flyby puts one individual on a straight line past the listener at a closest distance d_0 and a speed v . Everything then follows from $r(t) = \sqrt{(d_0^2 + (vt)^2)}$:

- the **level** as $1/r$,
- the **pan** as the sine of the bearing, scaled by *Sweep*,
- the **air absorption** as a lowpass falling with distance travelled,
- the **Doppler** from the radial velocity.

The two measured numbers fix the trajectory rather than shaping an envelope. *Rise* is how far the pass comes up over its own approach — a median of 13.3 dB across the library’s clean passes — and *Pass Time* is the width of the level bump 6 dB down from its peak, a median of 1.37 s. For a $1/r$ law that happens at $r = 2d_0$, so those two between them give d_0 and where the trajectory starts.

The library’s passes range from 0.26 to 6.8 s wide, and that spread is the pass *distance* rather than the speed: a near miss is over in a quarter of a second whatever the insect is doing.

Cicadas and crickets are a different instrument

Neither beats its wings. A cicada buckles a tymbal membrane and a cricket draws a scraper across a file, and what comes out is a resonant body driven in pulses. That is a carrier and a pulse rate, not a fundamental and a harmonic stack, which is why it is a separate layer with its own panel.

	CARRIER	Q	PULSES/S	CHIRPS/S	DUTY	WITHIN-CHIRP DUTY
Cicada	5549 Hz	13.2	268	12.5	0.48	0.79
Cricket	4518 Hz	25.8	36	10.5	0.33	0.27

Twice as sharp and seven times slower is the whole distance between a dry rattle and a pure whistling trill. Nothing else in the measurement separates them — so there is deliberately **no Stridulator selector**. A chip that picked between two *models* would be claiming a difference the recordings do not contain. Both sets of numbers are shipped as factory presets, and every one of them is a knob you can move.

Scrape is the last column of that table: how much of each pulse period the insect is actually driving its body. A scraper crossing a file drives the harp for most of a wing stroke; a tymbal snaps rib by rib and drives it briefly. Model both as a single click into the resonator — which is what version 0.2.0 did — and the insect is sounding for 6 per cent of each period, which is neither of them. At *Scrape* 0 you get that single click back exactly.

Chorus is how many are calling, each with its own phase, its own rates and its own drifting clock. *Scatter* is how unlike they are, and its range is set by the library rather than chosen — but in two different ways, because the library bounds the two halves of it differently.

The **carrier** is bounded tightly. A chorus recording measures the *composite* resonance, and a composite at Q 25.8 cannot come from callers spread much wider than a thirteenth of their carrier. At the top of the knob the carriers scatter 3 per cent and no further: a species’ carrier is its anatomy, and every member of it shares one.

The **rhythms** are not bounded at all, and they scatter far more — 45 per cent on the chirp rate, 30 on the pulse rate, 35 on the duty. A clock is not anatomy and no two callers keep the same time.

A chorus is not twelve of the same insect

Neither of those is enough on its own, and finding out why is the one thing in this plugin that was found by ear first and measured afterwards.

Twelve callers within a few per cent of one chirp rate drift in and out of phase *together*: the chorus throbs at its own chirp rate and drops into near-silence between. Measured as the tenth percentile of the band's envelope over its median, nine cricket references sit between 0.16 and 0.85 and version 0.2.0 rendered 0.08 — holes no field has.

And widening the spread does not fix it by itself, because twelve *exactly periodic* trains are a picket fence however far apart the pickets stand. A real caller is not periodic: a lone cricket's own chirp-rate peak is 0.73 of its centre wide. So every caller here carries a filtered random walk on its chirp rate, at the corner *Wander Rate* already sets for the wing layer — the same mechanism that keeps a swarm from sounding like a chord.

Nothing below 80 Hz

The lowest wingbeat in the library is the hornet's 85.7 Hz. Below that, the recordings carry wind, traffic and handling noise and nothing else, so the plugin generates nothing there and *Highpass* sits at 80 by default. It is not a cautious setting; it is the bottom of what an insect makes.

Distance and air

Distance is air absorption plus a downward tilt, and it is bypassed outright at zero rather than parked out of the way, because no distance means no air to absorb. *Air* is how much of the top end that distance costs — dry air absorbs more than humid.

Space is kept low by default and its enclosure is fixed small. These are outdoor recordings, and a field has almost nothing close enough to reflect off; eight discrete early reflections outdoors is exactly what makes a reverb sound like a bathroom. *Beehive Interior* is the one factory preset that wants a real enclosure, and it is inside a box.

The plugin window

InsectSwarm draws its own window with X11 and Cairo on Linux, and Cairo on the win32 backend on Windows. There is no toolkit dependency, which is what keeps the plugin one self-contained file. It is embedded in the host's own window through CLAP's GUI extension and repainted from the host's timer, and it resizes by zooming one layout, from half size to four times.

The window is the suite's, in InsectSwarm's own wasp-yellow theme on a chitin-dark chassis, with a cloud of insects milling behind the wordmark and a streak drawn right across whenever one of them passes the listener. The cloud thickens with how busy the plugin is; the streaks are deterministic in the flyby number, so a pinned *Random Seed* gives a repeatable picture as well as a repeatable sound.

Gestures

GESTURE	EFFECT
Drag a knob up or down	Change the value
Shift-drag	Fine control, a fifth of the travel
Double-click a knob, or right-click anything	Back to the default
Scroll wheel over a control	Step the value
Click a knob's value	Type a value in, with units
Click a selector's name	Open its list and pick a value
Click a selector's ◀ or ▶	Step one choice
Click the preset name	Open the preset browser
◀ or ▶ beside the preset name	Previous or next preset
SAVE	Save the current settings as a user preset
MIXER	Open the layer mixer

The line at the bottom of the window shows what the control under the pointer does — the same one-line explanation that appears in the *What it does* column of the parameter reference.

The mixer

Every layer's level lives on the panel that layer belongs to, which is right for editing one layer and wrong for balancing them against each other. **MIXER** opens the same controls arranged the other way round: one strip per layer — swarm, flyby, stridulation, bed — with its level as a fader. They are the plugin's own parameters, not a second set: moving a fader moves the knob on the panel, and the host sees the same automation it always would.

M mutes a layer and **S** solos one, which is how a preset gets built from nothing: solo one layer, get it right, bring the next one back. Several layers can be soloed at once.

Mute and solo are **not** parameters and are not saved with a preset. They work by holding a layer's level at the bottom of its range and remembering what it was, so while either is active the preset bar shows a **SOLO ON** or **MUTE ON** chip — click it to release every hold at once. **SAVE** releases them first, so a muted layer can never be written into a preset as a silent one, and so does loading a preset. Touching a held layer's fader also releases the holds rather than fighting the hand on it.

Parameter reference

Every range, default, unit and explanation below is read from the plugin's own parameter table when this manual is built, so it cannot drift from what the window and the host show.

There are 54 parameters, grouped the way the plugin window groups them. Every one is automatable and modulatable from the host, and every one can be typed in directly by clicking its value in the window. The name in `code` is the key used in preset files.

SWARM

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Species <code>species</code>	Hornet, Bumblebee, Wasp, Housefly, Honeybee, Mosquito, Dragonfly	Honeybee	Which measured insect the swarm is made of. The choice sets four things at once, all of them from the reference library: the wingbeat rate, the tilt and the resonance fitted to that species' measured harmonic stack, and how harmonic its buzz is to begin with. That last one is the difference nobody expects. A honeybee's buzz measures a harmonic-to-noise ratio of 4.3 dB and a mosquito's 12.8 – so a bee is very nearly as much noise as tone, which is exactly why a stack of oscillators never sounds like one, and a mosquito really is the thin whine it seems to be. Dragonfly is the odd row. Only 8 per cent of its frames are periodic at all, against 56 to 94 for everything else: it is a clatter of wings and not a buzz, and it is shipped that way rather than forced into a tone the recordings do not contain.
Rate <code>rate_shift</code>	-24.00 st ... 24.00 st	0.00 st	Shifts the wingbeat rate off the measured one, in semitones. At zero each species beats at its measured median: 85.7 Hz for a hornet, 143.4 for a bumblebee, 150.6 for a wasp, 193.1 for a housefly, 221.2 for a honeybee and 463.7 for a mosquito. It is an offset rather than an absolute rate on purpose. The species row stays the thing that was measured, and this says how far from it you have gone.
Count <code>count</code>	1 ... 64	12	How many individuals are flying. One is one insect; sixty-four is a hive. The count is what turns a tone into a swarm, and the mechanism is measured rather than assumed: a single close insect measures a harmonic-to-noise ratio of 8 to 13 dB, while the library's hive and swarm recordings measure 0 to 2 dB at the same clarity. Many fundamentals at once <i>are</i> noise. Nothing else has to be added to make a crowd sound like one.
Swarm Level <code>swarm_level</code>	-inf dB ... 6.00 dB	-14.00 dB	Level of the swarm. The whole layer is normalised for the count first, so adding individuals thickens the sound without also making it louder.
Spread <code>spread</code>	0.00 ct ... 400.00 ct	150.00 ct	How widely the individuals' wingbeat rates scatter, in cents. This is the one default in the plugin that is calibrated rather than measured, and the reason is worth stating plainly: the library cannot measure it. A hive recording yields one dominant pitch frame by frame, not sixty separate ones, so what comes out of it is how much <i>that</i> pitch moved – which is Wander, and is a different quantity. What the library does measure is where the scatter ends up. A single close insect comes out at 8 to 13 dB harmonic-to-noise and a hive or a swarm at 0 to 2, because many fundamentals at once <i>are</i> noise. So this is set to the value that lands there: at the default Count of twelve, 150 cents renders at 1.7 dB. At 70 it renders at 4.0 and still sounds like a small number of insects, which is what it is. It does nothing at all at a Count of one, and correctly so – one insect is one insect however wide the distribution it was drawn from.
Wander <code>wander</code>	0.00 ct ... 200.00 ct	18.00 ct	How far one individual's rate drifts while it flies, in cents per 85 ms frame. Measured 10 to 24 across the species, median 15. This is the number that buries the Doppler shift. A bee crossing at 3 m/s shifts its own pitch by 30 cents; its rate wanders by more than that on its own, which is why a flyby reads as a level change and not as a pitch bend. See Speed.
Wander Rate <code>wander_rate</code>	0.10 Hz ... 20.0 Hz	3.00 Hz	How fast that drifting is – the corner of the filtered noise driving it. Low and the swarm breathes; high and every individual is unsteady on the note.
Rasp <code>rasp</code>	0.0 % ... 100.0 %	50.0 %	How much of one individual's buzz is turbulent air rather than the beat itself. It is the single control over how tonal the layer is, and its scale is the measurement: the species row carries that species' measured harmonic-to-noise ratio, and this crossfades from twice that down to nothing at all. At the centre the layer reproduces the measurement. Turned down a honeybee becomes the clean buzz it is usually drawn as and never is; turned up it becomes the rasp it actually measures as.
Roam <code>roam</code>	0.00 dB ... 12.00 dB	4.00 dB	How far one individual's level drifts while it flies, in decibels. An insect is never a fixed distance from the microphone. It closes on it and backs off again, and at close range that is most of what makes a single fly or mosquito sound alive rather than like a held tone – the inverse square law is steep enough that a few centimetres are several decibels. This is the amplitude counterpart of Wander, which does the same thing to the rate. It applies to each individual separately, so it scales itself: at a Count of one it is the whole sound moving, and in a swarm of sixty the independent drifts largely cancel and it reads as the crowd breathing. That is why it is turned up on the single-insect presets and left low on the hives. The

excursion is bounded and the compensation is set so that the loudest moments stay where the Swarm Level put them: turning this up adds the quieter moments rather than louder ones, so it can never overload a patch that was in range without it. A solo insect loses about 2 dB of average level at 8 dB of Roam, which is the insect spending time further away and is the point. It does not touch the Flyby layer, which already has a trajectory and gets its level from the geometry.

Roam Rate roam_rate	0.02 Hz ... 4.00 Hz	0.40 Hz	How fast that drifting is – the corner of the filtered noise driving it. An insect crosses its own body length many times a second but changes where it is in the room over seconds, so this sits well below Wander Rate.
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WING

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Tilt tilt	-100.0 % ... 100.0 %	0.0 %	Tilts the fitted shelf brighter or darker. At zero each species has the tilt fitted to its measured stack – 3.5 dB for a honeybee, 36 for a housefly, which is the difference between a buzz with a top end and one that is all fundamental.
Formant formant	-24.00 st ... 24.00 st	0.00 st	Moves the wing resonance off its fitted centre, in semitones. Every species' measured stack has the same form – a peak somewhere between 150 and 460 Hz and then a fall of 5 to 10 dB per octave – and the fitted centres are 159 Hz for a hornet, 227 for a wasp, 307 for a honeybee, 415 for a housefly, 459 for a bumblebee and 1323 for a mosquito. Because the resonance is absolute and the wingbeat rate is not, moving Rate without moving this is what a real insect does when it flies harder: the beat changes and the body it radiates from does not.
Resonance resonance	-100.0 % ... 100.0 %	0.0 %	How sharp that resonance is, against its fitted value. The fits run from 0.16 for a housefly – a broad hump – to 0.94 for a hornet, a honeybee and a wasp, which is a distinct formant you can hear as a pitch of its own.
Stroke stroke	0.0 % ... 100.0 %	0.0 %	How unequal the two half-strokes are. A wing produces a pressure pulse on the downstroke and another on the upstroke, and when the two are equal the odd harmonics cancel and the buzz sits an octave up. At zero the two are identical, which is what the species fits assume, so zero is where the shipped table is correct. Turning it up restores the odd harmonics and drops the apparent pitch by an octave – the audible difference between a bumblebee, whose second harmonic measures 11.7 dB <i>above</i> its fundamental, and a mosquito, whose does not.
Bite bite	0.0 % ... 100.0 %	45.0 %	How sharp each stroke's pulse is. A narrow pulse has harmonics far up the spectrum and reads as a hard, papery buzz; a wide one is soft and rounded. It is the excitation's width, before the species' own shelf and resonance shape it.
Flutter flutter	0.0 % ... 100.0 %	25.0 %	Amplitude modulation at the wingbeat rate itself: the individual getting louder and quieter as its wings turn relative to the listener. Small amounts give the buzz its live, unsettled quality; large amounts make it a tremolo.

FLYBY

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Flyby Rate flyby_rate	0.02 /s ... 5.00 /s	0.20 /s	How often one individual passes the listener. Independent of the swarm: a flyby is its own voice on its own trajectory, and it is what makes an insect read as moving rather than as getting louder.
Flyby Level flyby_level	-inf dB ... 6.00 dB	-18.00 dB	Level of the flyby layer at its closest point.
Rise flyby_rise	0.00 dB ... 36.00 dB	13.30 dB	How far the pass rises above its own approach. Measured at a median of 13.3 dB across the ten recordings in the library that are a single clean pass, from 9.5 to 44.2. This is the flyby's real cue. The pitch barely moves; the level moves a great deal.
Pass Time flyby_pass	0.10 s ... 8.00 s	1.37 s	How long the pass takes, measured as the width of the level bump 6 dB down from its peak. The library's clean passes measure 0.26 to 6.8 s, median 1.37 – and the spread is the pass distance, not the speed: a near miss is over in a quarter of a second whatever the insect is doing.

Speed 0.20 3.20 m/s Flight speed, which sets the Doppler shift through $(c+v)/(c-v)$. It is here because it is physically right, not

flyby_speed	m/s ... 20.00 m/s		because it is audible, and the library is clear about which: at the measured median of 3.2 m/s the shift across a pass is 30 cents, while the same insects' wingbeat rates wander by 43 to 103 cents on their own. The Doppler is buried in the wander, and the seven recordings here that appear to show a large one are showing an insect changing gear. Turn it well past anything an insect can do and it becomes an effect.
Sweep flyby_sweep	0.0 % ... 100.0 %	80.0 %	How far across the stereo field a pass travels. At zero it arrives and leaves in the same place.

STRIDULATE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Stridulate Level strid_level	-inf dB ... 6.00 dB	-inf dB	Level of the stridulation layer. Off by default: it is a second instrument sharing a window with the first, and most presets want one or the other.
Carrier carrier	800 Hz ... 16.00 kHz	5.55 kHz	Where the resonant body rings. Measured as the spectral peak: 5549 Hz across the fourteen cicada references and 4518 across the nine cricket ones, with individual recordings from 1963 Hz to 14.7 kHz.
Carrier Q carrier_q	2.00 ... 200	13.2	How sharp that resonance is, measured as the peak frequency over its 6 dB bandwidth. This is the one number that separates the two mechanisms cleanly: 13.2 for a cicada, 25.8 for a cricket. A cricket is nearly a sine wave. A cicada is a rattle with a colour.
Pulse Rate pulse_rate	5.00 Hz ... 600 Hz	268 Hz	How fast the clicks arrive inside one chirp. Measured on the envelope of the carrier band alone, so it is the insect's rate and not whatever else was in the recording: 268 a second for a cicada, 36 for a cricket.
Echeme Rate echeme_rate	0.20 Hz ... 40.0 Hz	12.5 Hz	How often the chirps themselves come. An echeme is one burst of clicks; this is the slower rhythm they are grouped into. Measured 12.5 a second for a cicada and 10.5 for a cricket, with the library running from 0.8 to 19.9.
Duty duty	0.0 % ... 100.0 %	48.0 %	What share of the time the chirping is sounding. Measured at 0.48 for a cicada and 0.33 for a cricket – a cicada is very nearly continuous, a cricket leaves two thirds of its time silent, and that gap is most of what makes it a chirp.
Chorus chorus	1 ... 32	6	How many of them are calling. Each gets its own carrier, its own rate and its own phase, so a chorus smears the echeme rhythm out exactly as a real one does – the library's chorus recordings measure an echeme periodicity half as clear as its solo ones.
Scatter strid_spread	0.0 % ... 100.0 %	50.0 %	How unlike the callers are: how far their carriers, their click rates and their chirp rates scatter around the settings above. At zero they are one insect heard several times over, which is the thing a chorus never sounds like. Its range is set by the library rather than chosen. A chorus recording measures the <i>composite</i> resonance, and the references put that at Q 13.2 for a cicada and 25.8 for a cricket – which cannot happen if the callers are spread much wider than a thirteenth of their carrier. So at the top of this knob the carriers scatter by 3 per cent and no more; a rendered chorus at 10 per cent measures half the Q the recordings do. The click and chirp rates scatter further, because those are heard as a rhythm and nothing in the library bounds them.
Scrape scrape	0.0 % ... 100.0 %	45.0 %	How much of each pulse period the insect is actually driving its resonator – one wing stroke dragging a scraper across a file, or one tymbal contraction buckling its ribs. At the bottom it is a single click ringing the body, which is what 0.2.0 always did and what its own calibration comment recorded as “6 per cent of it is sounding”. Measured inside a chirp, the references are on for a median 0.27 of the time for a cricket and 0.79 for a cicada – so a click is right for neither, and the two mechanisms do not agree with each other either. This is the control that separates them.

AIR

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Distance distance	0.0 % ... 100.0 %	20.0 %	How far away the insects are. Air absorption plus a downward tilt, and bypassed outright at zero, because no distance means no air to absorb.

Air air	0.0 % ... 100.0 %	50.0 %	How much of the top end that distance costs. Humid air absorbs less than dry.
Width width	0.0 % ... 100.0 %	75.0 %	How widely the individuals are spread across the stereo field. The library's stereo references measure a side-to-mid ratio with a median of -7.8 dB for single insects, so even one insect is not a point source.
Space space_amount	0.0 % ... 100.0 %	12.0 %	How much reverberant field there is. Kept low by default: these are outdoor recordings, and a field has almost nothing close enough to reflect off.
Size space_size	0.0 % ... 100.0 %	55.0 %	How big that space is.
Damping space_damping	0.0 % ... 100.0 %	50.0 %	How quickly the space eats the top end. Foliage eats a great deal.

BED

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Bed Level bed_level	-inf dB ... 6.00 dB	-inf dB	Level of the field the insects are in: a quiet broadband bed under everything else. Off by default, because what it models is the recordist's afternoon rather than the insect, and a preset that wants it should say so.
Bed Tone bed_tone	100 Hz ... 12.00 kHz	1.20 kHz	Where the bed's energy sits.
Bed Tilt bed_tilt	-100.0 % ... 100.0 %	-20.0 %	Tilts the bed brighter or darker about its tone.

FILTER

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Filter Type filter_type	Lowpass, Bandpass, Highpass, Notch	Lowpass	Shape of the output filter.
Highpass highpass	20.0 Hz ... 2.00 kHz	80.0 Hz	Permanent highpass. The default of 80 Hz sits just under the lowest wingbeat in the library – a hornet at 85.7 Hz – so nothing the engine generates is cut and nothing below it is generated.
Filter Cutoff filter_cutoff	30.0 Hz ... 20.00 kHz	20.00 kHz	Corner of the output filter.
Filter Resonance filter_reso	0.0 % ... 100.0 %	10.0 %	Resonance of the output filter.
Filter Key Track filter_keytrack	0.0 % ... 100.0 %	0.0 %	How far the filter follows the played note.

ENVELOPE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Attack attack	1.00 ms ... 20.00 s	300 ms	Fade-in of the whole swarm when a note starts.
Decay	5.00 ms ...	400 ms	Fall from the initial level to the sustain.

decay	20.00 s		
Sustain sustain	0.0 % ... 100.0 %	100.0 %	Level held while the note is down.
Release release	5.00 ms ... 30.00 s	900 ms	Fade-out after the note is let go.
Velocity To Level vel_to_level	0.0 % ... 100.0 %	40.0 %	How much velocity sets the level.
Velocity To Swarm vel_to_swarm	0.0 % ... 100.0 %	30.0 %	How much velocity sets how many individuals are flying and how hard they beat – which is what a disturbed swarm actually does.

OUTPUT

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Output Gain gain	-inf dB ... 12.00 dB	-3.00 dB	Output level.
Max Individuals max_voices	8 ... 256	128	Ceiling on individuals sounding at once across every held note, so the cost is bounded whatever Count and the note count ask for.
Random Seed seed	0 ... 999	0	Non-zero gives the same swarm every time. Zero is always different.

The preset library

16 factory presets ship with the plugin. They are installed beside the binary and exposed through CLAP preset discovery, so they appear in the host's own browser as well as in the plugin window's.

Beehive Interior

Inside the box. The same dense swarm in a small hard space, with the reverberant field up and its size down – the one place in this plugin where a real enclosure belongs. (*bees, hive, indoor*)

Bumblebee Garden

Four bumblebees, measured at 143 Hz. Its second harmonic sits 11.7 dB above its fundamental in the references, which is the whole reason a bumblebee reads as heavier than a honeybee rather than merely lower. (*bumblebee, garden, low*)

Cicada Noon

Sixteen cicadas in the heat. Not a wingbeat at all: a tymbal buckling 268 times a second into a body resonant at 5549 Hz with a Q of 13, which the library measures as sounding nearly half the time. Scrape is low, at 0.15: a tymbal snaps rib by rib, so each buckling drives the body briefly – unlike a cricket, which drags a scraper across a file and sounds for most of every stroke. (*cicada, chorus, heat*)

Cricket Field

Twelve crickets after dark. Not the same mechanism as a cicada, which is what 0.3.0 changed: twice the Q at 25.8, a seventh of the pulse rate at 35.9, two thirds of the time silent – and Scrape at 0.45, because a file-and-scraper drives the harp for most of each wing stroke where a tymbal only snaps. Measured inside a chirp the references are sounding 0.27 of the time for a cricket and 0.79 for a cicada; one click into a resonator is 0.06 and is neither. (*cricket, chorus, night*)

Distant Swarm

A swarm across a field. Distance is air absorption and a downward tilt, and at this range the top of every wingbeat has gone. (*bees, distant, soft*)

Dragonfly Pond

Four dragonflies. The row the library would not give a tone to: only 8 per cent of its frames are periodic at all, so this is the clatter of wings it actually measures as. (*dragonfly, water, clatter*)

Hive Wall

Forty-eight bees at the entrance of a hive. Wide enough in rate that the individual wingbeats stop resolving and the whole thing measures as noise, which is what a hive is. (*bees, hive, dense*)

Honeybee Field

Twelve honeybees working a flower bed. The wingbeat is the library's measured median of 221 Hz and the spread across the twelve is what puts the layer at the harmonic-to-noise ratio a hive measures. (*bees, swarm, warm*)

Hornet Close

Two hornets at arm's length. The lowest wingbeat in the library at 85.7 Hz, and the one species whose fitted resonance sits between its first and second harmonics – so the pitch you hear is an octave above the beat. (*hornet, close, threat*)

Housefly Window

Three flies against glass, measured at 193 Hz with a resonance at 415. Bite up, because a fly is a papery buzz rather than a round one. (*fly, indoor, busy*)

Mosquito In The Ear

One mosquito, as close as it ever gets. The most harmonic thing in the library at 16 dB harmonic-to-noise, which is why a mosquito is a whine where a bee is a buzz. (*mosquito, solo, close*)

Mosquito Night

A few of them in a dark room, passing at irregular intervals. The passes are what make it unbearable; the swarm underneath is barely there. (*mosquito, flyby, night*)

Single Bee

One honeybee, close. At a Count of one the Spread does nothing – one insect is one insect – so this is the measured stack on its own, at the 8 to 13 dB harmonic-to-noise the library's close single recordings come out at. (*bees, solo, close*)

Summer Meadow

Everything at once and nothing in front: bees working the flowers, cicadas in the trees behind them, and a little of the field itself. The only factory preset that uses the bed. (*mixed, ambience, wide*)

Swarm Rising

A disturbed swarm, played hard. Velocity To Swarm is at its top, so a soft note is a calm and thinner swarm and a hard one is every individual flying – which is the mapping the whole table is defined at. (*bees, dynamic, playable*)

Wasp Picnic

Half a dozen wasps circling, with one passing close every few seconds. The flyby rises 13.3 dB over its own approach, which is the median of the ten clean passes in the library. (*wasp, flyby, summer*)

Using it in a host

Notes

A note starts the swarm and holding it keeps it flying. The ADSR shapes the whole scene rather than individual insects, and *Release* is what fades it out. The played note transposes the wingbeat rate and the stridulation carrier together, so InsectSwarm is playable as an instrument as well as usable as an ambience — though an insect two octaves up stops being an insect fairly quickly.

Velocity To Swarm makes velocity behave like a disturbed swarm: it raises the number of individuals and how hard they beat together. It works downwards from full velocity, unlike the usual convention, and deliberately — most hosts send velocity 1, and at any other convention an untouched note would land a semitone off the measured species row.

Insects need long notes. Their character is in the statistics of many individuals and in the slow wander of their rates, and neither is audible in a short one.

There are 4 voices, each with up to 64 individuals, and *Max Individuals* caps the total across all of them.

Automation and modulation

Every parameter is automatable, and host parameter modulation (`CLAP_EVENT_PARAM_MOD`) is supported globally. Per-note modulation and note expressions are ignored. Parameter changes are sample accurate, and everything that reaches an individual — its rate, its excitation, its shaper, and how many of them there are — is re-derived while the note is held, so an automation ramp over a bar is a swarm changing rather than one that had to be retriggered.

Reproducible renders

Random Seed at 0 never repeats. Any other value renders the same swarm for the same notes every time, and the output is byte-identical across runs at both 48 and 96 kHz. Each voice's individuals are seeded from its own slot and key rather than from the shared generator, so a fixed seed promises the same swarm even when note events arrive before the seed has been applied.

CPU cost

Cost is bounded by *Count*, the note count and *Max Individuals*. One individual is a phase accumulator, two stroke pulses, a band-limited noise source, a one-pole shelf and one resonator — cheap enough that the default preset's twelve are a small fraction of one core. Nothing else in the engine varies much: *Chorus* adds one resonator each, and *Space* is the room model.

Two calibrations run outside the audio path and only when a parameter that reaches them has moved: one measures what a single individual's excitation and shaper come out at, the other does the same for one caller. They are what make *Swarm Level* and *Stridulate Level* mean a level rather than a function of whichever timbre knob was touched last.

Rendering and tails

The tail is the release plus whatever the last flyby and the room are still doing. A flyby runs to the end of its own trajectory, which is a couple of *Pass Times*, so a preset with slow passes wants two or three seconds past the end of the note when bouncing.

Headroom

Every factory preset renders between -20.8 and -28.8 dBFS RMS with peaks no higher than -3.5 dBFS, at the default output gain. The one layer to watch is the stridulation, and how much depends on *Scrape*: at the bottom of that knob a cricket is 36 clicks a second each ringing for under two milliseconds, so 6 per cent of it is sounding and it peaks some 18 dB over its own average. Opening *Scrape* fills those gaps in and the crest factor falls with it — the level stays put either

way, because the layer's normalisation is measured from the same shape the audio path plays. At a level a swarm would use both are comfortable; pushed to the top of its knob it will reach the output stage's soft clipper, which is what the top of that knob is for.

What is still being fitted

InsectSwarm 0.5.0 is a first fit, and the measurements say where it is not there yet. All of this is in the plugin's `TODO.md` with what is known about it.

- **The Hornet row rests on one recording**, 4.2 seconds of it. Its fitted resonance sits between the first and second harmonics, which reproduces the measured stack faithfully — but means the pitch you hear is an octave above the wingbeat. That is what the recording is; it is also the thinnest evidence in the table.
- **The Wasp and Dragonfly rows rest on two each.**
- **The flyby's level trajectory is the $1/r$ law**, which is right for a point source in free field and is not quite what the library's ten clean passes trace. The suite's rule allows a measured curve shipped as coefficients; extracting those ten envelopes is the obvious next step.
- **The pulse train inside a chirp is exactly periodic**, which no tymbal is. The *chirp* clock wanders as of 0.3.0 and the pulse clock does not, because the references bound the first and say nothing about the second.
- **Nothing measures a swarm's inter-individual rate spread**, which is why *Spread* is calibrated rather than fitted.

Reference and limits

Where the model comes from

- **The reference library itself**, which supplied nearly everything: the seven wingbeat rates, the seven harmonic stacks and the shaper fitted to each, the harmonic-to-noise ratio of a single insect and of a hive, the rate wander, the flyby's rise and width, and both stridulators' carriers, resonances, click rates, chirp rates and duty cycles. The numbers and the scripts that produced them are in the plugin's [tools/analysis/](#).
- The physical reading behind the layers is the standard one: **flight tone** as the pressure pulses of a reciprocating wing, which is why it is a harmonic series on the wingbeat rate and why the two half-strokes matter; **turbulence** as the air shed by the same wing, which is why it carries the stroke's bandwidth rather than being flat; and **stridulation** as a click train ringing a resonant body, which is why it has a carrier and a Q and no harmonic stack at all. The library decided every number; the physics only decided what to measure.
- Where nothing in the library isolates a quantity — *Spread*, *Flutter*, the space controls — the model is stated as chosen or calibrated rather than fitted, both here and in the chapter above.

What it does not do

- **No birds, no rain, no wind.** Those are other instruments in the suite.
- **No night-chorus arrangement.** Which species call at which hour, how a chorus starts and stops, how one caller triggers its neighbours — that is a scheduler rather than a resonator, and it belongs to NightLife. This plugin owns the stridulation *mechanism*, not the arrangement of an evening.
- **No sub-bass.** Nothing below 80 Hz is generated, for the measured reason above.
- **No audible Doppler**, for the measured reason above. *Speed* is there and it is physically correct; it is simply smaller than the insect's own wander until you push it past what an insect can do.