The smell of death

Characterization and applications

François Verheggen

Gembloux Agro-Bio Tech - Université de Liège

ECE 2026 – July 2nd 2026


Laboratory of Chemical and Behavioral Ecology
Thanatochemistry

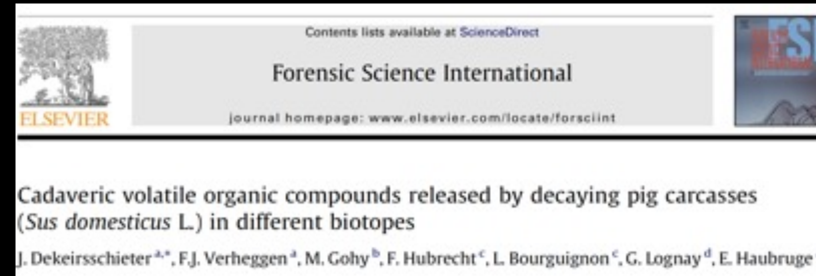
Back in 2007 …

Jessica Dekeirsschieter sur le terrain

What is the smell of death?

Do insects impact the smell of death?

How does the environment impact the smell of death?



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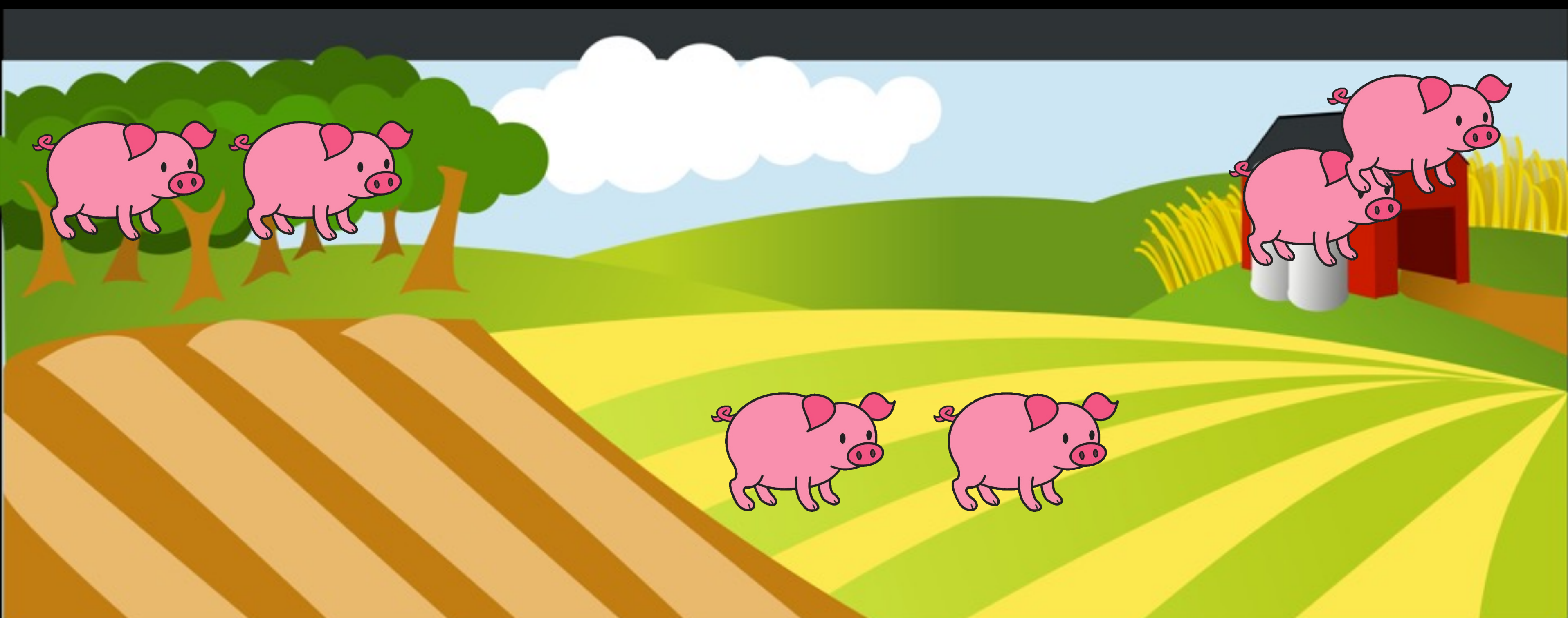
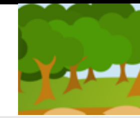
Cadaveric volatile organic compounds released by decaying pig carcasses (*Sus domesticus* L.) in different biotopes

J. Dekeirsschieter[a,*], F.J. Verheggen[a], M. Gohy[b], F. Hubrecht[c], L. Bourguignon[c], G. Lognay[d], E. Haubruge[a]

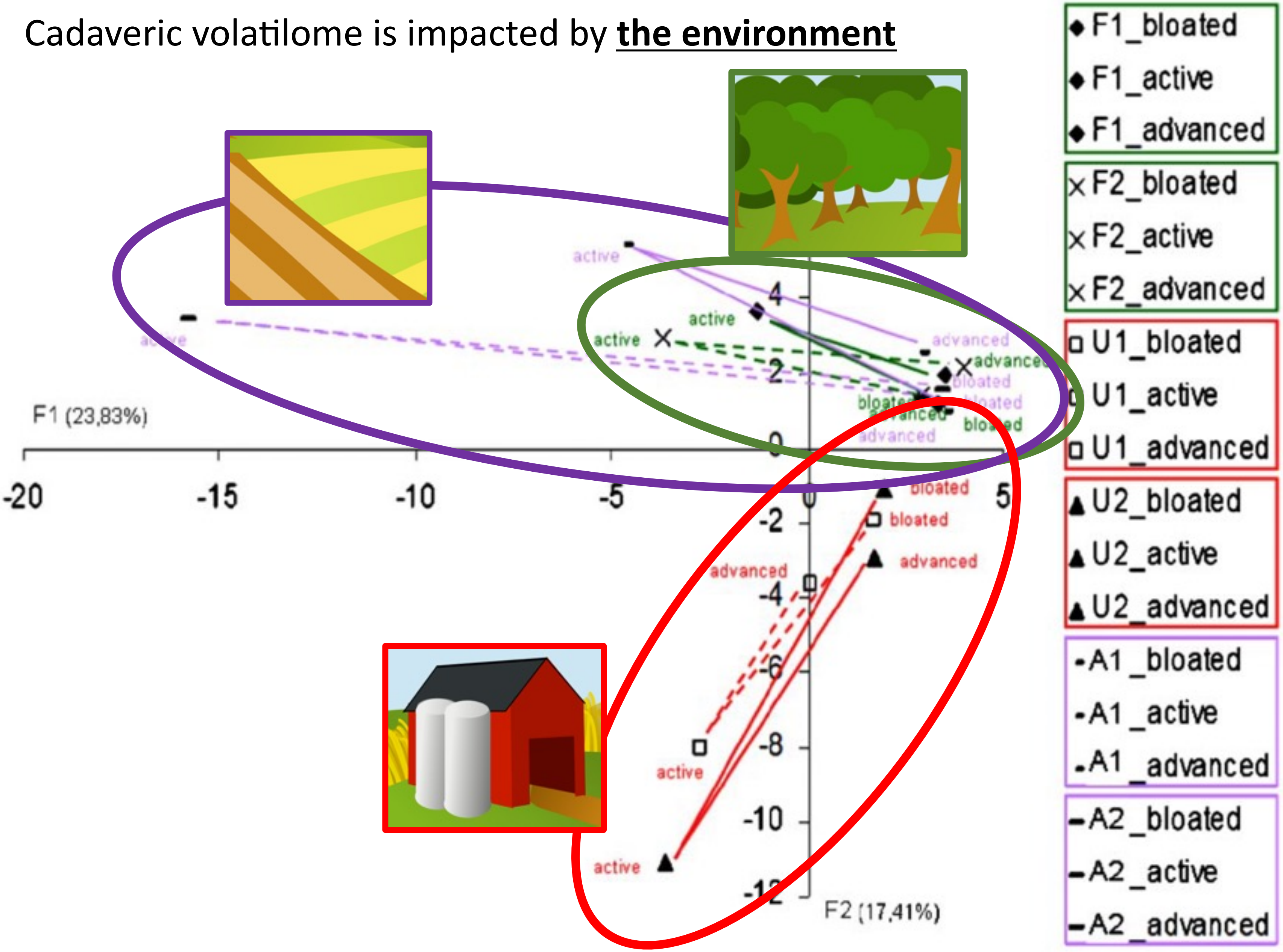


Typical decomposition stages (in a forest biotope)

			
Acids			
Formic acid	▲	▲	–
Propanoic acid	▲	▲	▲
Butanoic acid	▲	▲	▲
2-Methylpropanoic acid	▲	▲	▲
2-Methylbutanoic acid	▲	▲	▲
3-Methylbutanoic acid	▲	▲	▲
Pentanoic acid	▲	▲	▲
4-Methylpentanoic acid	▲	▲	–
Hexanoic acid	▲	▲	▲
Benzoic acid	▲	▲	–
Heptanoic acid	▲	▲	–
Octanoic acid	–	▲	–
Benzoylformic acid	–	▲	–
Nonanoic acid	–	▲	–
Esters			
Propan-2-yl-nitrate	▲	▲	–
Butyl formate	▲	▲	▲
Propyl acetate	–	–	▲
Butyl acetate	–	–	▲
Butyl 2-methylpropanoate	–	▲	▲
Butyl butanoate	▲	▲	▲
Butyl 3-methylbutanoate	▲	▲	▲
Butyl 2-methylbutanoate	–	▲	▲
Butyl pentanoate	–	▲	–
Phenyle butanoate	–	▲	–
2-Methylester, propanoic acid	▲	▲	▲
Ketones			
Acetone	▲	–	–
Butan-2-one	▲	–	–
2,3 Butanedione	▲	–	▲
Pentan-2-one	▲	▲	▲
(E)-Pent-3-en-2-one	–	▲	–
Heptan-2-one	▲	▲	–
1-Phenylethanone	▲	▲	–
Nonan-2-one	▲	–	–
Aldehydes			
Propen-2-al	▲	–	–
But-2-enal	▲	▲	–
2-Methylpropanal	–	–	▲
Butanal	▲	▲	▲
2-Methylbutanal	▲	–	–
Pentanal		▲	▲
Benzaldehyde	▲	▲	–
Heptanal	▲	▲	–
Alcohols			
Ethanol	–	▲	–
2-Methyl-1-Propan-1-ol	▲	▲	▲

			
Butan-1-ol	▲	▲	▲
(2S)-Butan-2-ol	▲	▲	▲
3-Methylbutan-1-ol	▲	▲	▲
3-Methylbutan-2-ol	–	–	▲
Pentan-1-ol	▲	▲	▲
2-Phenylethanol	▲	–	–
2-Ethylhexan-1-ol	▲	–	–
Nitrogen compounds			
Acetamide	▲	▲	▲
N-Methylacetamide	▲	▲	▲
N,N-Dimethylformamide	▲	▲	▲
Propanamide	–	▲	–
N-Methylpropanamide	–	▲	–
N,N-Dimethylacetamide	▲	▲	▲
Butanamide	▲	▲	–
N,N-Dimethylpropanamide	–	▲	–
3-Methylbutanamide	–	▲	–
N-Methylbenzamide	▲	▲	–
N,N-Dimethylbenzamide	–	▲	–
N,N-Dimethylnitrous amide	▲	▲	▲
Trimethylamine	▲	▲	▲
Acetonitrile	▲	–	▲
2-Dimethylaminoacetonitrile	–	▲	–
Benzonitrile	▲	▲	–
2-Phenylacetonitrile	–	–	▲
Octanenitrile	▲	–	–
Nonanenitrile	▲	–	–
Sulfur compounds			
Methadithione	▲	–	▲
Methanethiol	▲	▲	▲
Sulfur dioxide	▲	▲	▲
Methyldisulfanylmethane	▲	▲	▲
Methylsulfanyldisulfanylmethane	▲	▲	▲
1-Methylsulfanylethanone	▲	–	–
1-Methylsulfonyloxybutane	▲	▲	▲
Cyclic hydrocarbons			
1-Methyl-4-(1-methylethyl) benzene	▲	▲	–
Cyclohexylcyclohexane	▲	▲	▲
Phenol	▲	▲	▲
4-Methylphenol	▲	▲	▲
Benzene-1,4-diol	▲	▲	–
Piperidin-2-one	▲	▲	▲
Benzooxazole	▲	▲	–
1H-pyrrole	–	▲	–
Pyridine	▲	–	–
3-Methylpyridine	–	▲	–
1H-Indole	–	–	▲
2,3,5-Trimethylpyrazine	▲	–	–
Quinazoline	▲	▲	▲
Quinoxaline	–	▲	–
2-Nitrophenol	▲	▲	–
3-Methylthiophene	–	▲	–
Halogen compounds			
1-Chloro-butane	▲	–	–
Non cyclic hydrocarbons			
4-Methylheptane	–	▲	▲
2-Methyldecane	–	–	▲
2,6-Dimethylundecane	▲	–	–
3-Hexylpentadecane	▲	–	–
Eicosane	▲	▲	▲
2-Methylprop-1-ene	▲	▲	▲
But-1-ene	▲	▲	–
(E)-But-2-ene	▲	▲	–
Pent-1-ene	–	▲	–
(Z)-Hex-2-ene	–	–	▲
Hept-1-ene	–	▲	▲

Cadaveric volatilome is impacted by **the environment**



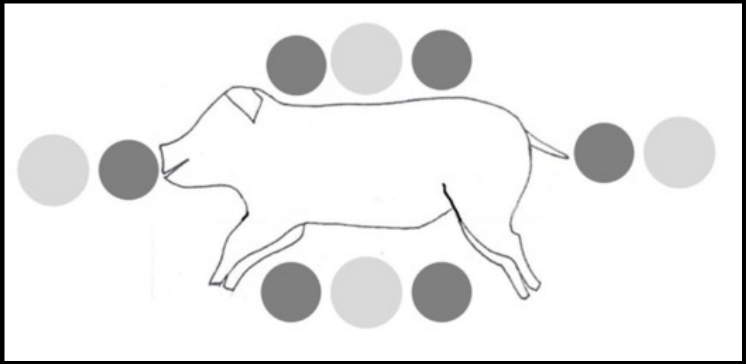
Hypothesis:
Biotopes impact decomposition process

Crop field (➤➤)

Forest (➤➤➤)

Urban (➤)

Hypothesis:
Biotopes impact insect diversity




A
B
C
D
E
F

Calliphora vicina

Lucilia sericata

Calliphora vomitoria

Sarcophaga carnaria

Musca domestica

Absent in urban biotope !

Journal of Insect Science
www.insectscience.org

Carrion beetles visiting pig carcasses during early spring in urban, forest and agricultural biotopes of Western Europe

Jessica Dekeirsschieter[1*], François J. Verheggen[1], Eric Haubruge[1] and Yves Brostaux[2]

Nicrophorus vespilloides (Silphidae)

Oiceoptema thoracica (Silphidae)

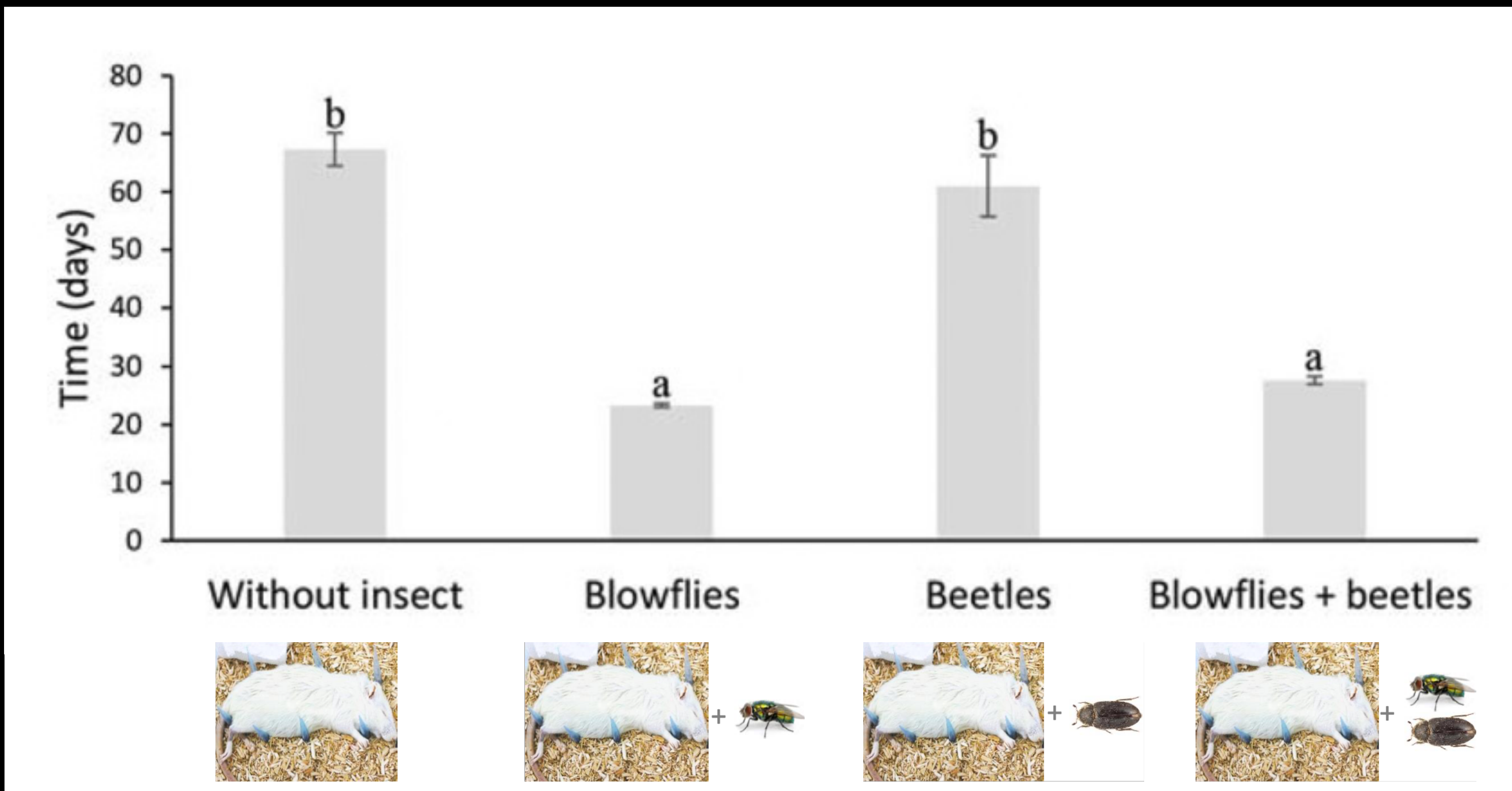
Entomologia Generalis, Vol. 39 (2019), Issue 1, 19–31
Published in print July 2019

Article

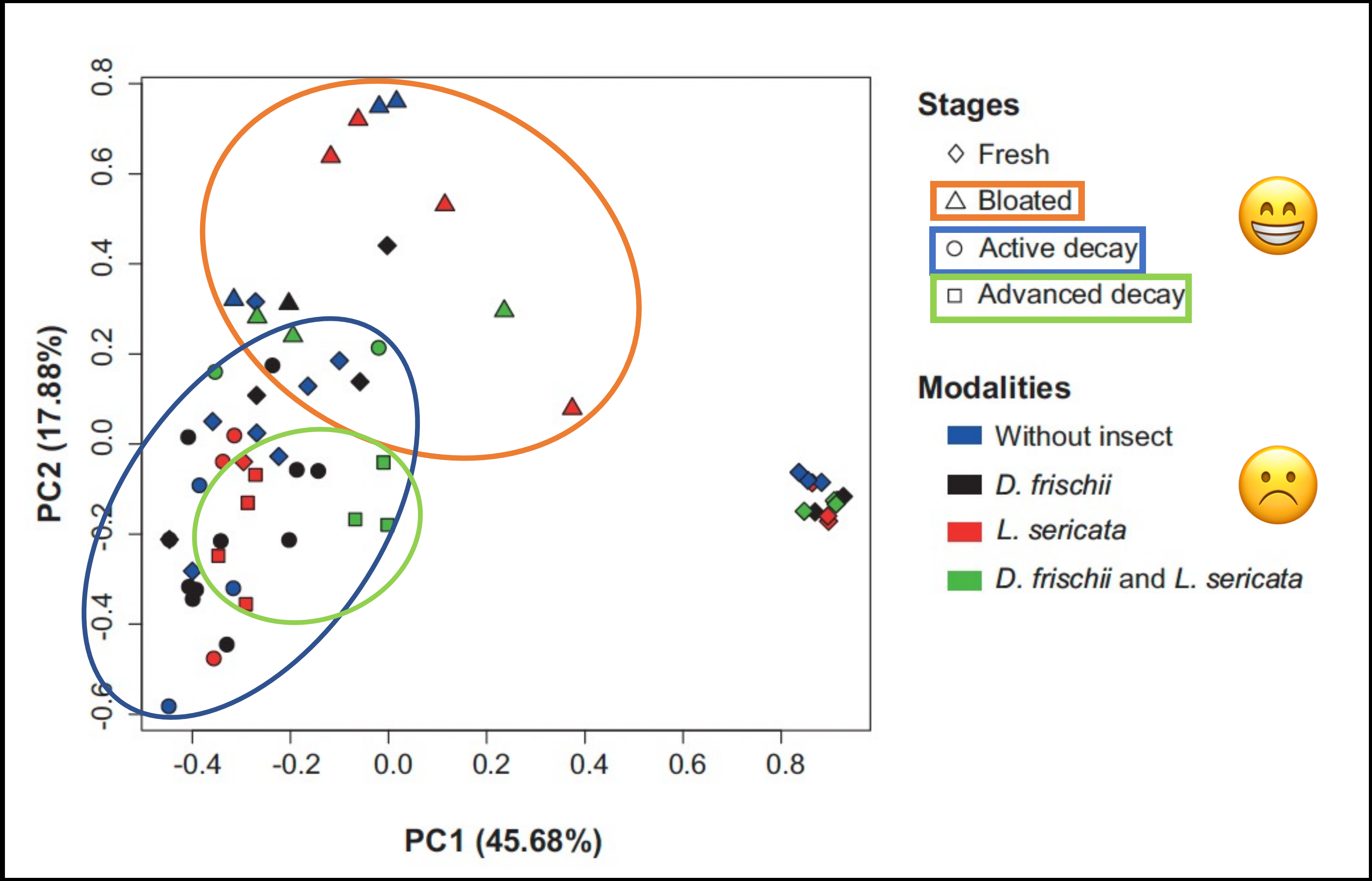
Impact of necrophagous insects on the emission of volatile organic compounds released during the decaying process

Clément Martin[1], Maryse Vanderplanck[2], Antoine Boullis[1], Frédéric Francis[1], Eric Haubruge[1] and François Verheggen[1]

Hypothesis:
Insects impact speed of decomposition



Hypothesis: Insects impact volatile emissions



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Behavioral assays

+

Electrophysiology

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Dimethyldisulphide and Butan-1-ol are the most perceived

and both are attractive

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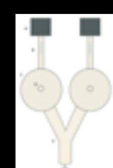

Dimethyldisulphide is attractive

Hypothesis:

Necrophagous coleopterans are attracted to the VOC released by advanced stages of decomposition rather than earlier ones

insects

MDPI

Article

Behavioral and Electrophysiological Responses of the Fringed Larder Beetle *Dermestes frischii* to the Smell of a Cadaver at Different Decomposition Stages

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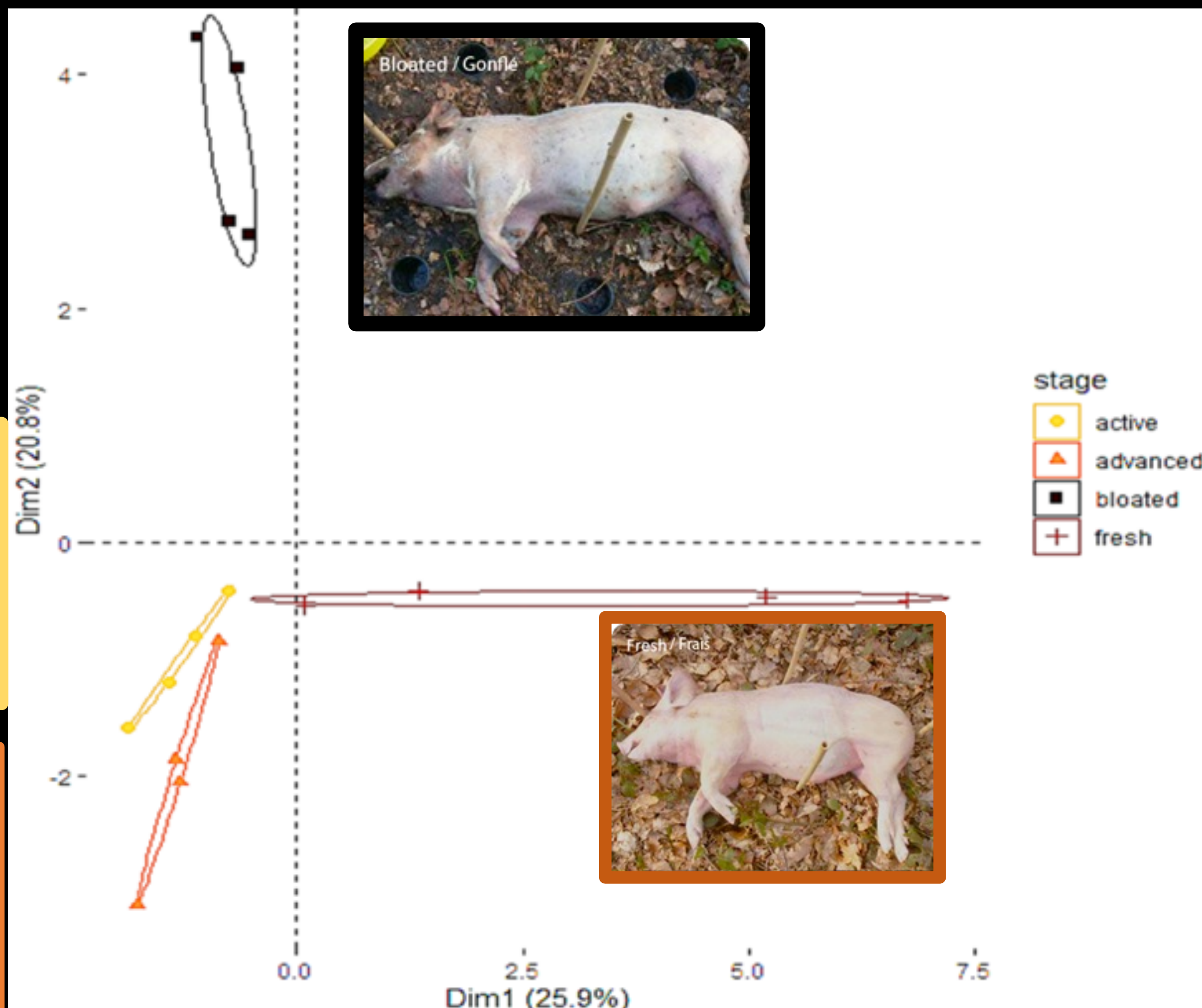

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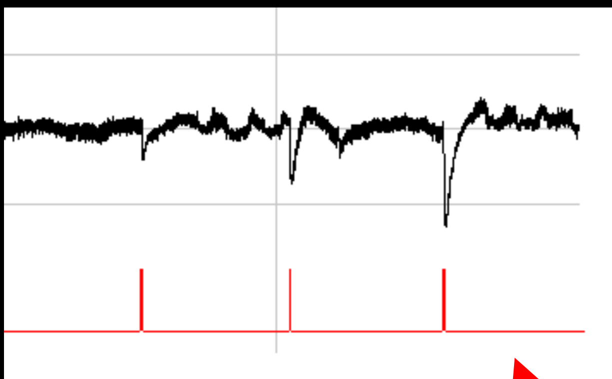

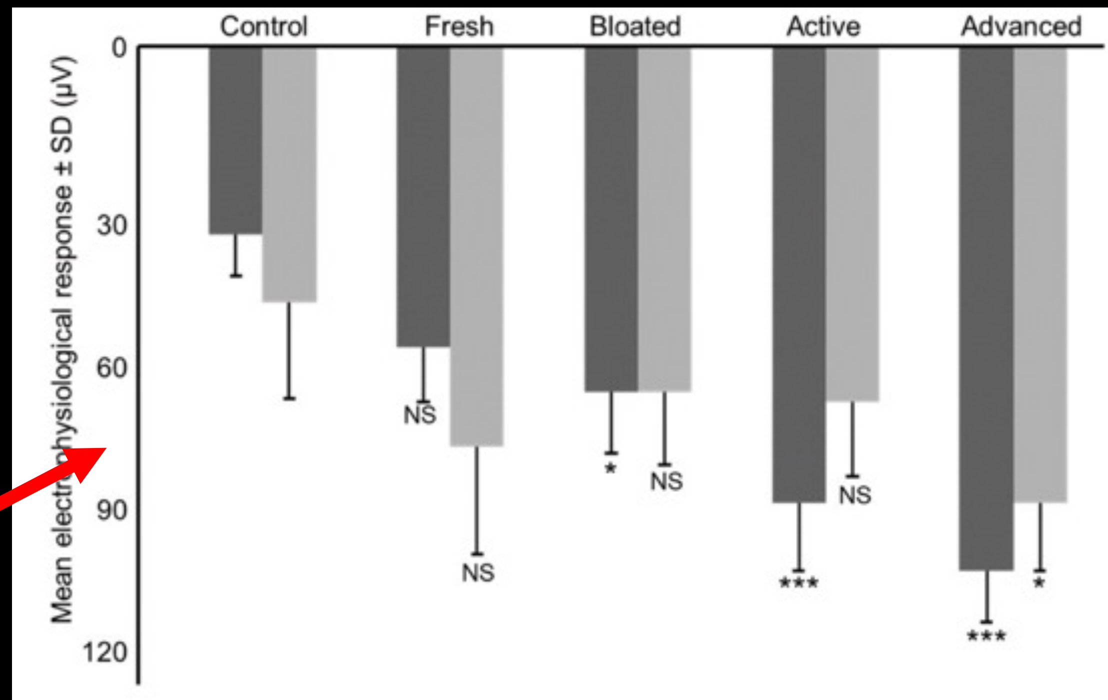

=> Antennae are more reactive to the volatile compounds released from advanced stages of decomposition

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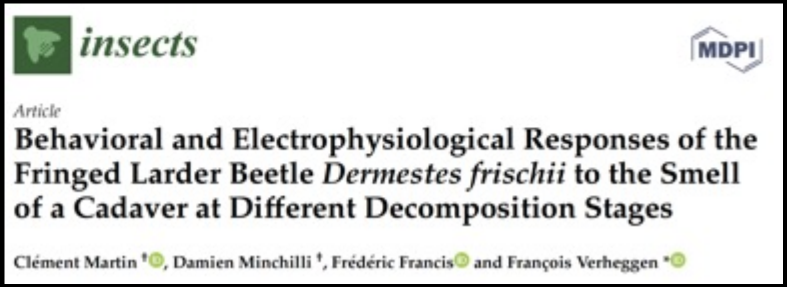

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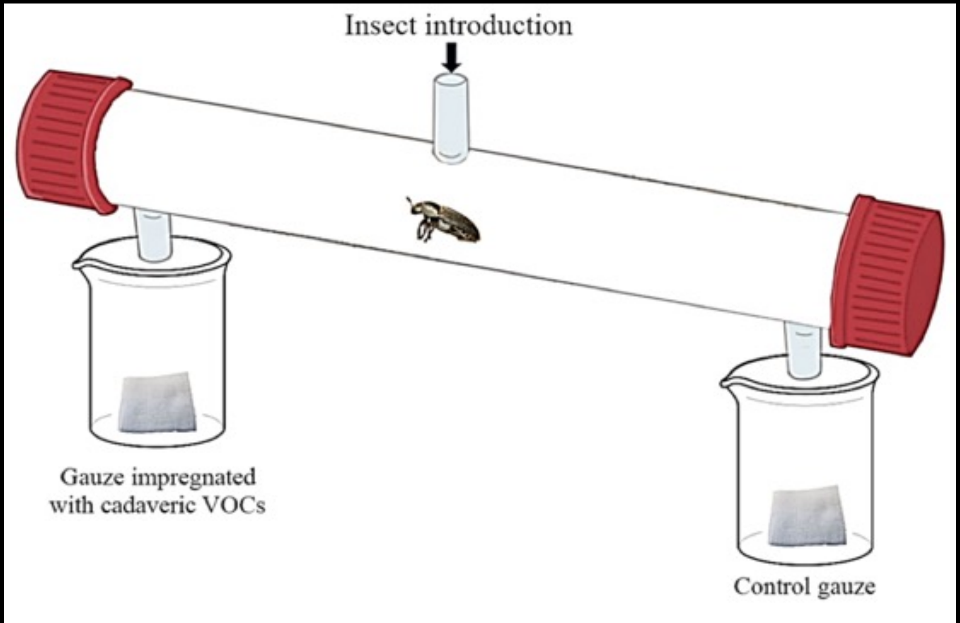

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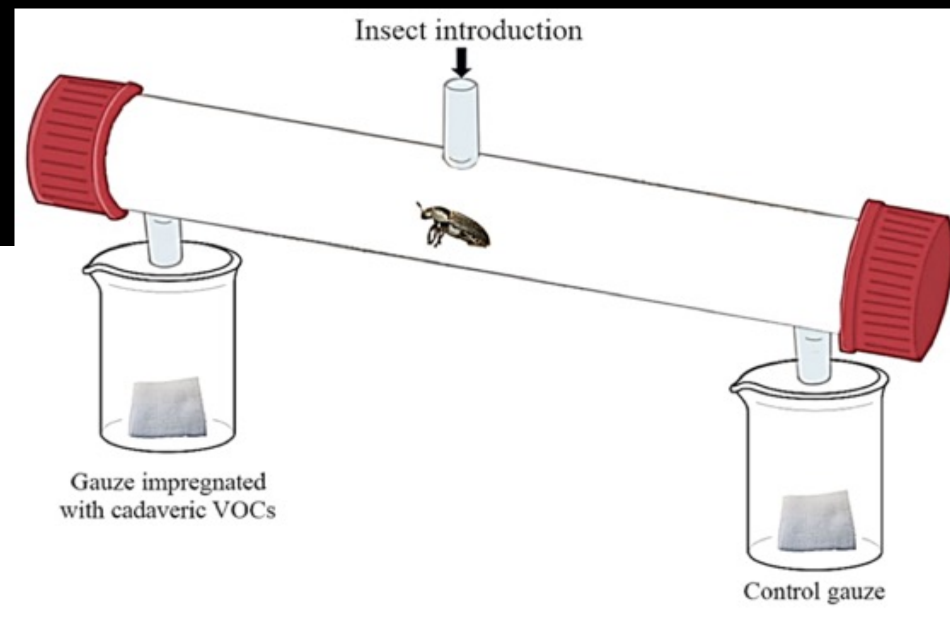
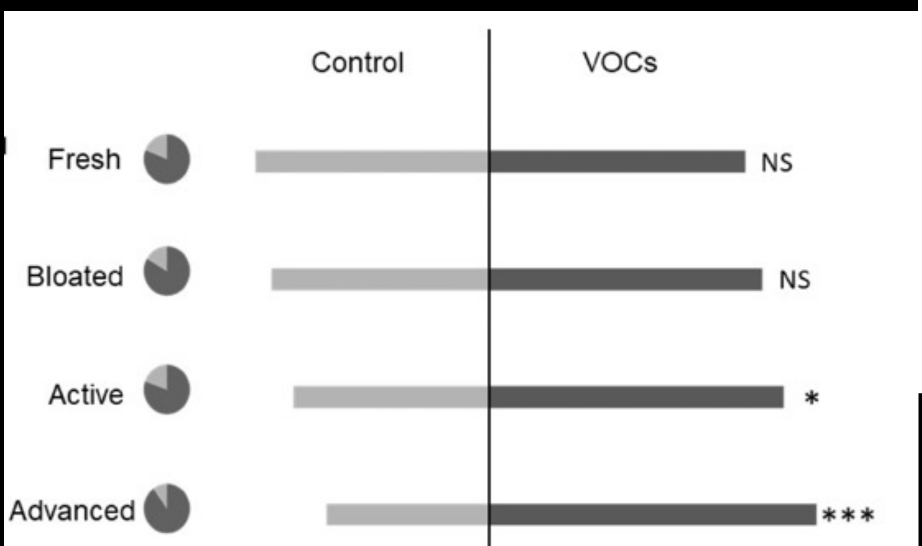




=> Insects are more attracted to the volatile compounds released from advanced stages of decomposition

Hypothesis:

Necrophilous species are attracted by the VOCs released by their hosts rather than by cadaveric VOCs.

Christine Frederickx

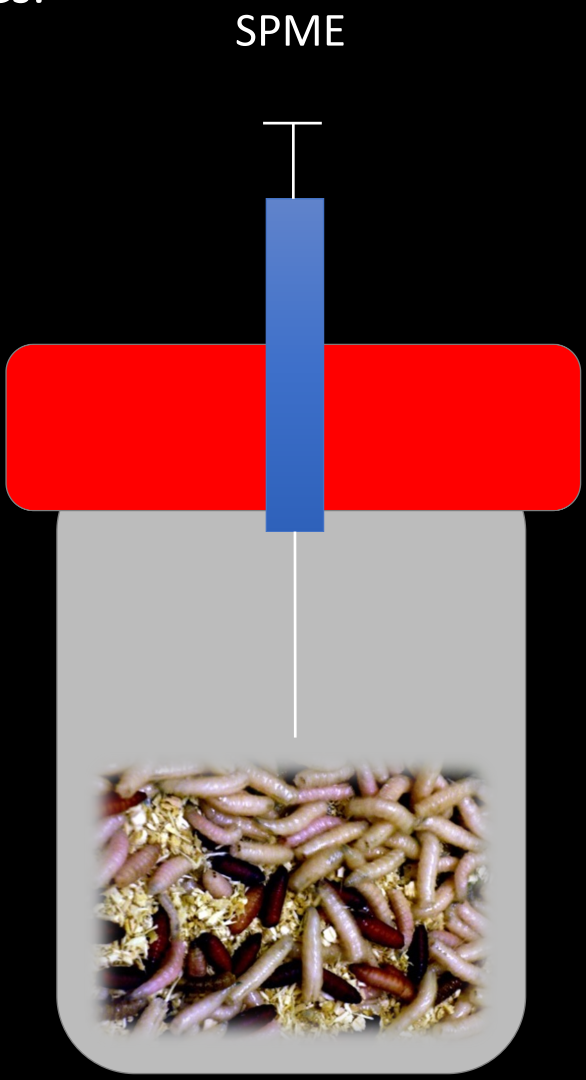
Nasonia vitripennis

Hypothesis:

Necrophilous species are attracted by the VOCs released by their hosts rather than by cadaveric VOCs.

Christine Frederickx

Retention time	Volatile chemicals
1.25	N.N-dimethylmethanamine
1.55	Methanethiol
1.60	Ethanol
1.64	Propan-2-amine
1.69	Propan-2-one
1.79	2-methyl-propan-2-ol
2.29	Ethyl acetate
2.31	Acetic acid
2.68	3-methylbutanal
2.79	2-methylbutanal
2.83	2-methylpropan-1-ol
3.16	Butan-2-one
3.21	1-methoxy-3-methylbutane
3.64	3-hydroxybutan-2-one
3.78	Methylcyclohexane
4.10	3-methylbutan-1-ol
4.18	2-methylbutan-1-ol
4.19	4-methylpentan-2-one
4.31	Methyldisulfanylmethane
5.93	Octane
6.24	Hexanal
7.30	2.4-dimethylheptane
7.54	N-ethyl-1.3-dithioisoindoline
8.15	2-methylpropyl 3-methylbutanoate
8.56	N-(2-aminoethyl)ethane-1.2-diamine
9.01	Ethyl 2-methylbutanoate
9.12	Ethyl 3-methylbutanoate
9.39	Ethylbenzene
9.65	1.4-dimethylbenzene
9.76	1.3-dimethylbenzene
10.16	3-methylbutyl acetate
10.39	2-methylbutyl acetate
10.50	1.2-dimethylbenzene
11.20	Heptanal
11.21	Methoxybenzene
11.83	4-methyl-1-propan-2-ylbicyclo[3.1.0]hex-3-ene
12.27	4.7.7-trimethylbicyclo[3.1.1]hept-3-ene
12.52	6.6-dimethyl-5-methylidenebicyclo[2.2.1]heptane
13.09	2-methyl-5-propan-2-ylcyclohexa-1.3-diene
13.17	Benzaldehyde
13.38	(E)-4-methylidene-1-propan-2-ylbicyclo[3.1.0]hexane
13.39	Methylsulfanyldisulfanylmethane
13.39	(Z)-4-methylidene-1-propan-2-ylbicyclo[3.1.0]hexane
13.46	7.7-dimethyl-4-methylidenebicyclo[3.1.1]heptane
13.70	1-methyl-2-propan-2-ylbenzene
13.85	Phenol
13.95	7-methyl-3-methylideneocta-1.6-diene
14.09	2.2.4.6.6-pentamethylheptane
14.43	3.7.7-trimethylbicyclo[4.1.0]hept-3-ene
14.59	1-methyl-4-propan-2-ylcyclohexa-1.3-diene
14.83	1-methyl-4-propan-2-ylbenzene
14.92	3-methylidene-6-propan-2-ylcyclohexene
15.14	1-methyl-4-prop-1-en-2-ylcyclohexene
15.33	1-methyl-4-propan-2-ylidenecyclohexene
15.47	(3E)-3.7-dimethylocta-1.3.6-triene
15.71	1-methyl-4-propan-2-ylcyclohexa-1.4-diene
15.78	2.2.5-trimethylhexane
16.17	2.4-dimethylundecane
16.96	Nonanal
17.17	(1R.4S)-1-methyl-4-propan-2-ylcyclohex-2-en-1-ol
17.65	4.7.7-trimethylbicyclo[3.1.1]hept-3-en-2-ol
17.92	7.7-dimethyl-4-methylidenebicyclo[3.1.1]heptan-3-ol
18.09	4-methyl-1-propan-2-ylcyclohex-3-en-1-ol
18.25	2-(4-methylcyclohex-3-en-1-yl)propan-2-ol
18.30	2-(2-butoxyethoxy)ethanol
18.85	1H-indole
19.06	5-prop-2-enyl-1.3-benzodioxole
19.34	Butyl butanoate
19.51	(1S.3aR.4S.8aS)-decahydro-4.8.8-trimethyl-9-methylene-1.4-methanoazulene
19.53	3-hydroxy-2.4.4-trimethylpentyl) 2-methylpropanoate
19.57	8-Isopropyl-1.3-dimethyl-tricyclo[4.4.0.0(2.7)]dec-3-ene
19.65	1.2-dimethoxy-4-prop-2-enylbenzene
19.78	(1R.4Z.9S)-4.11.11-trimethyl-8-methylidenebicyclo[7.2.0]undec-4-ene
19.78	2.4-ditert-butylphenol
20.12	4-methoxy-6-prop-2-enyl-1.3-benzodioxole
20.37	2.6-dimethoxy-4-prop-2-enylphenol
20.74	Tetradecanoic acid
20.96	Pentadecanoic acid
21.11(	3-decanoyloxy-2-hydroxypropyl) decanoate
21.16	(E)-hexadec-9-enoic acid
21.22	Hexadecanoic acid
21.25	Ethyl hexadecanoate
21.42	Heptadecanoic acid
21.56	(Z)-octadec-9-enoic acid
21.65	Heptadecene-8-carbonic acid
21.99	Octadecanoic acid
22.56	Octadecane
22.66	Nonadec-1-ene
22.75	Eicosane
22.93	Z-tricos-9-ene
24.37	(6E.10E.14E.18E)-2.6.10.15.19.23-hexamethyltetracosa-2.6.10.14.18.22-hexaene
27.52	(3S.8S.9S.10R.13R.14S.17R)-10.13-dimethyl-17-[(2R)-6-methylheptan-2-yl]-2.3.4.7.8.9.11.12.14.15.16.17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol



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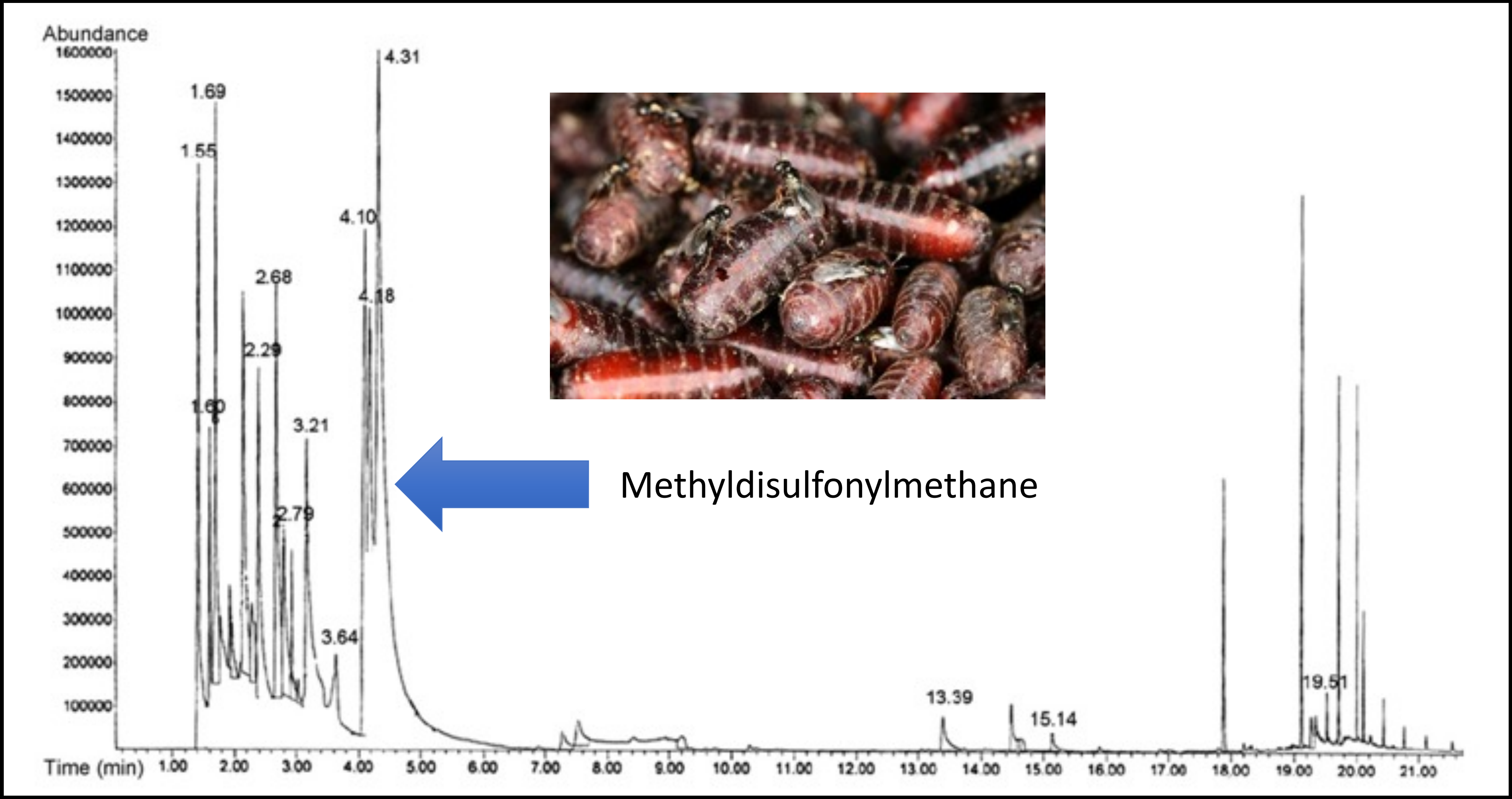
Associative Learning of *Nasonia vitripennis* Walker (Hymenoptera:Pteromalidae) to Methyldisulfanylmethane*



Hypothesis:

GCxGC-TOFMS allows the detection of more cadaveric VOCs than GC-MS

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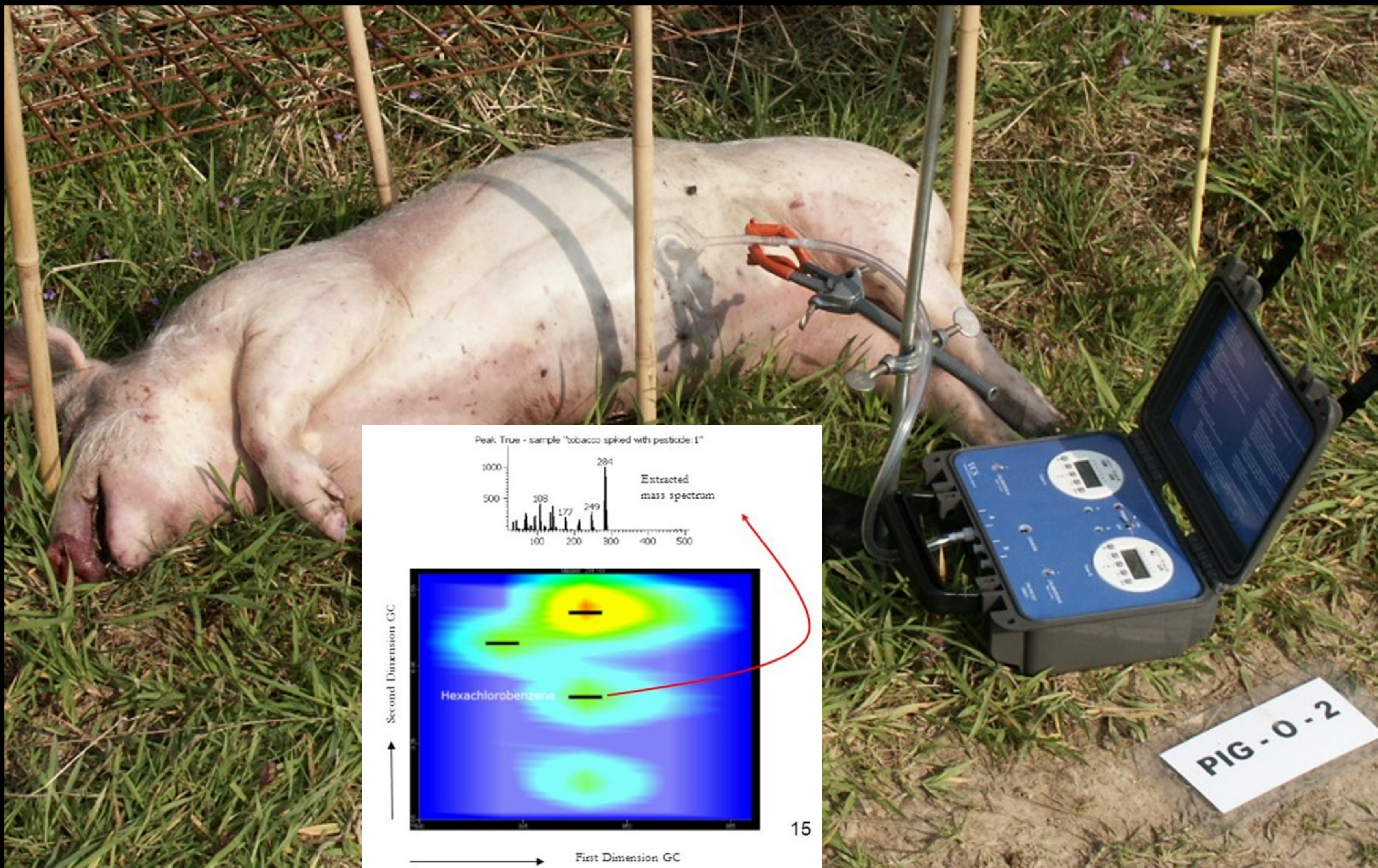
Enhanced Characterization of the Smell of Death by Comprehensive Two-Dimensional Gas Chromatography-Time-of-Flight Mass Spectrometry (GCxGC-TOFMS)

Jessica Dekeirsschieter[1], Pierre-Hugues Stefanuto[2], Catherine Brasseur[2], Eric Haubruge[1], Jean-François Focant[2*]



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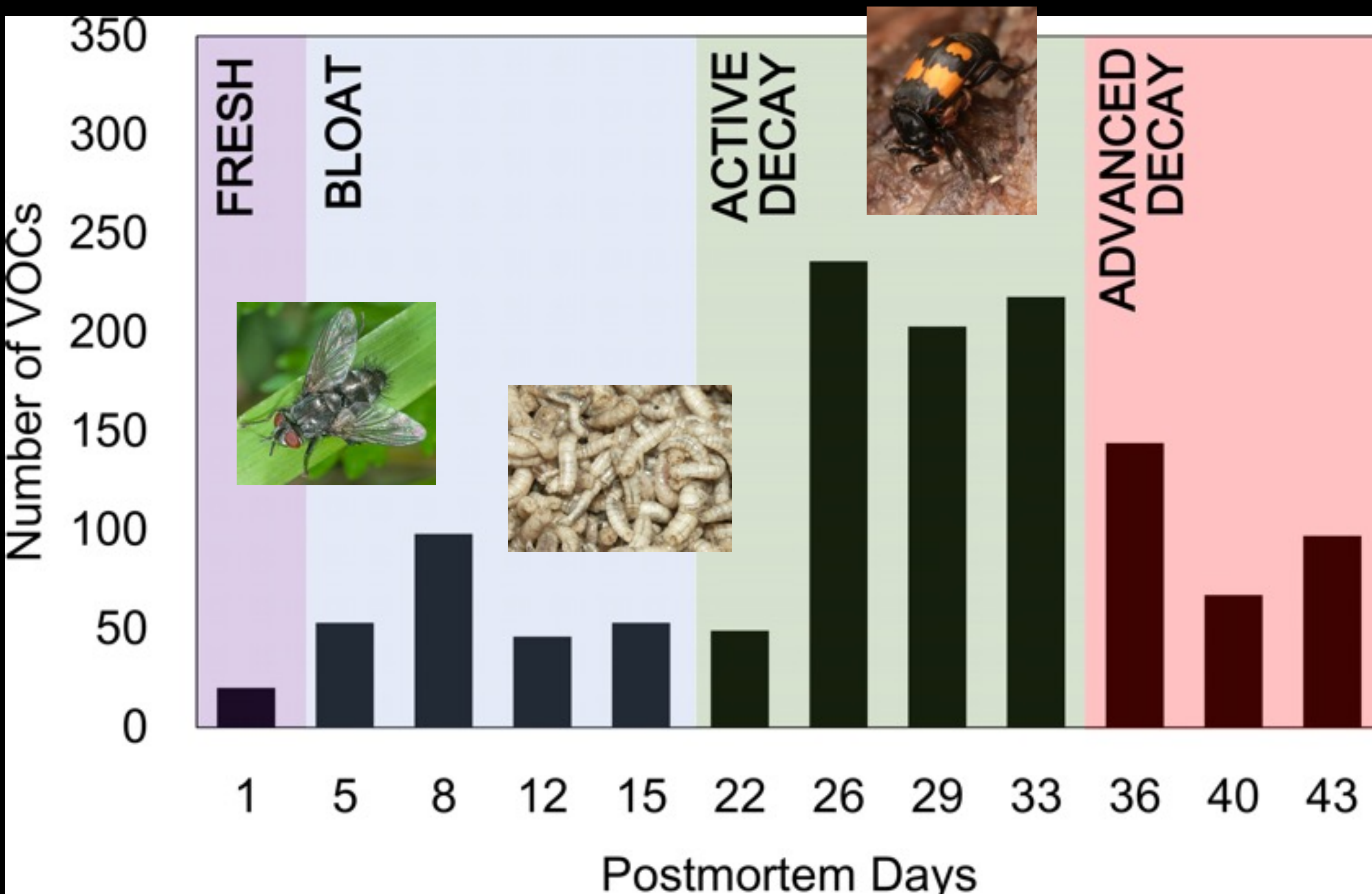


Hypothesis:

Soil composition affects decomposition and associated VOCs


Contents lists available at ScienceDirect

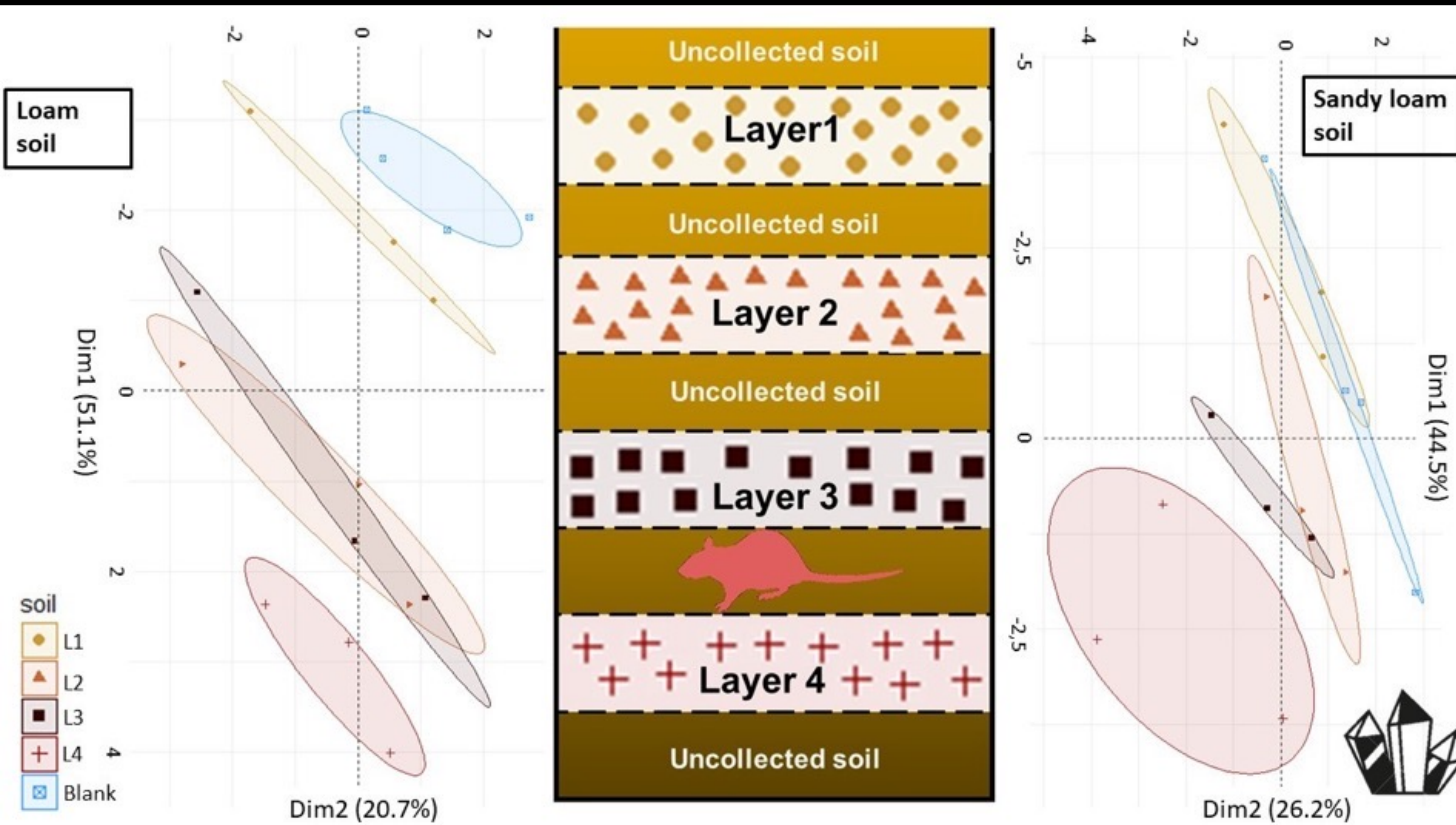
Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

ELSEVIER

Forensic taphonomy: Characterization of the gravesoil chemistry using a multivariate approach combining chemical and volatile analyses

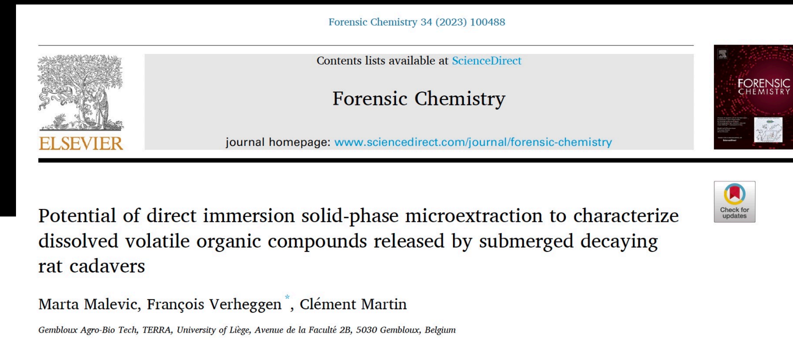
Clément Martin[a], Philippe Maesen[b], Damien Minchilli[a], Frédéric Francis[a], François Verheggen[a,*]



Loam soil
Sandy loam soil
Uncollected soil
Layer1
Uncollected soil
Layer 2
Uncollected soil
Layer 3
Layer 4
Uncollected soil
Dim1 (51.1%)
Dim2 (20.7%)
Dim1 (44.5%)
Dim2 (26.2%)
soil
L1
L2
L3
L4
Blank

Hypothesis:

Immersive SPME allows the collection of decaying VOCs from an immersed cadaver



Forensic Chemistry 34 (2023) 100488

Contents lists available at ScienceDirect

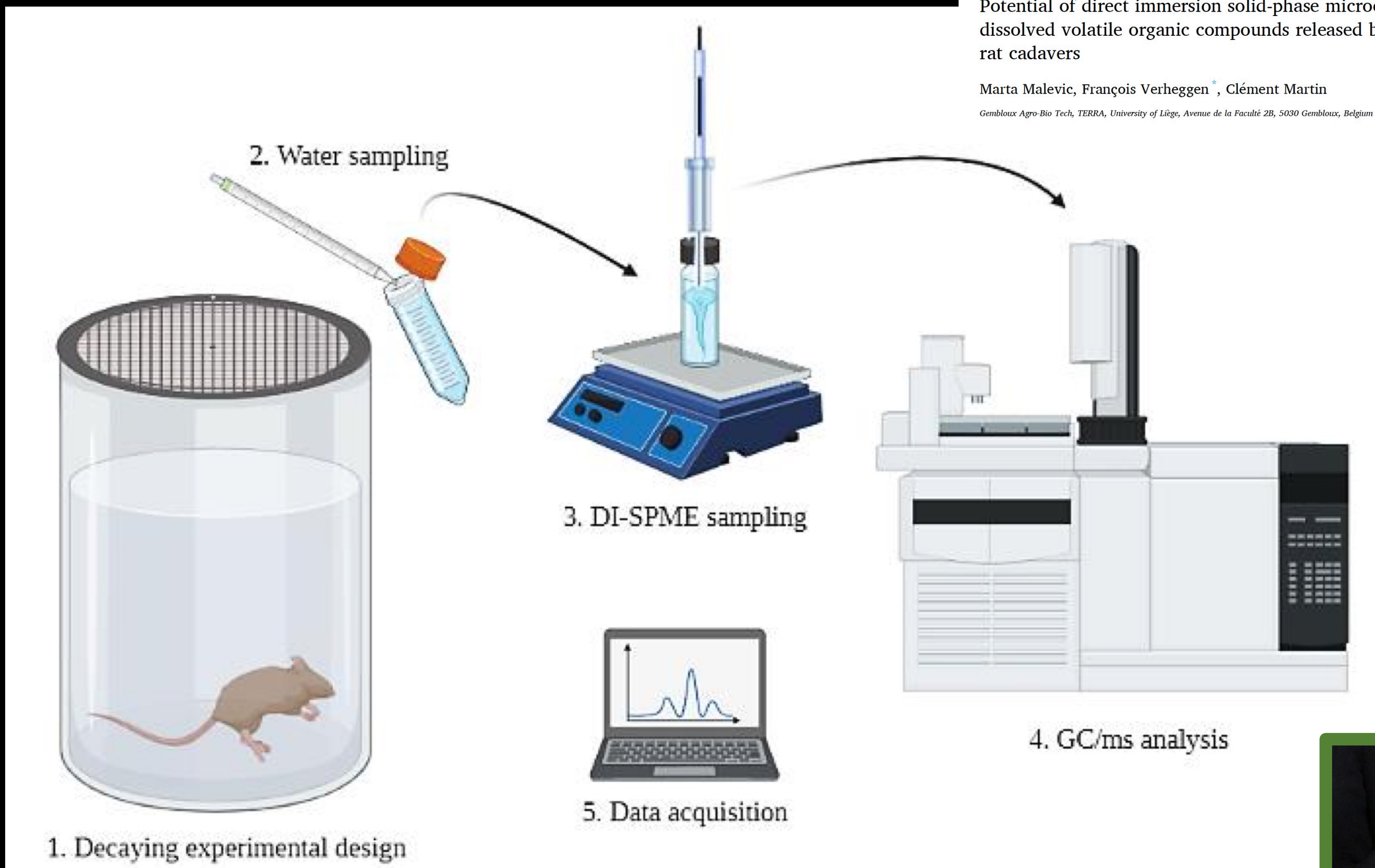
Forensic Chemistry

journal homepage: www.sciencedirect.com/journal/forensic-chemistry

Potential of direct immersion solid-phase microextraction to characterize dissolved volatile organic compounds released by submerged decaying rat cadavers

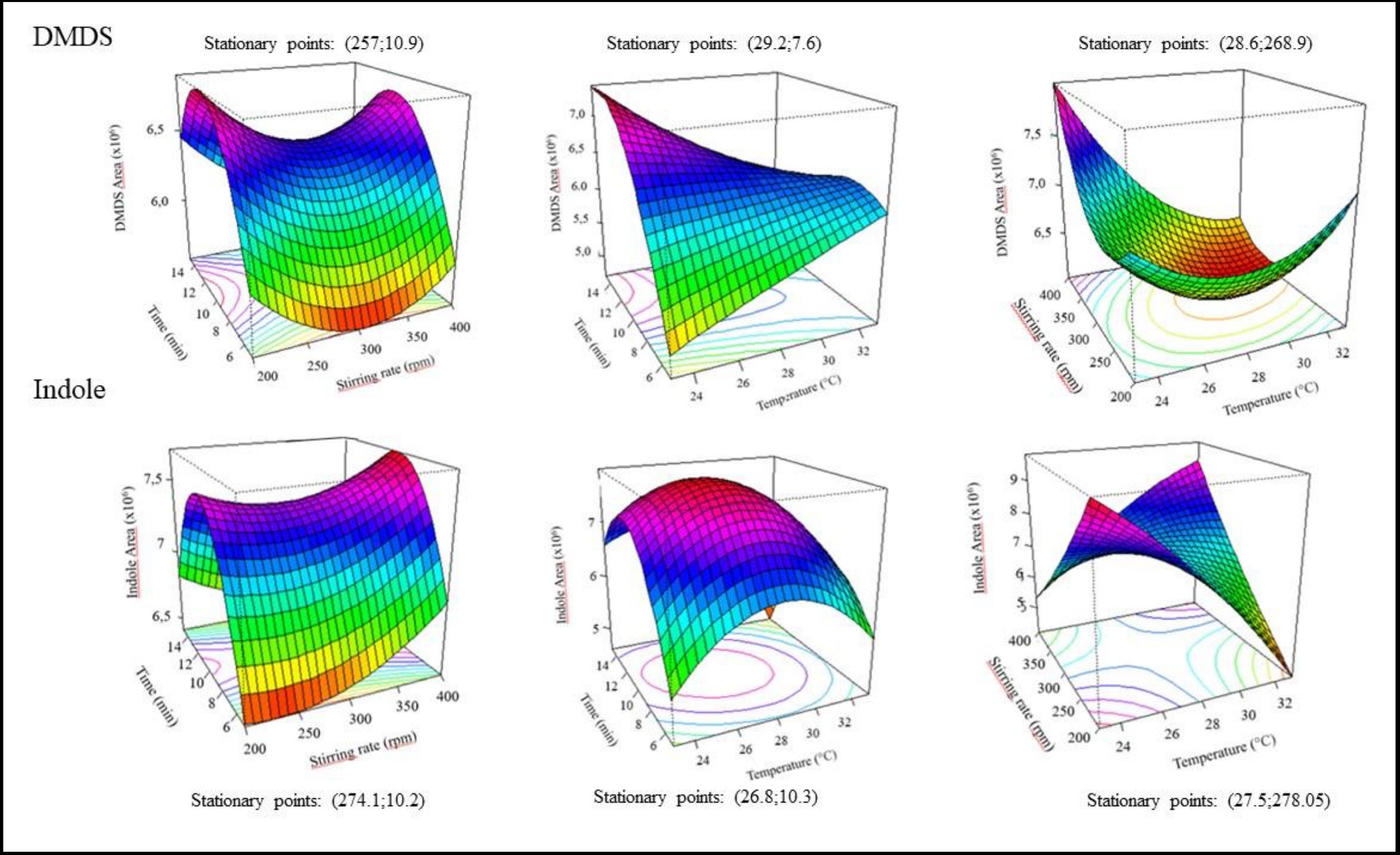
Marta Malevic, François Verheggen *, Clément Martin

Gembloux Agro-Bio Tech, TERRA, University of Liège, Avenue de la Faculté 2B, 5030 Gembloux, Belgium



Hypothesis:

Immersive SPME allows the collection of decaying VOCs from an immersed cadaver

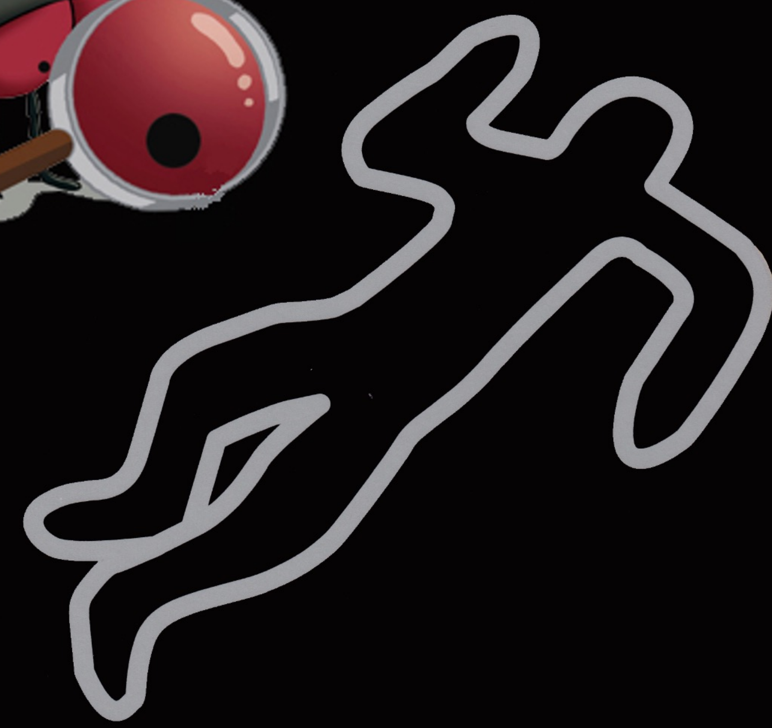


Hypothesis:

Immersive SPME allows the collection of decaying VOCs from an immersed cadaver

Aldehyde	Tetradecanal
Carboxilic acids	Lactic acid
	Dodecanoïc acid
	Formic acid
	Tetradecanoic acid *
	9-Hexanoic acid *
	9-Octadecenoic acid *
Halogene	Amonium chloride
Hydrocarbons	Pentane, 3-methyl-
	Hexane, 2-methyl-
	Phenol, 4-(1,1-dimethylpropyl)-
	Cyclopentane, methyl-
Ketones	5.9-undecadien-2-one, 6,10 dimethyl-
	Non-identified ketone
Nitrogen containing compounds	Indole
	3,6,6-trimethyl-1-O-tolyl-1,5,6,7-tetrahydro-indazol-4-one
Sulphur containing compounds	Dimethyl disulfide *
	Dimethyl trisulfide *

What about humans?



Hypotheses:

Fresh human cadavers release VOCs

We are not all equals in terms of cadaveric VOCs

Forensic Chemistry 35 (2023) 100516

Contents lists available at ScienceDirect

Forensic Chemistry

journal homepage: www.sciencedirect.com/journal/forensic-chemistry

All equal in the face of death! – Characterization of the volatile cadaveric compounds of fresh stage human corpses

Clément Martin, François Verheggen *

TERRA, Gembloux Agro-Bio Tech, University of Liège. Passage des Déportés 2, 5030 Gembloux, Belgium

Hypotheses:

Fresh human cadavers release VOCs

We are not all equals in terms of cadaveric VOCs

Conclusions:

Fresh human cadavers release VOCs

We are ~~not~~ all equals in terms of cadaveric VOCs

Forensic Chemistry 35 (2023) 100516

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List of identified cadaveric compounds from 20 human corpses experiencing the fresh decomposition

Chemical name	Occurrence (# corpses)	Mean
Sulfide		
dimethyl disulfide	18	99125.6
dimethyl trisulfide	4	547.4
Alkanes		
unidentified C7 alkane	8	79206.3
2.4-dimethylheptane	1	126.0
Ketones		
2-pentatone	3	9313.4
2-hexanone	1	129282.9
2-heptanone	18	1063418.6
Aldehydes		
hexanal	3	21488.0
heptanal	4	5187.6
octanal	2	385.9
nonanal	1	20637.1
benzaldehyde	1	4830.9
Alcohols		
2-methyl-1-propanol	7	14719.5
3-methyl-1-butanol	16	27113.4
benzyl alcohol	1	62003.5
Aromatics		
p-xylene	3	8058.1
phenol	2	95867.0
toluene	7	174245.4
limonene	12	27717.0
styrene	3	2321.8
Furans		
2-pentyl-furan	4	4526.3
Esters		
ethyl acetate	10	360281.2
butyl butyrate	9	7910.6

A close collaboration with the Belgian police forces

The Odor of Death: An Overview of Current Knowledge on Characterization and Applications FREE

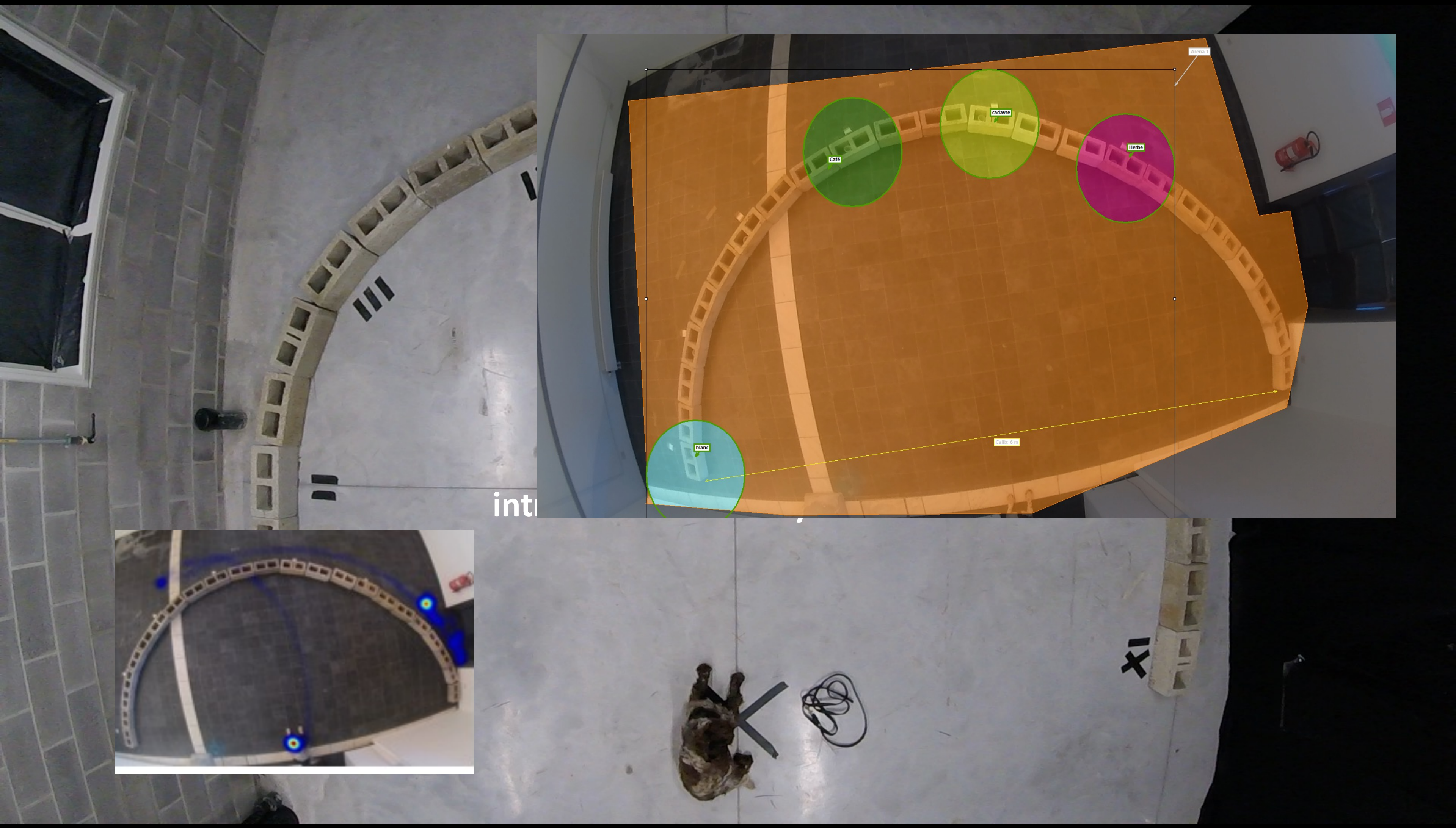
François Verheggen, Katelynn A. Perrault, Rudy Caparros Megido, Lena M. Dubois, Frédéric Francis, Eric Haubruge, Shari L. Forbes, Jean-François Focant, Pierre-Hugues Stefanuto

BioScience, Volume 67, Issue 7, July 2017, Pages 600–613,

frontiers | Frontiers in Analytical Science

What a good boy! Deciphering the efficiency of detection dogs

Clément Martin[1], Noémie Willem[2], Sorenza Desablens[2], Vincent Menard[2], Sophia Tajri[1], Solène Blanchard[1], Yves Brostaux[3], François Verheggen[1] and Claire Diederich[2]*



JOURNAL OF FORENSIC SCIENCES

ORIGINAL PAPER

General

Copycatting the smell of death: Deciphering the role of cadaveric scent components used by detection dogs to locate human remains

Clément Martin MSc[1] | Marta Malević MSc[1] | Claire Diederich PhD[2] | François Verheggen PhD[1]

=> *Dogs are able to recognize a synthetic blend of few cadaveric components*

=> *The absolute concentration of some chemicals are driving their response*

⇒ *What really counts for a dog is the presence of specific chemical families (sulfur, nitrogen, aromatic)*

⇒ *Distractive odors are not impactful*

Some take home messages. ‘The smell of death’ …

- is impacted by the biotope
- is made of hundreds of compounds
- is impacted by the decomposition stage
- is impacted by the presence of necrophagous insects
- is perceived and attractive for necrophagous insects
- can be collected from buried & submerged cadavers
- can even be collected from fresh human corpses
- is not affected by size, gender, weight in humans
- has applications in ‘cadaver’ dogs training

LA LIBERTÉ DE CHERCHER

The smell of death
Edvard Munch (1895)




ANNUAL REVIEWS

Forensic Entomology: From cadaver colonization to crime elucidation

Clément MARTIN, Zachary BURCHAM, Ian DADOUR, François VERHEGGEN

(In Press)

« L’horreur de ce laboratoire est une belle chose pour qui sait voir et méditer »

JH Fabre, 1900

* The horror of this laboratory is a beautiful thing for those who know how to see and meditate.