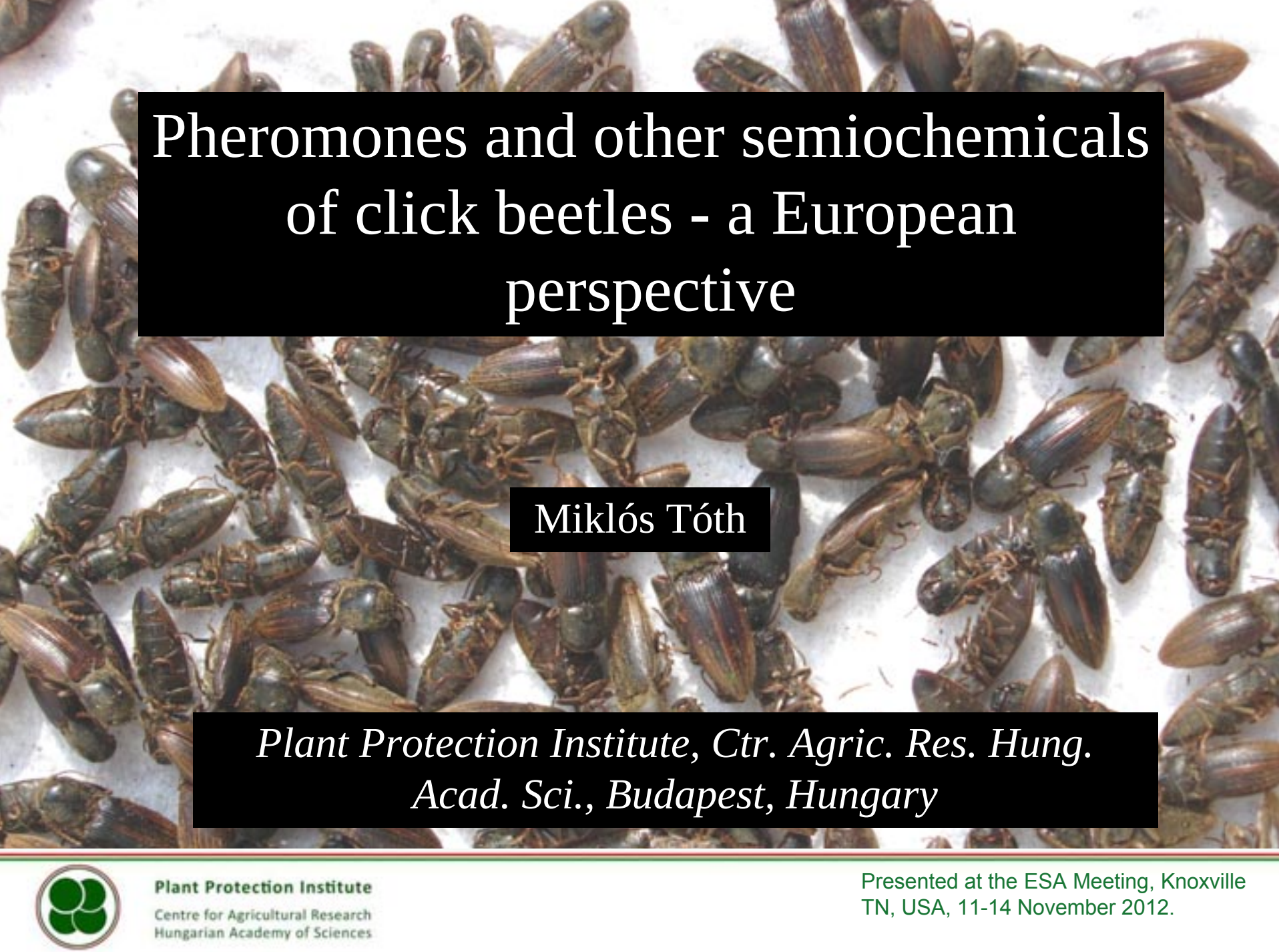




Pheromones and other semiochemicals of click beetles - a European perspective

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Wireworms, the larvae of click beetles (Coleoptera: Elateridae) are important soil-dwelling polyphagous pests all over the world.



www.naturamediterraneo.com



www.photoshelter.com

Traditional forecast and monitoring involves labour-intensive soil sampling methods,



Photo L. Furlan



and to obtain wireworms from soil samples collected is time-consuming (several days or more).

Photo L. Furlan

Pheromone-baited traps are much easier and simpler to use.

However, the pheromone composition should be identified first!



Photo M. Tóth

On the picture: the YATLOR FUNNEL (or YF) trap design specifically developed for pheromone trapping of click beetles (Furlan, Inform. Fitopat. 10:49, 2004)

Pheromone structures - first identifications

The very first chemical structures elucidated from click beetles (female-produced pheromone) came from North America and were organic acids



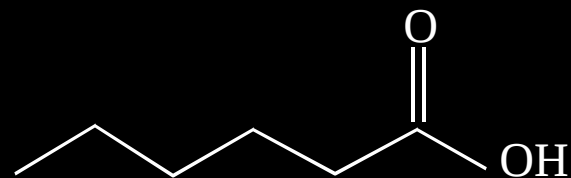
Limonius californicus
www.bugguide.net



valeric acid (pentanoic acid)

Limonius californicus

(Jacobson, Science 159:208, 1968)



caproic acid (hexanoic acid)

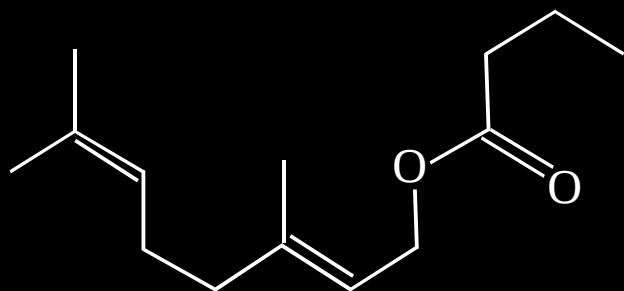
Limonius canus

(Butler, Environ. Entomol. 4:229, 1975)

Pheromone structures - first identifications

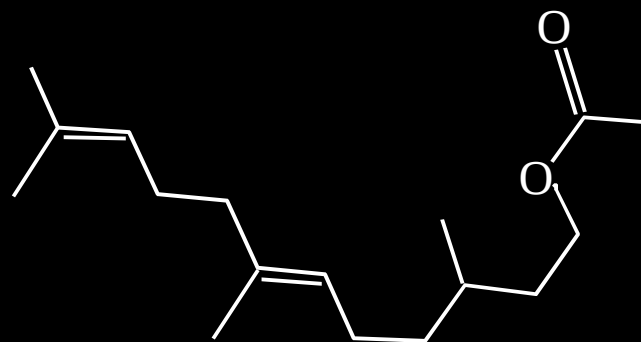
In Europe, starting from the eighties, a number of geranyl and farnesyl esters were identified mainly by scientists from the Soviet Union.

Example structures:



geranyl butyrate
[(*E*)-3,7)-dimethyl-2,6-
octadienyl butyrate]

i.e. *A. sputator*



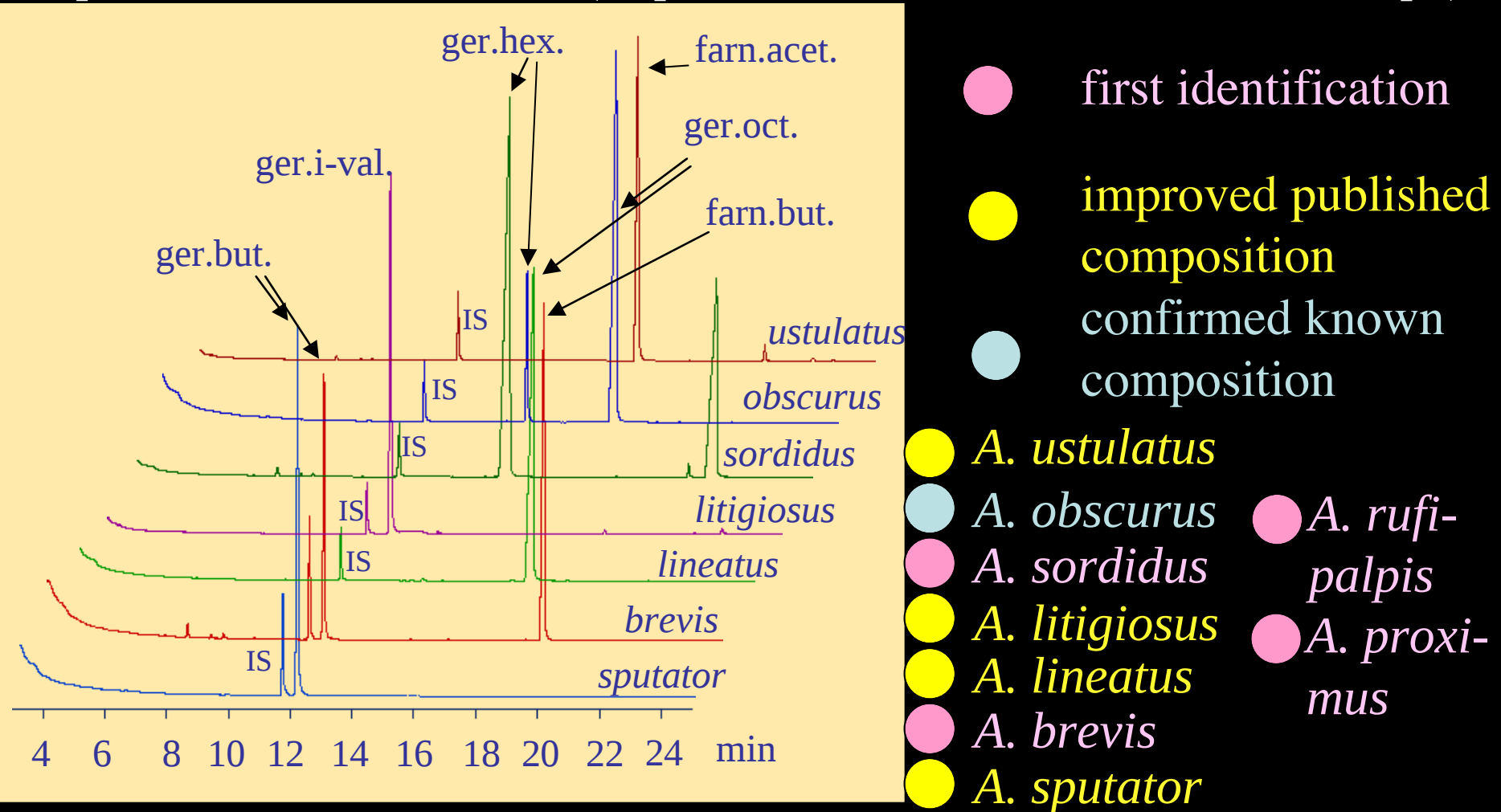
(*E,E*)-farnesyl acetate
[(*E*)-3,7,11)-trimethyl-2,6,10-
dodecatrienyl acetate]

i.e. *A. ustulatus*

First report on similar structures from: Oleschenko, 1979 (cited in Kamm, Coleopt. Bull. 37:16, 1983)

Pheromone structures - my lab's contribution

In the 1990-s we identified new and revisited known (but inactive) pheromones of elaterids (important in Central and Western Europe)



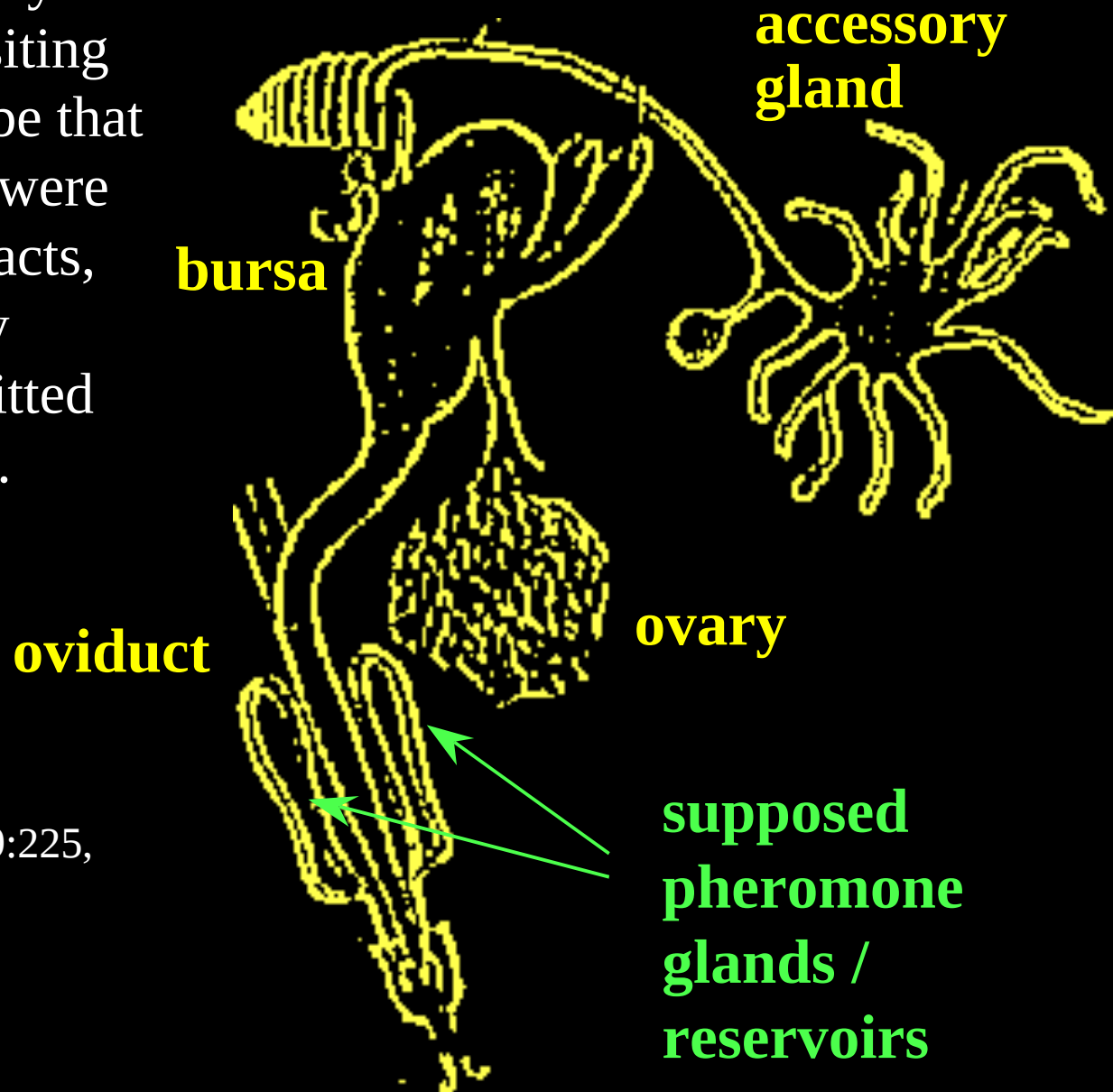
GC analysis of pheromone gland extracts of *Agriotes* spp.

(after Tóth, J. Chem. Ecol. 28:1641, 2002, and Pest Manag. Sci. 59:417, 2003)

Pheromone structures - my lab's contribution

One reason for the relatively frequent necessity of revisiting published structures may be that most early identifications were based on direct gland extracts, which may not necessarily represent composition emitted into the air by the females.

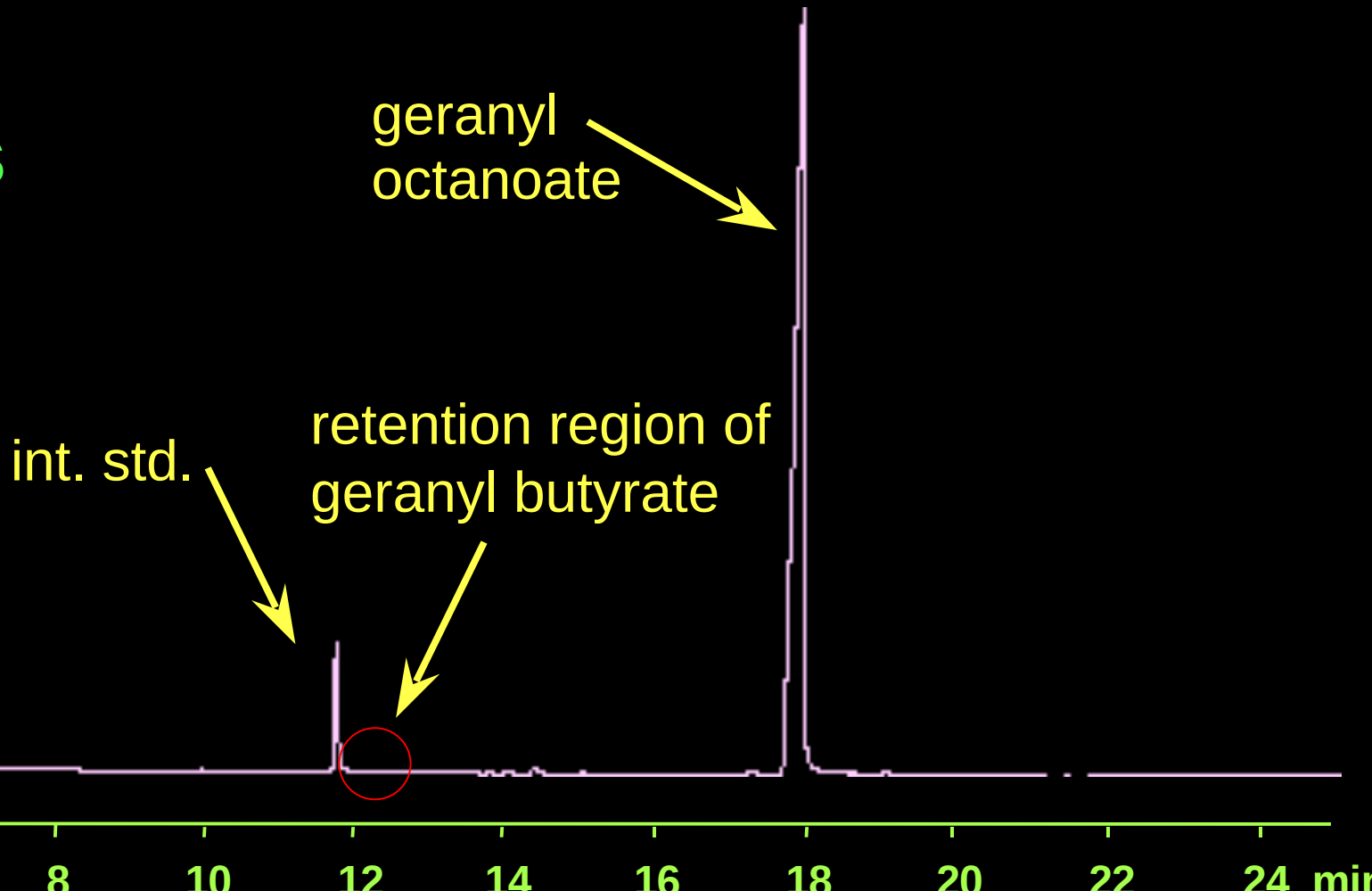
(After Ivaschenko, Zool. Zh. 59:225, 1980).



Gland extract vs. volatile collection (example No. 1)

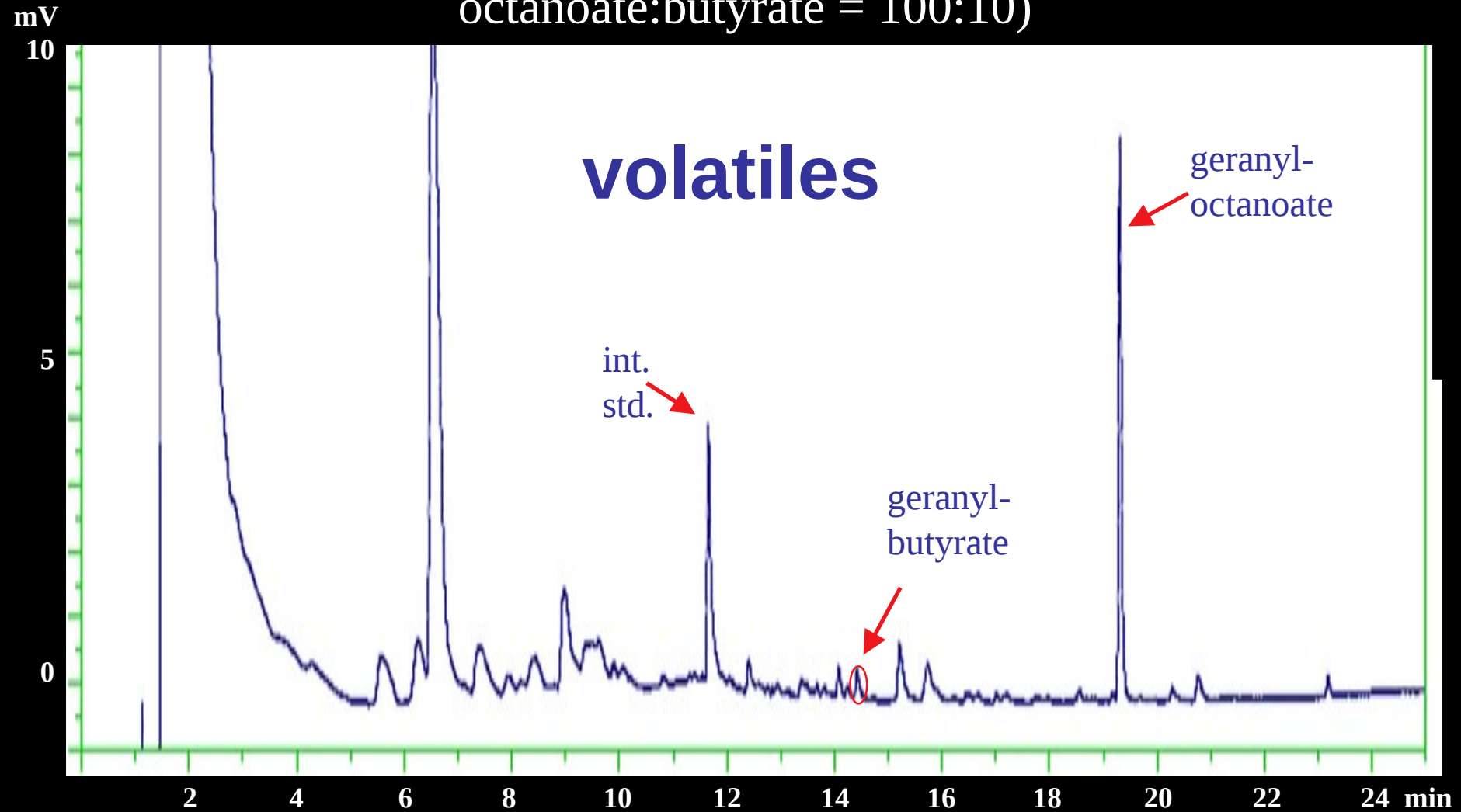
Gland extracts of *A. lineatus* were dominated by a single very large peak of geranyl octanoate, geranyl butyrate was hardly detectable (ratio of octanoate:butyrate = 100:<0.01)

glands



Gland extract vs. volatile collection (example No. 1)

In volatile collections the butyrate was well visible (ratio of octanoate:butyrate = 100:10)



(After Vuts, Chemoecol. 22:23, 2012)

Gland extract vs. volatile collection (example No. 1)

In the field the presence of the butyrate was absolutely necessary for attraction.

Total caught
in test:
279
beetles

Rümlang,
May 23 -
August 14,
1997



Geranyl octanoate	Geranyl butanoate	E,E-farnesyl acetate	Geraniol	Geranyl hexanoate	Neryl isovalerate	<i>A.lineatus</i>
10	.	.	.	.	.	0
30	.	.	.	.	.	2
100	.	.	.	.	.	0
10	1	.	.	.	.	273
10	.	1	.	.	.	2
10	.	.	1	.	.	1
10	.	.	.	1	1	0
10	.	.	.	.	.	1

(After Tóth, Pest Manag. Sci. 59:417, 2003)

Gland extract vs. volatile collection (example No. 1)

It appears that volatile collections reflect better the true pheromone composition of a given species than gland extracts do.

Total caught
in test:
279
beetles

Rümlang,
May 23 -
August 14,
1997



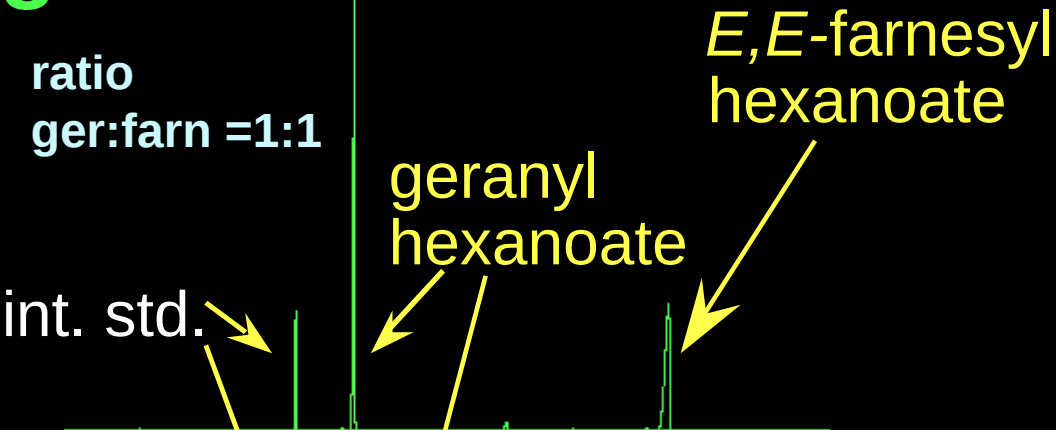
Geranyl octanoate	Geranyl butanoate	E,E-farnesyl acetate	Geraniol	Geranyl hexanoate	Neryl isovalerate	<i>A. lineatus</i>
10	.	.	.	.	.	0
30	.	.	.	.	.	2
100	.	.	.	.	.	0
10	1	.	.	.	.	273
10	.	1	.	.	.	2
10	.	.	1	.	.	1
10	.	.	.	1	1	0
10	.	.	.	.	.	1

(After Tóth, Pest Manag. Sci. 59:417, 2003)

Gland extract vs. volatile collection (example No. 2)

In *A. sordidus*, in gland extracts large amounts of (*E,E*)-farnesyl hexanoate were present, with only traces in volatile collections.

glands



volatiles

ratio
ger:farn =1:<0.1

?

This chromatogram shows the composition of volatile collections. The x-axis represents time in minutes, ranging from 15 to 50. The y-axis represents intensity. A large peak is visible at approximately 26 minutes, labeled 'geranyl hexanoate'. A very small peak is visible at approximately 49 minutes, labeled '*E,E*-farnesyl hexanoate'. The ratio of geranyl to farnesyl is noted as 1:<0.1. A question mark is placed near the baseline at approximately 50 minutes.



A. sordidus

Photo J. Vuts

Gland extract vs. volatile collection (example No. 2)

In field tests on *A. sordidus*, no influence of the addition of the farnesyl compound could be observed.

glands

ratio
ger:farn =1:1

int. std.

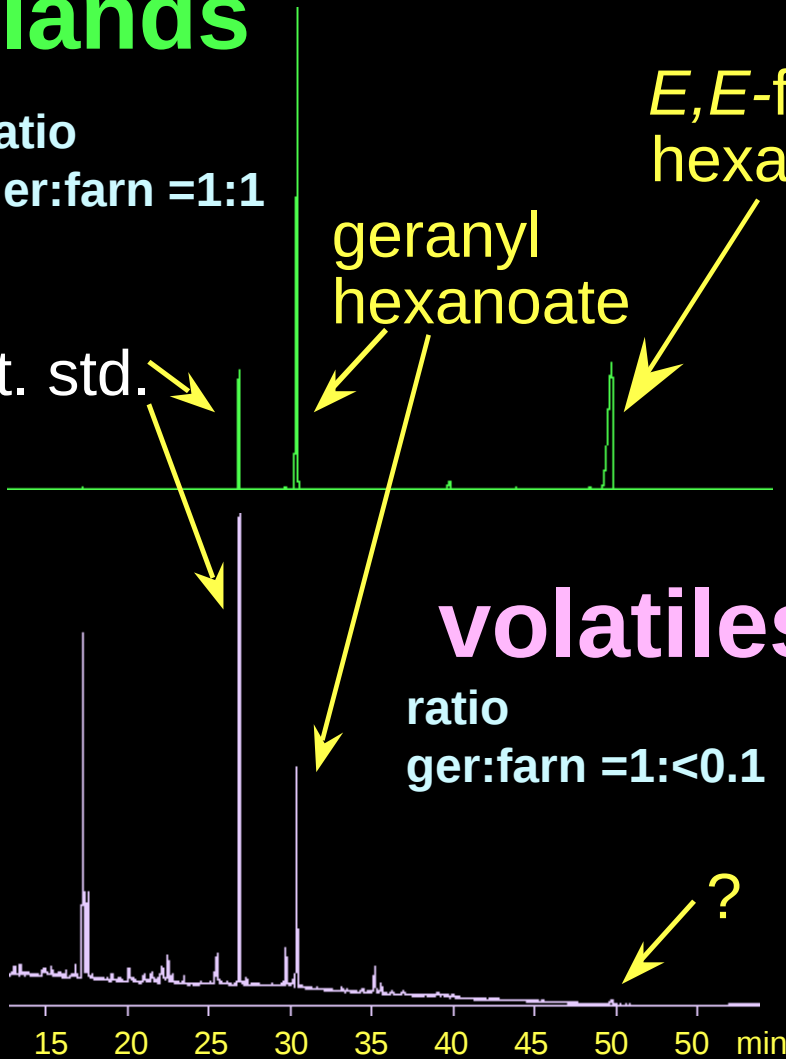
E,E-farnesyl
hexanoate

geranyl
hexanoate

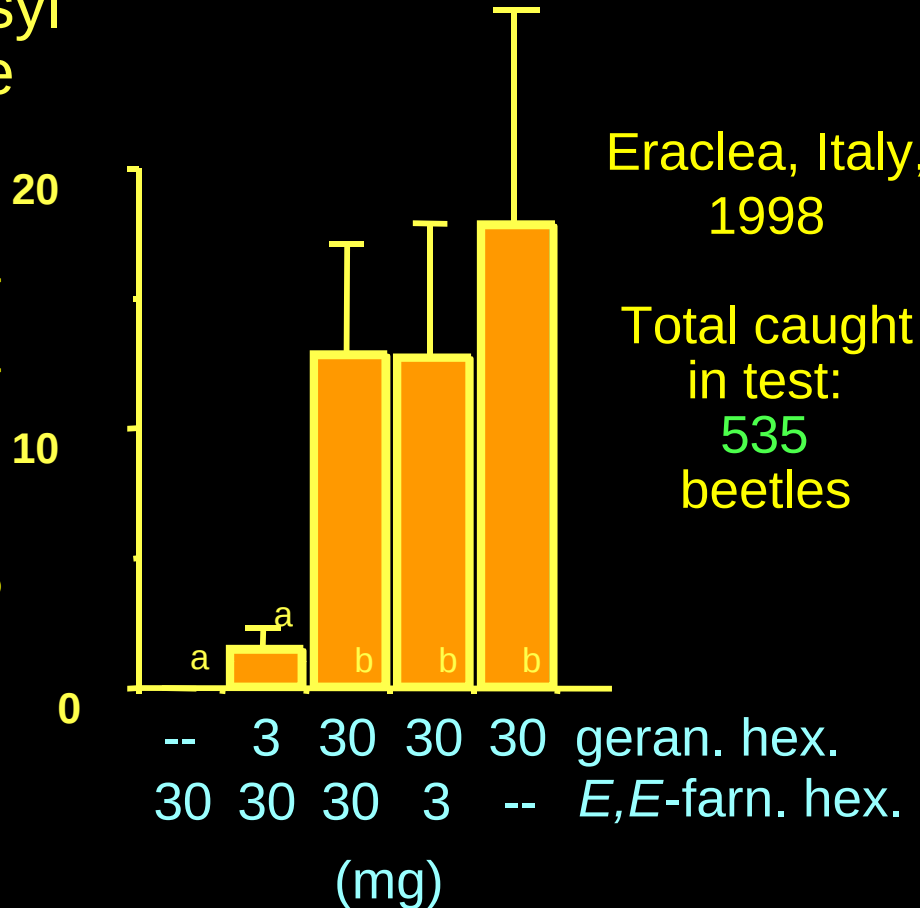
volatiles

ratio
ger:farn =1:<0.1

?



average catch/trap/inspection



Eraclea, Italy,
1998

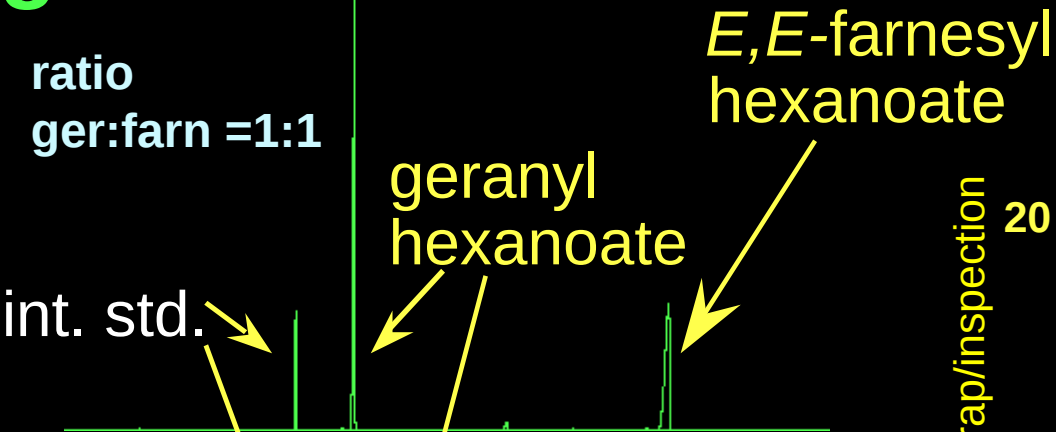
Total caught
in test:
535
beetles

(after Tóth M, et al., unpublished)

Gland extract vs. volatile collection (example No. 2)

Consequently, by definition, only geranyl hexanoate can be termed a pheromone component in this species.

glands

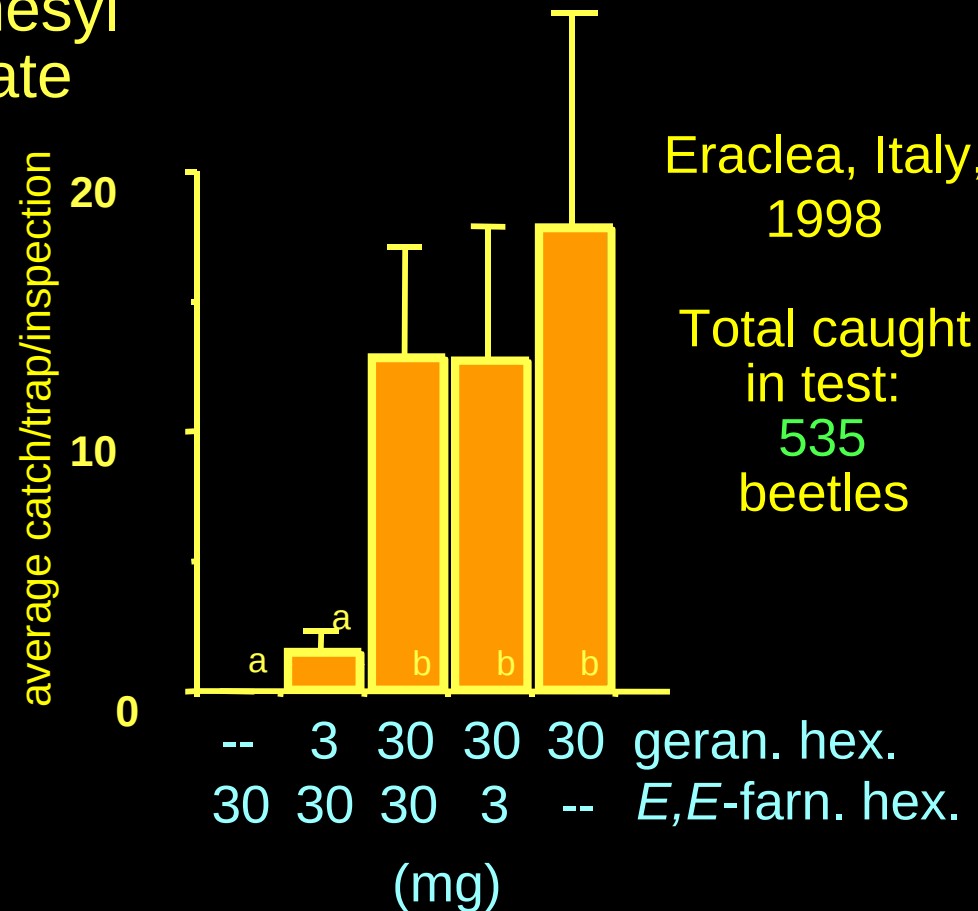


volatiles

ratio
ger:farn =1:<0.1

?

This chromatogram shows the composition of volatile collection. The x-axis represents time in minutes, ranging from 15 to 50. The y-axis represents intensity. A dominant peak for geranyl hexanoate is visible at approximately 27 minutes. The ratio of geranyl to farnesyl is 1:<0.1. A small peak at approximately 50 minutes is marked with a question mark.

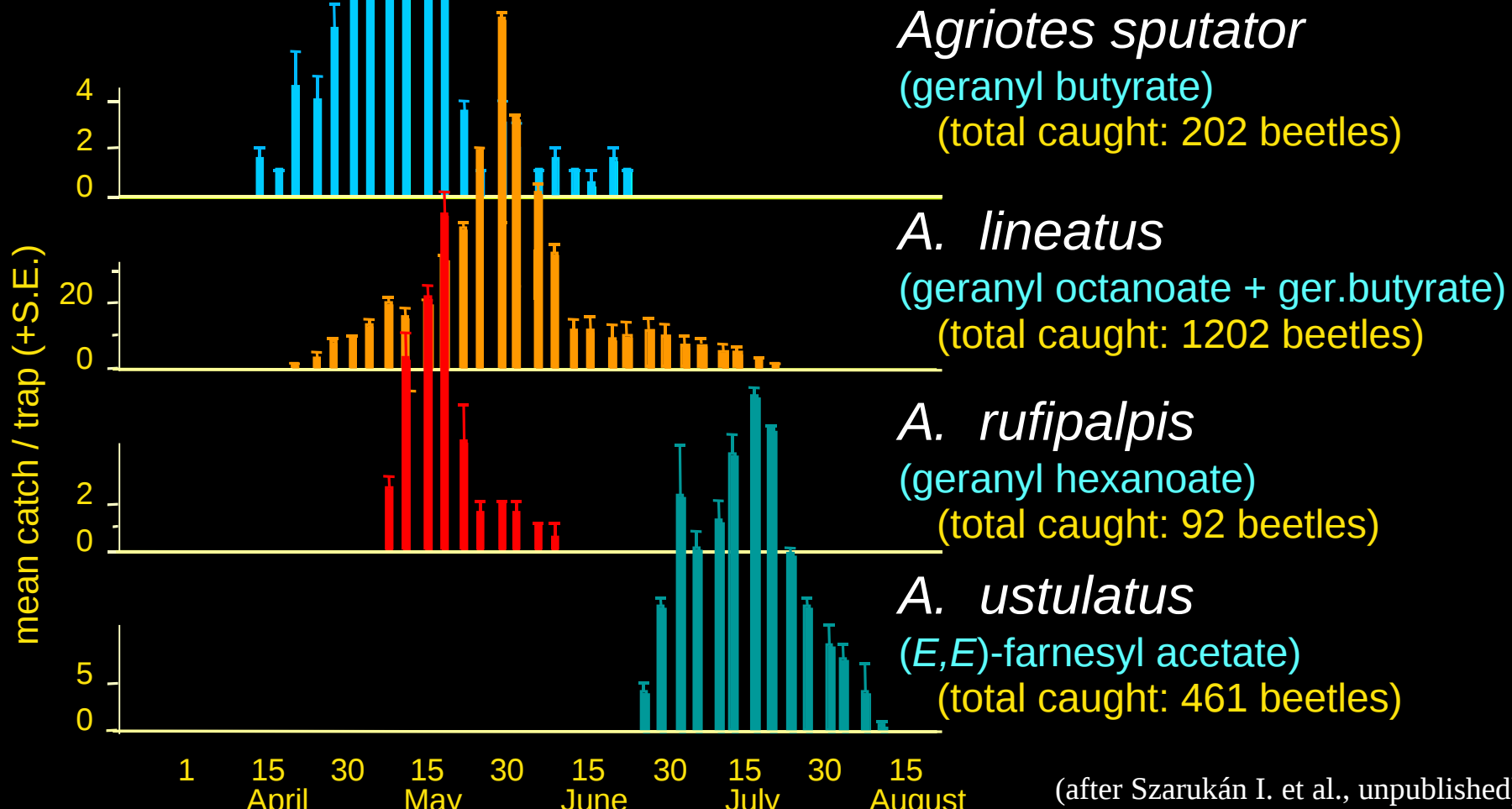


(after Tóth M, et al., unpublished)

Pheromone traps in use in Europe

As a result of our studies pheromone traps are available for 9 *Agriotes* spp., (including all of the most important click beetle pests) in Europe.

Debrecen, Hungary, 1999



Pheromone traps in use in Europe

One application of the traps in recent years was to determine the occurrence and abundance of the click beetle spp. in Europe.

A. sordidus / *rufipalpis* bait

Geranyl hexanoate

1998 - 2006

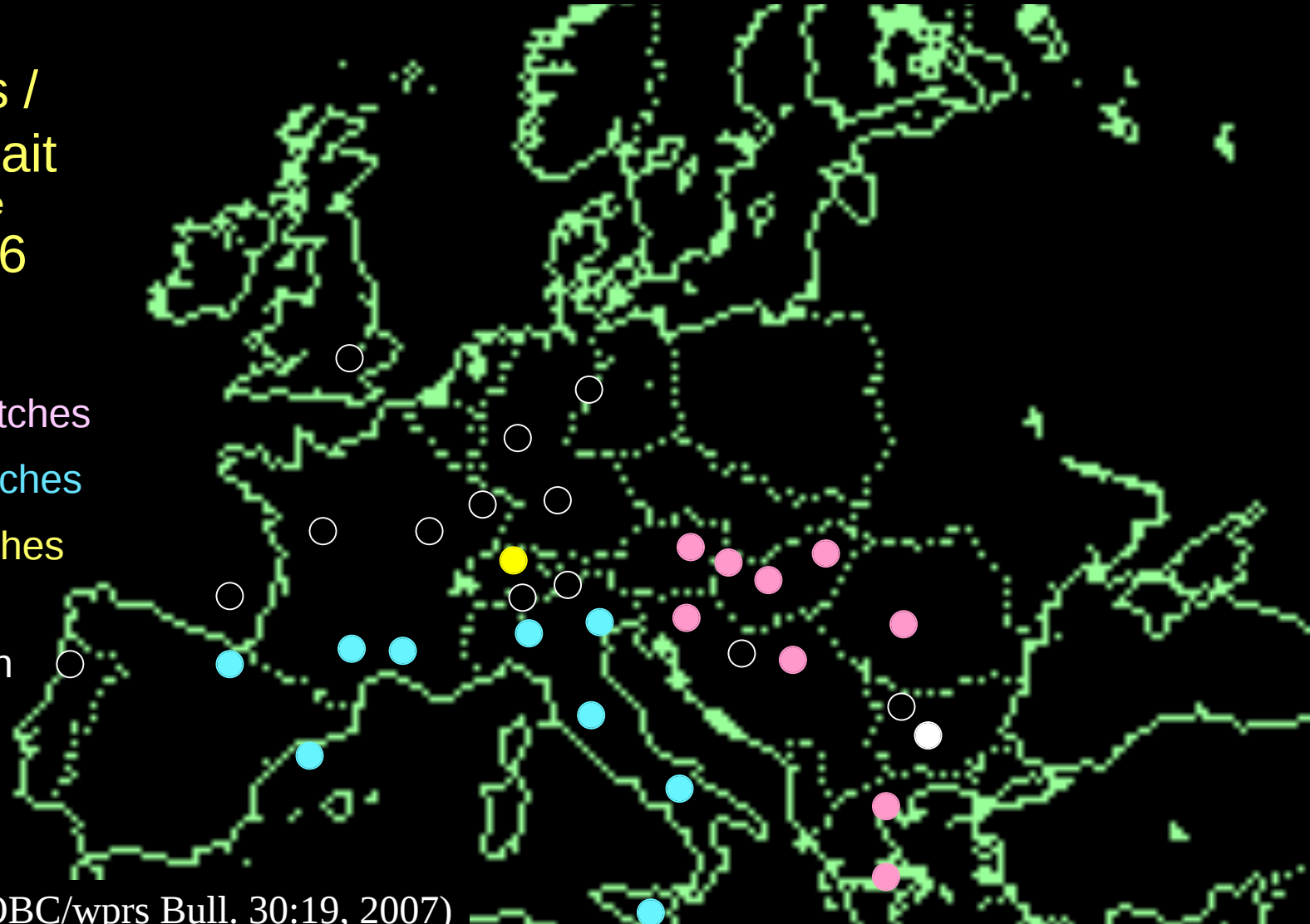
● *rufipalpis* catches

● *sordidus* catches

● *gallicus* catches

● *Cidnopus*
pilosus catch

○ no catch



(after Furlan, IOBC/wprs Bull. 30:19, 2007)

Pheromone traps in use in Europe

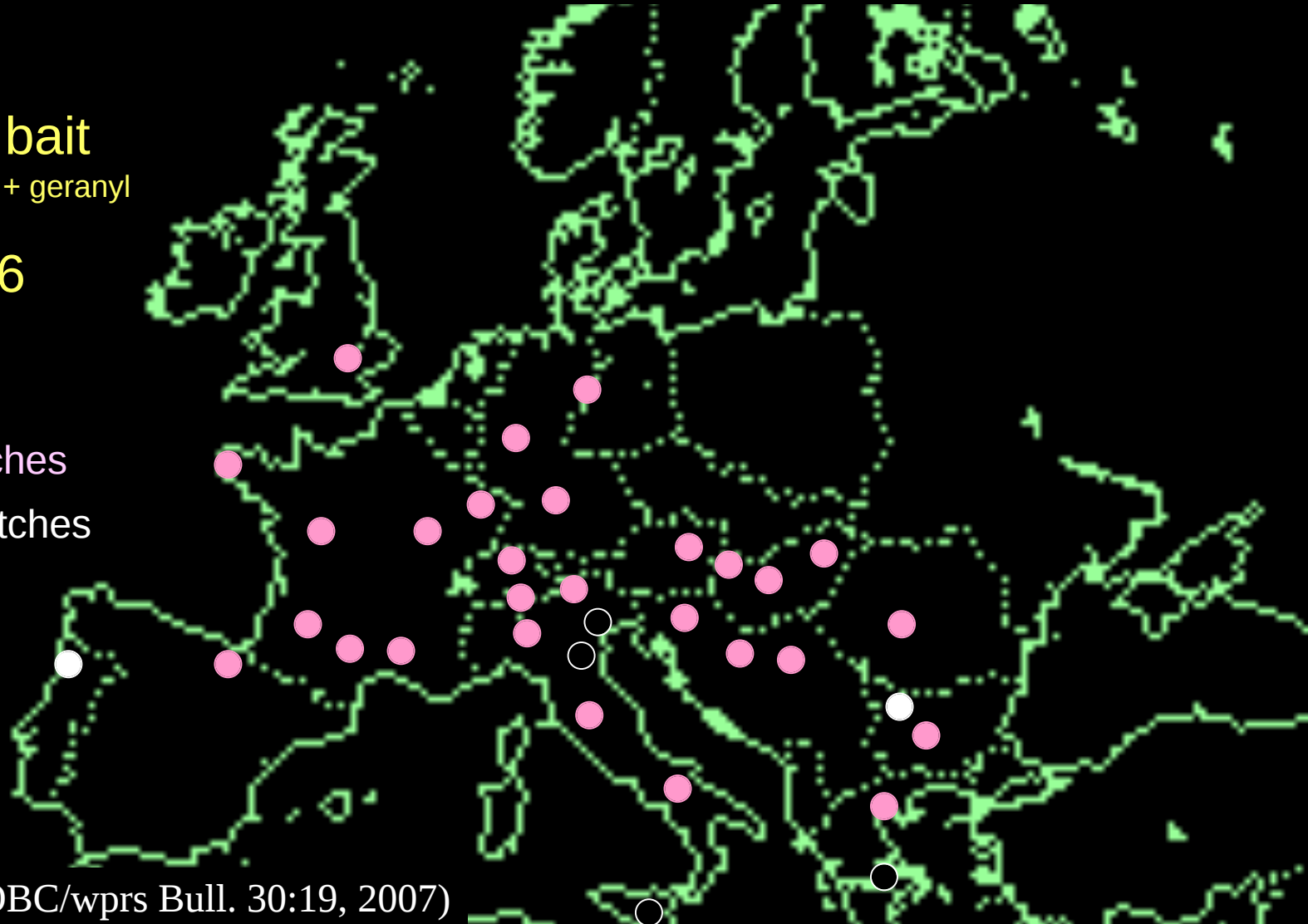
One application of the traps in recent years was to determine the occurrence and abundance of the click beetle spp. in Europe.

A. lineatus bait

Geranyl octanoate + geranyl butyrate

1998 - 2006

- lineatus catches
- proximus catches
- no catch



(after Furlan, IOBC/wprs Bull. 30:19, 2007)

Females responding to the pheromone

Click beetle pheromone traps capture large numbers of males. In some species, however, users reported on the presence of females in the catch!

The phenomenon most frequently was reported
in:

A. sordidus and *A. brevis* –
Lorenzo Furlan, Italy

A. ustulatus – István Szarukán,
Hungary



Females responding to the pheromone

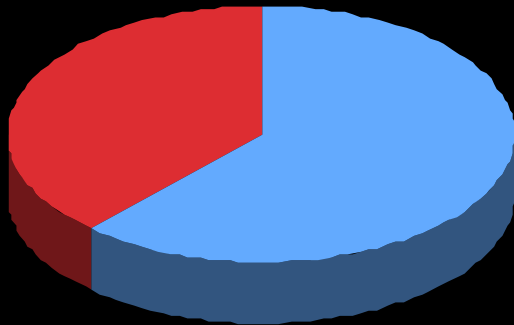
On closer scrutiny, beetle catches in pheromone baited traps indeed contained a sizeable proportion of female beetles in these species!

A. brevis

pheromone components:
(*E,E*)-farnesyl butyrate +
geranyl butyrate

Veneto, Italy, 2001

Total caught: 1173 beetles

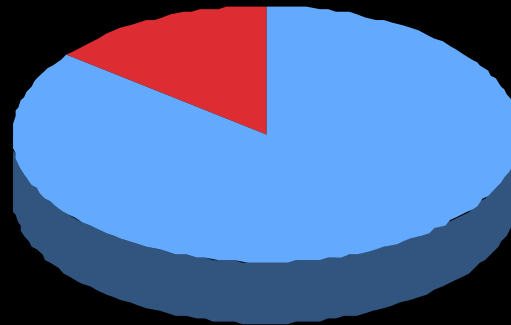


A. sordidus

pheromone component:
geranyl hexanoate

Berton-Greggio, Italy, 2001

Total caught: 367 beetles

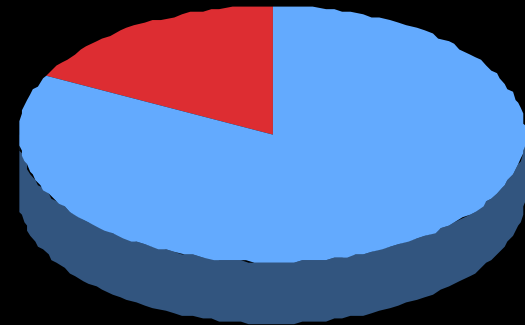


A. ustulatus

pheromone component:
(*E,E*)-farnesyl acetate

Eraclea, Italy, 2000

Total caught: 114 beetles



Females responding to the pheromone

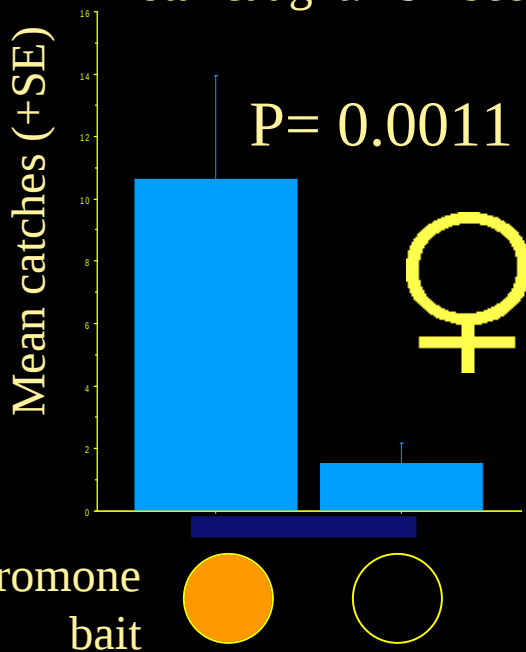
Female catches in pheromone baited traps were significantly higher than in unbaited traps.

A. brevis

pheromone components:
(*E,E*)-farnesyl butyrate +
geranyl butyrate

Eraclea, Italy, 2000

Total caught: 194 beetles

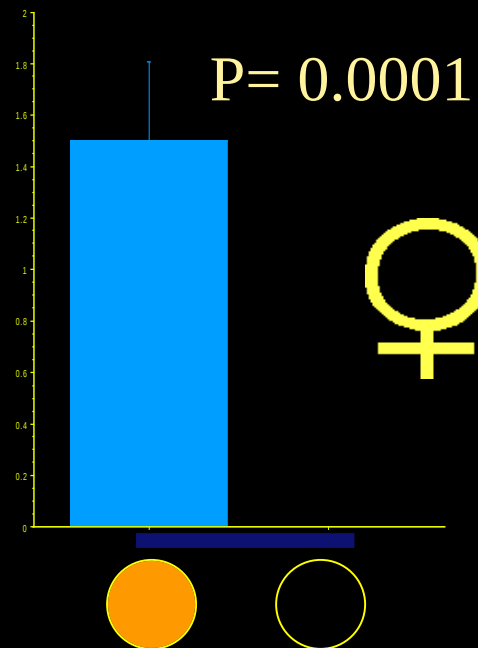


A. sordidus

pheromone component:
geranyl hexanoate

Berton-Greggio, Italy, 2001

Total caught: 42 beetles

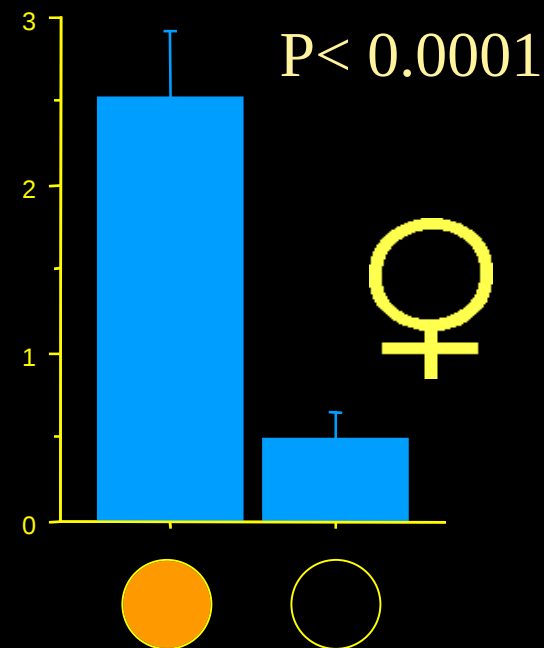


A. ustulatus

pheromone component:
(*E,E*)-farnesyl acetate

Debrecen, Hungary, 2003

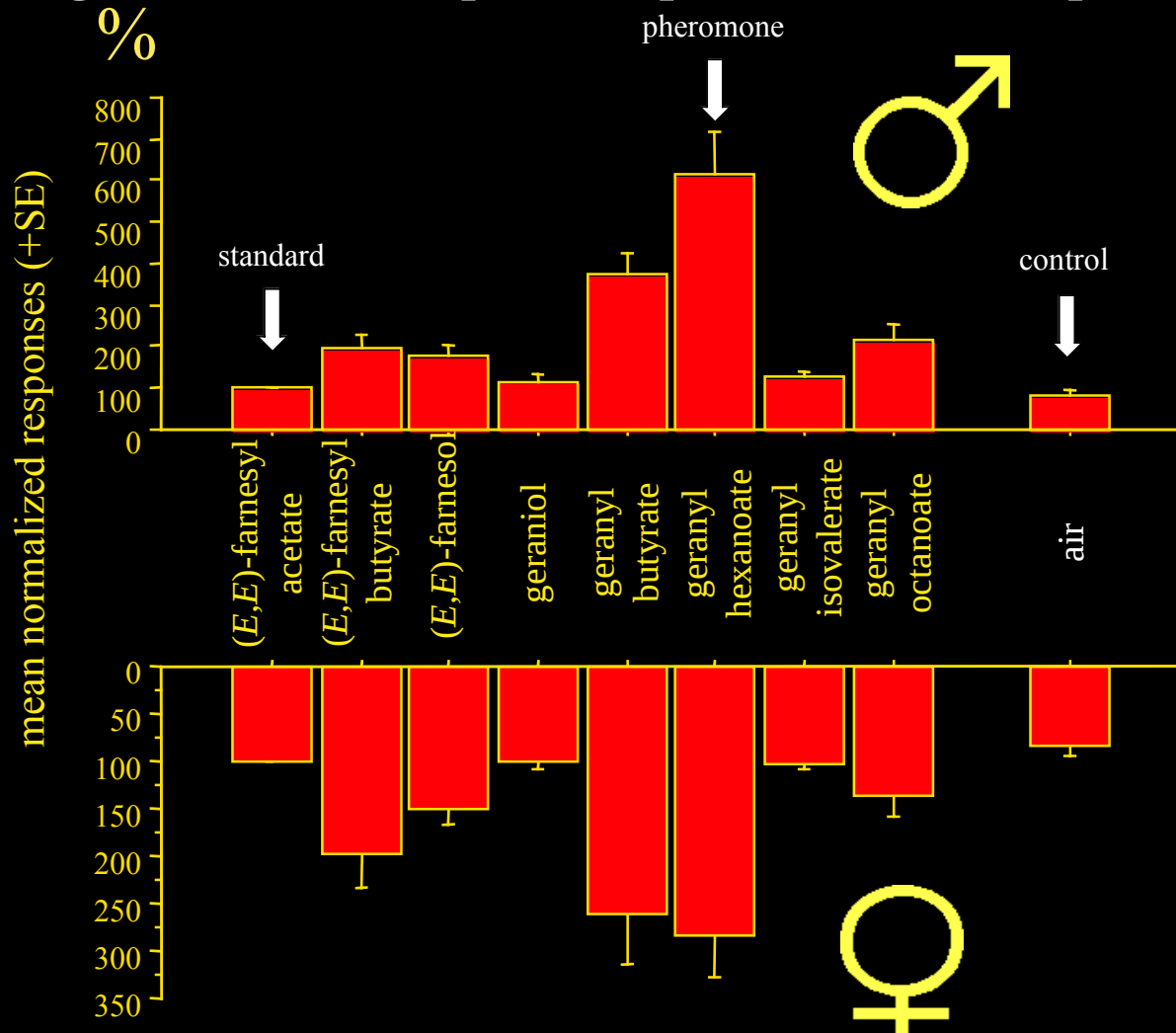
Total caught: 116 beetles



Females responding to the pheromone

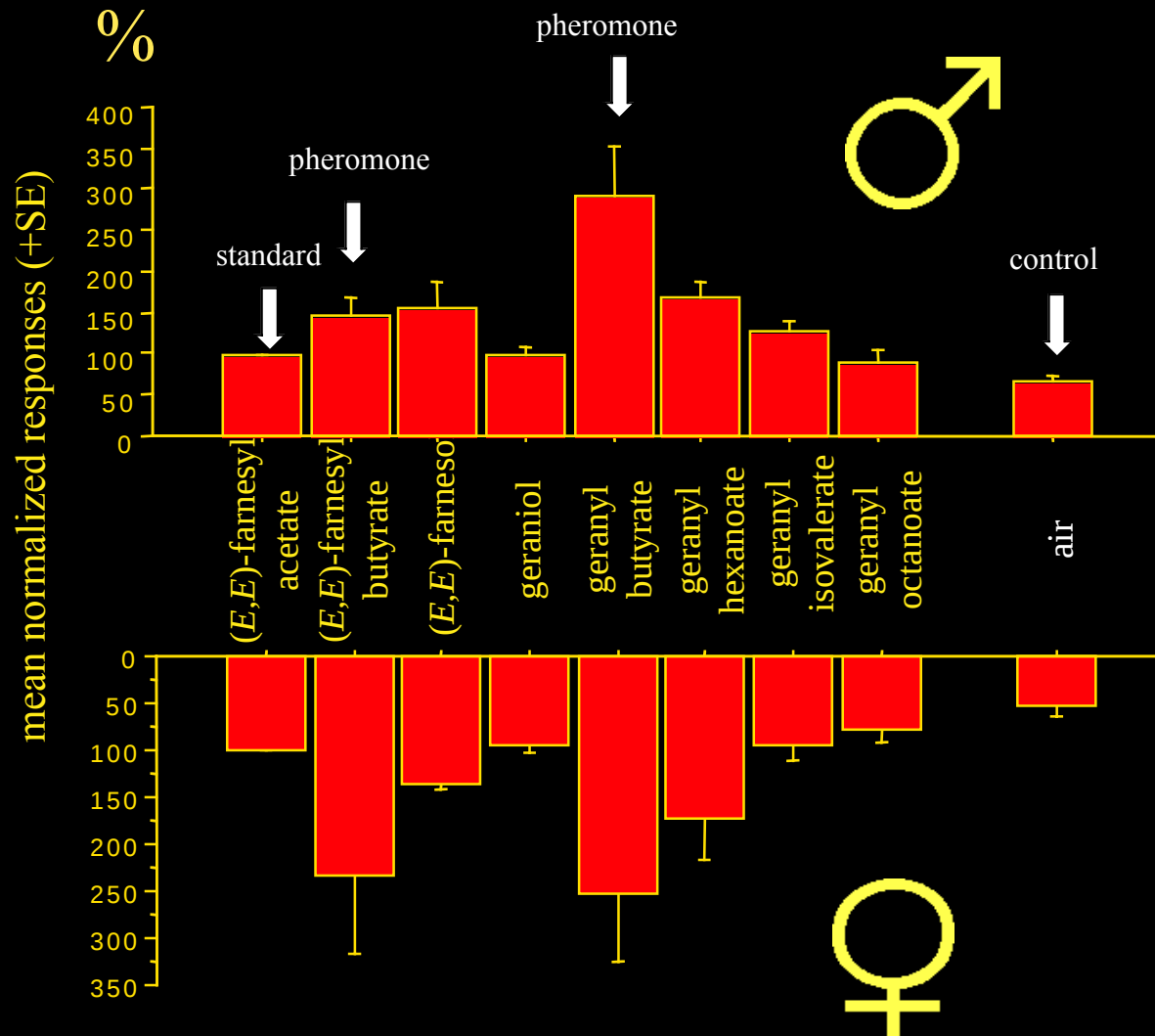
In EAG screenings of synthetic pheromone compounds of click beetles, female antennae showed similar response spectra as male antennae, responding best to the respective pheromone component.

Agriotes sordidus



Females responding to the pheromone

This suggested that females were capable of detecting their respective pheromone components.

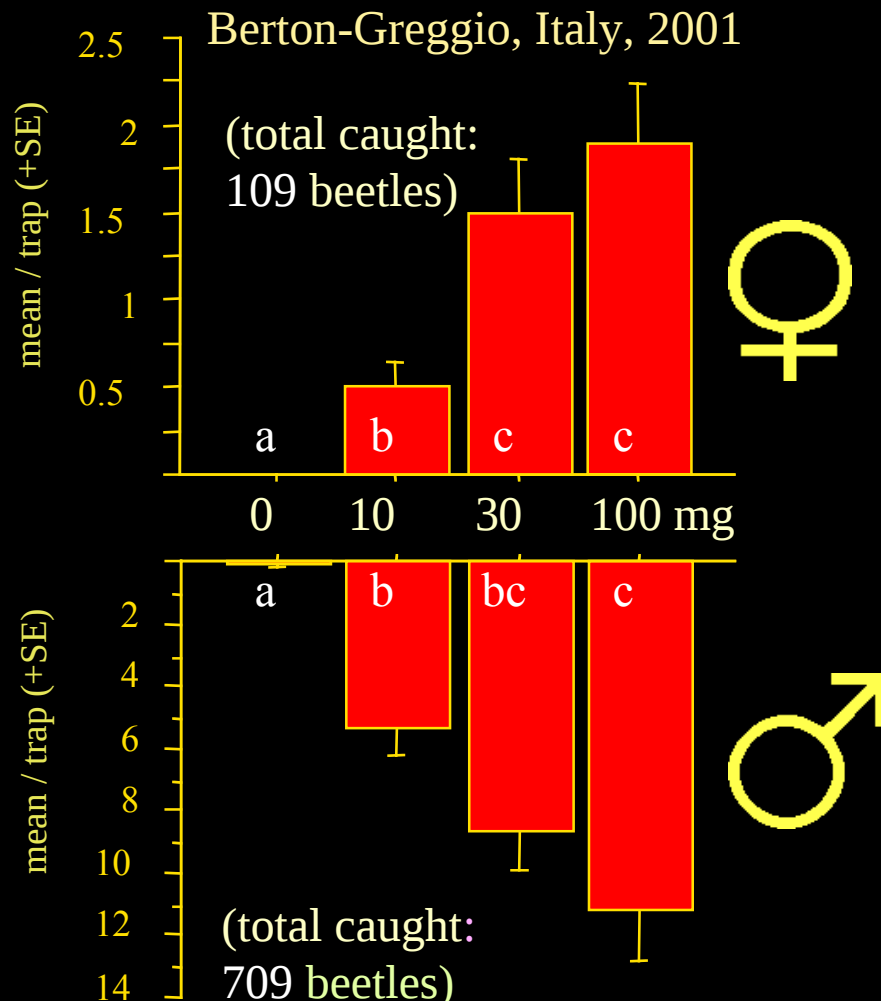


*Agriotes
brevis*

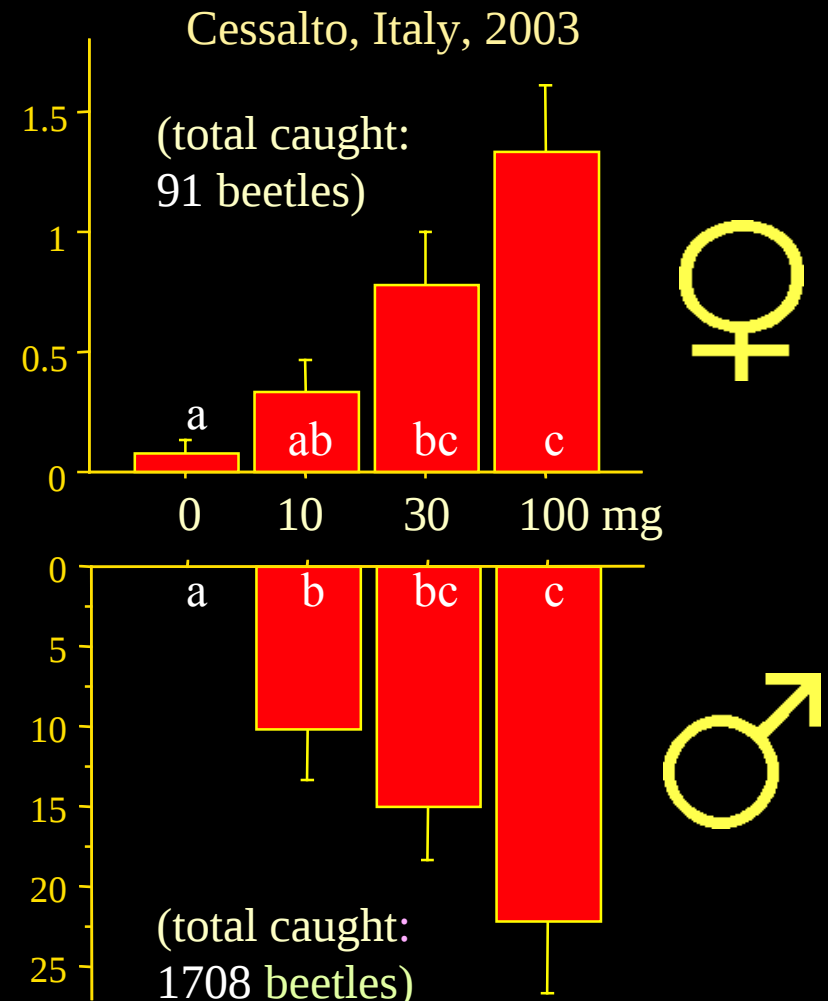
Females responding to the pheromone

Female catches in pheromone baited traps showed dose dependence, similar to catches of male beetles.

A. sordidus



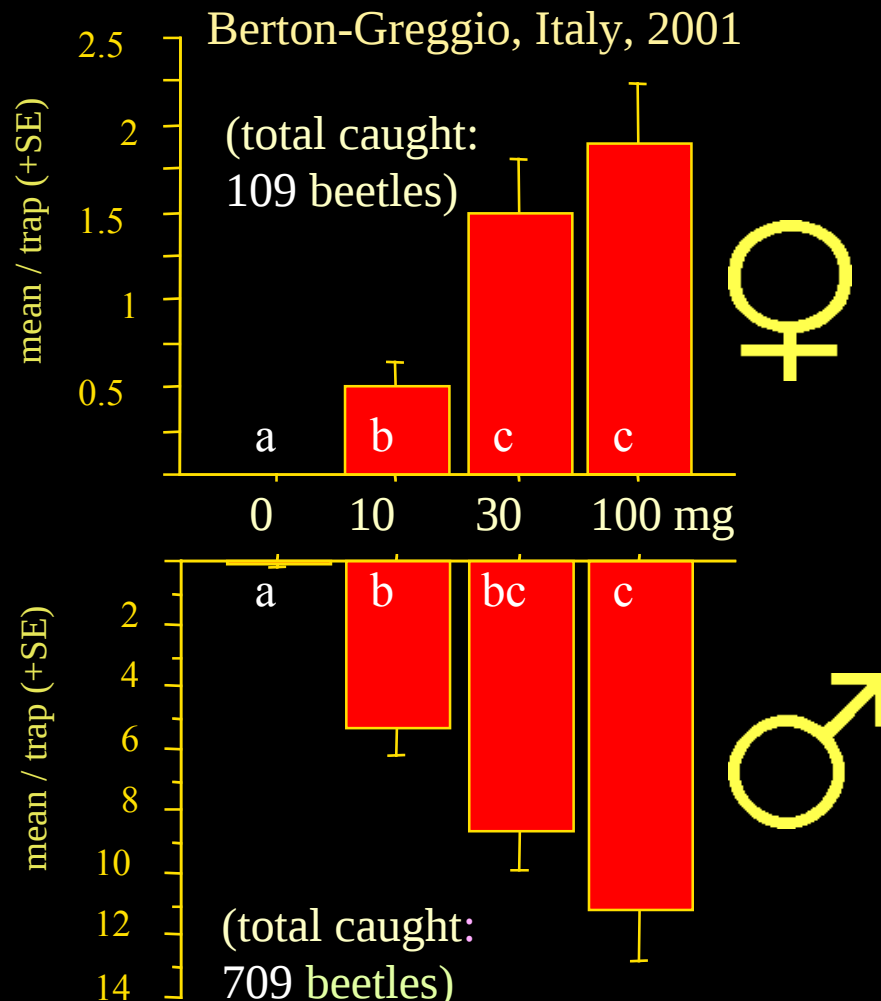
A. ustulatus



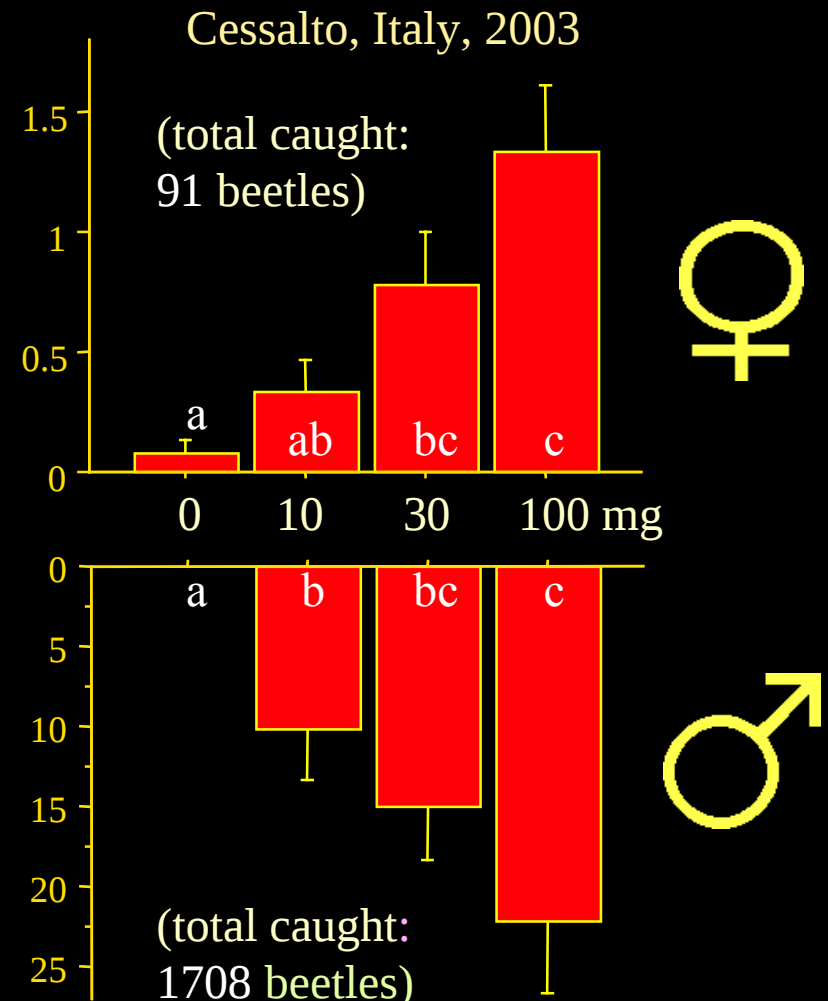
Females responding to the pheromone

The demonstrated female attraction to the resp. pheromone brings up the possibility of developing a trap catching females also.

A. sordidus



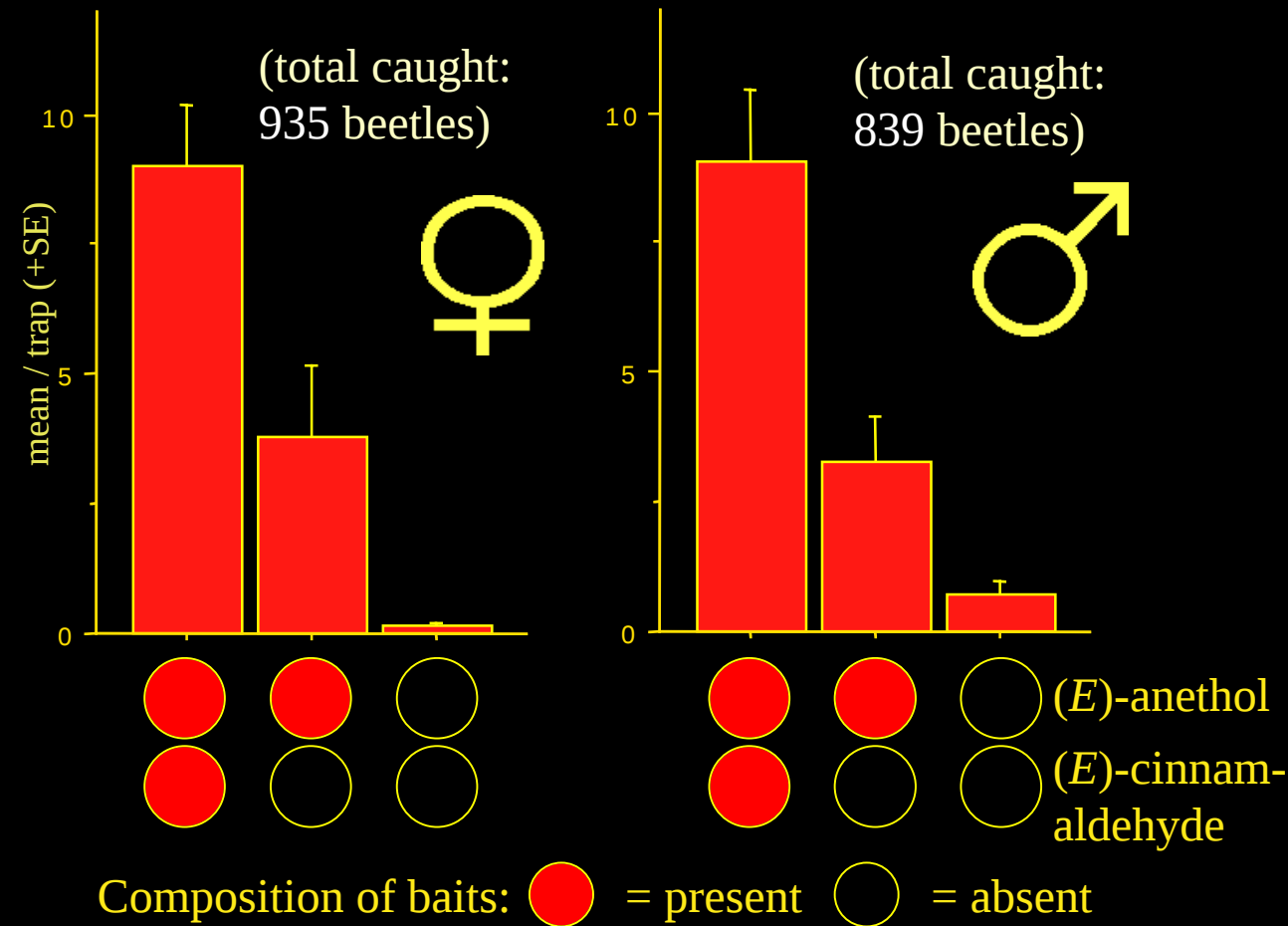
A. ustulatus



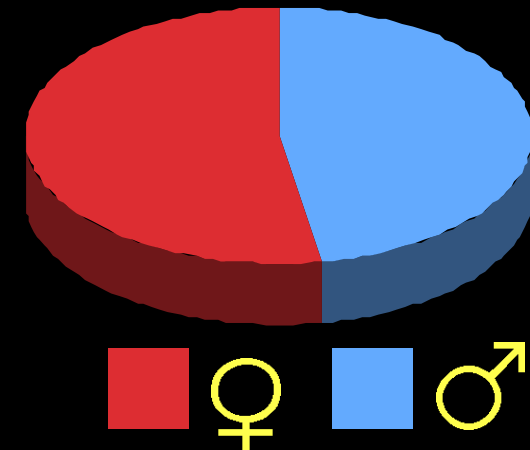
Efficient click beetle traps for both sexes?

In the flower visitor *A. ustulatus*, a floral lure has been discovered, which attracts both females and males.

Debrecen, Hungary, 2006



Sex ratio in catch of the 2 component floral lure (total caught 1232 beetles)



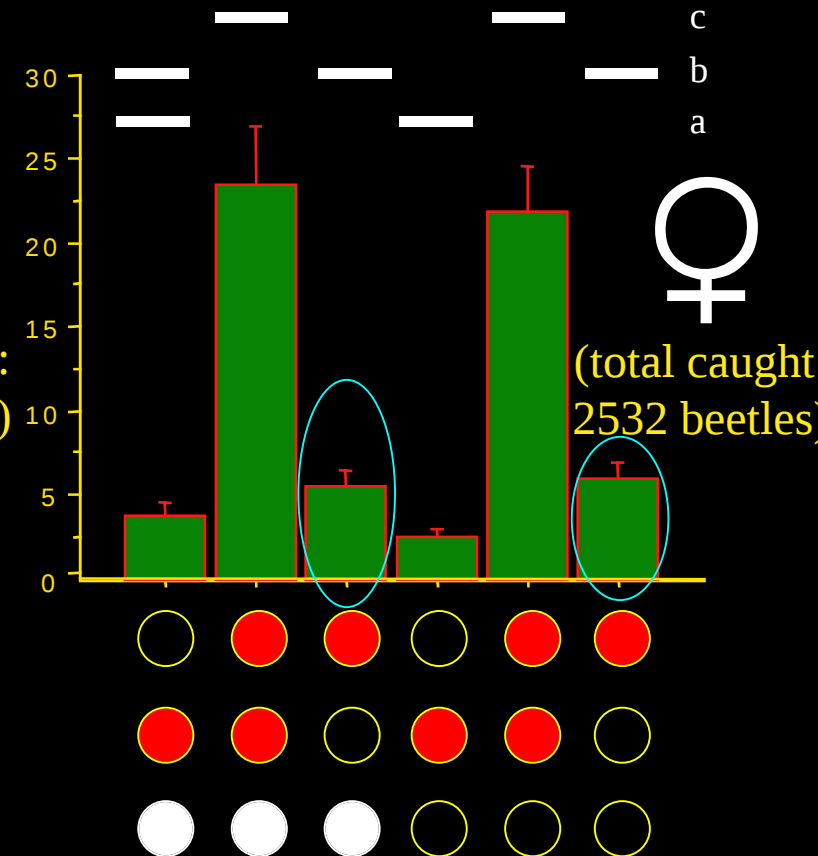
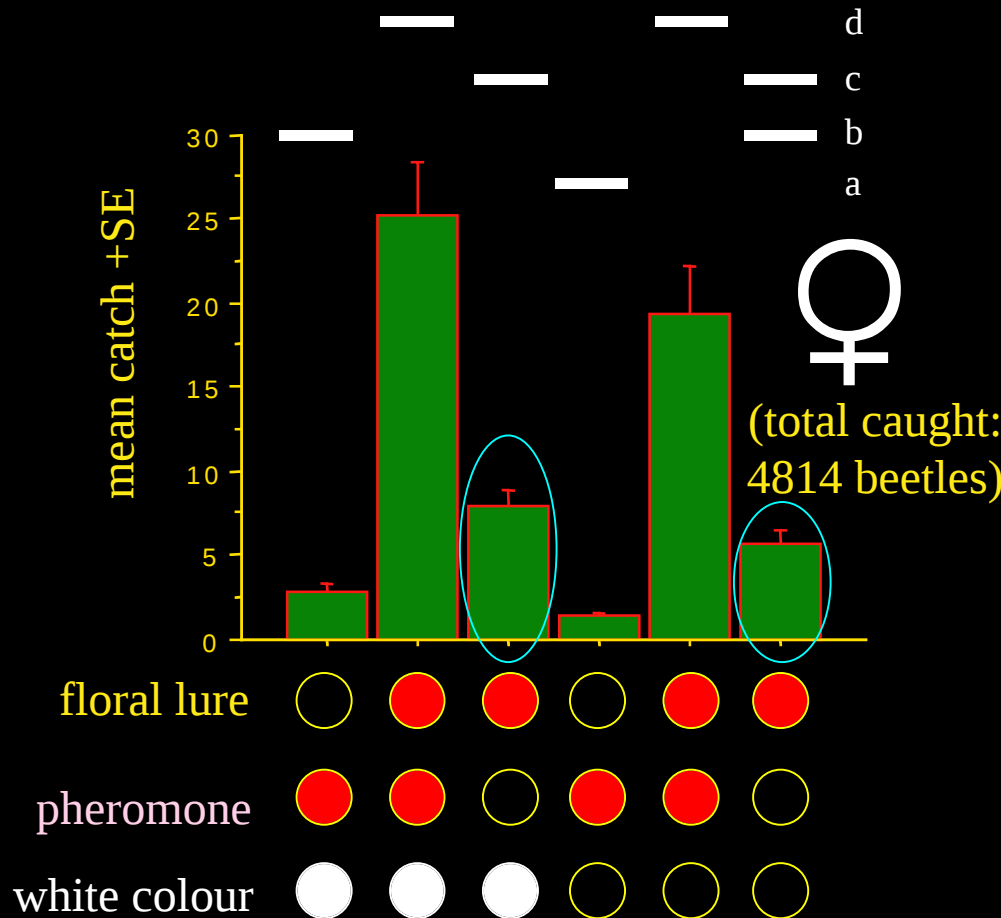
(After Tóth, Acta Phytopath. Hung. 46:235, 2011)

Efficient click beetle traps for both sexes?

White colour (a known attractive visual cue for *A. ustulatus*) showed negligible influence on traps baited with floral or pheromonal lures

Debrecen, 2008

Eraclea, 2008



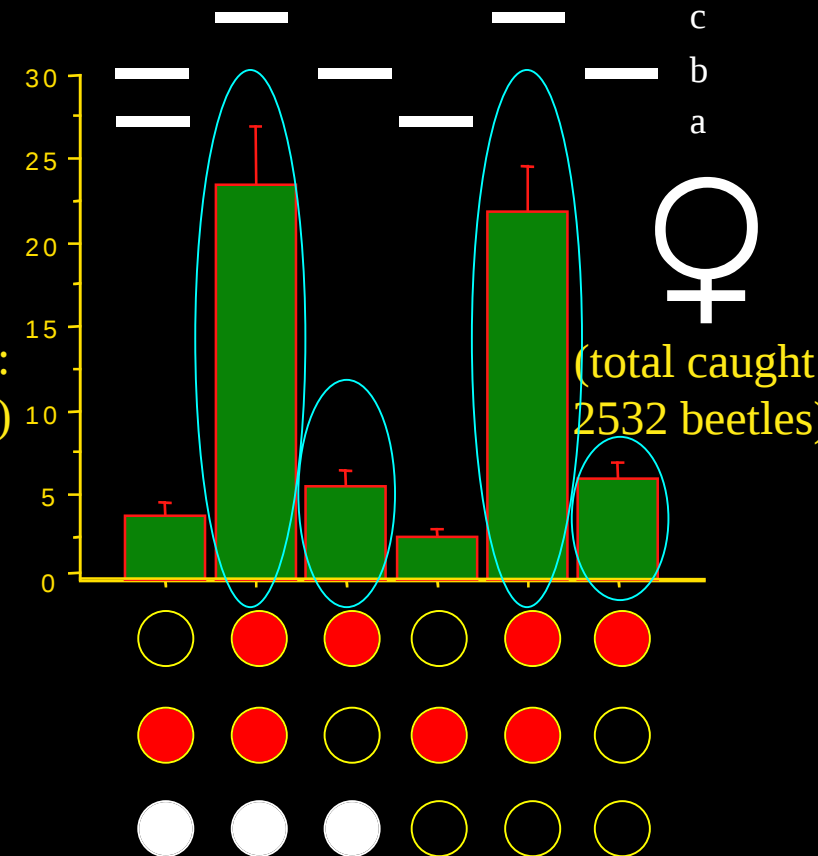
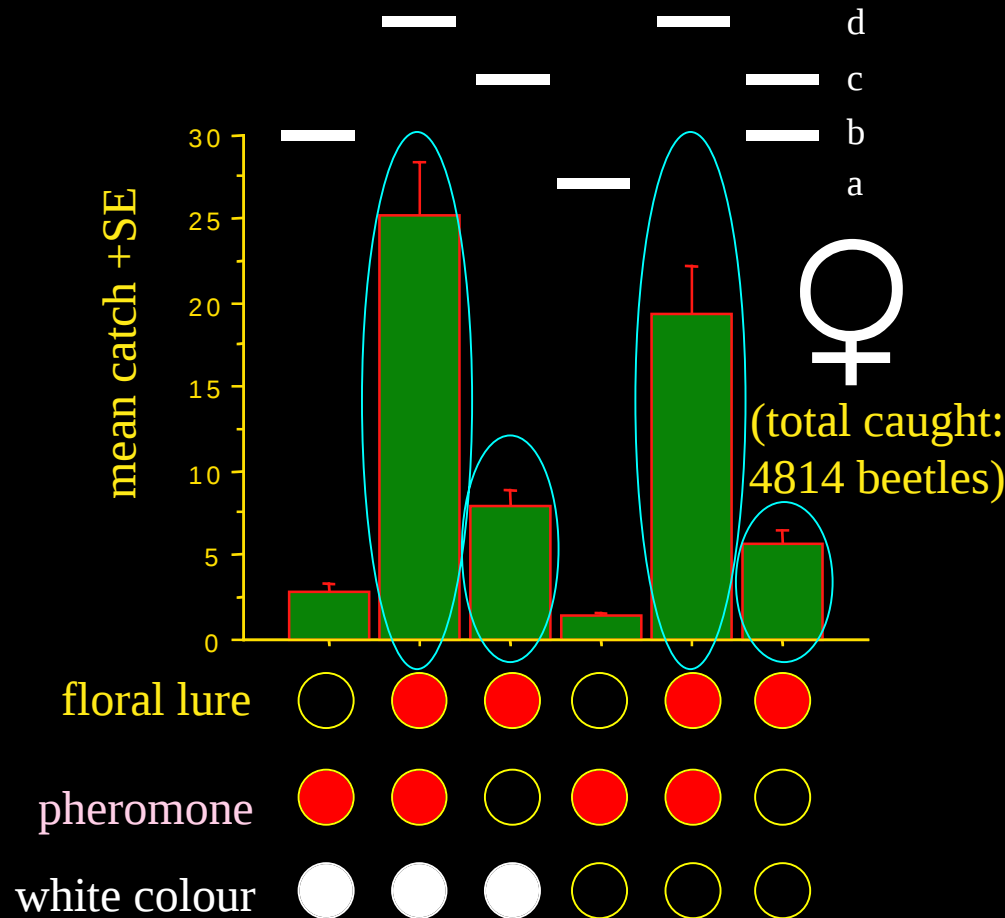
(After Tóth M. et al., in preparation)

Efficient click beetle traps for both sexes?

The addition of the pheromone to the floral lure in the same trap increased catches of females!

Debrecen, 2008

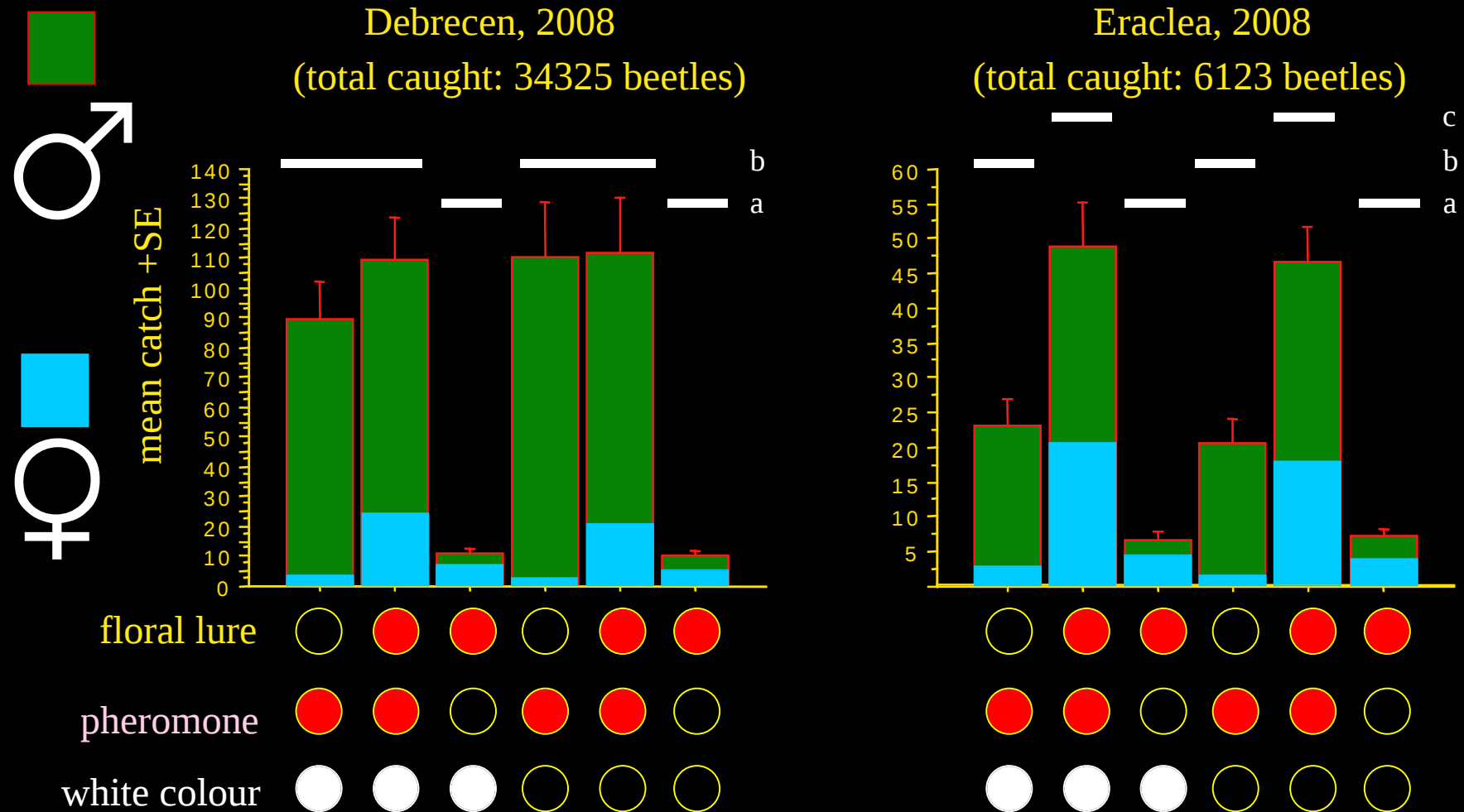
Eraclea, 2008



(After Tóth M. et al., in preparation)

Efficient click beetle traps for both sexes?

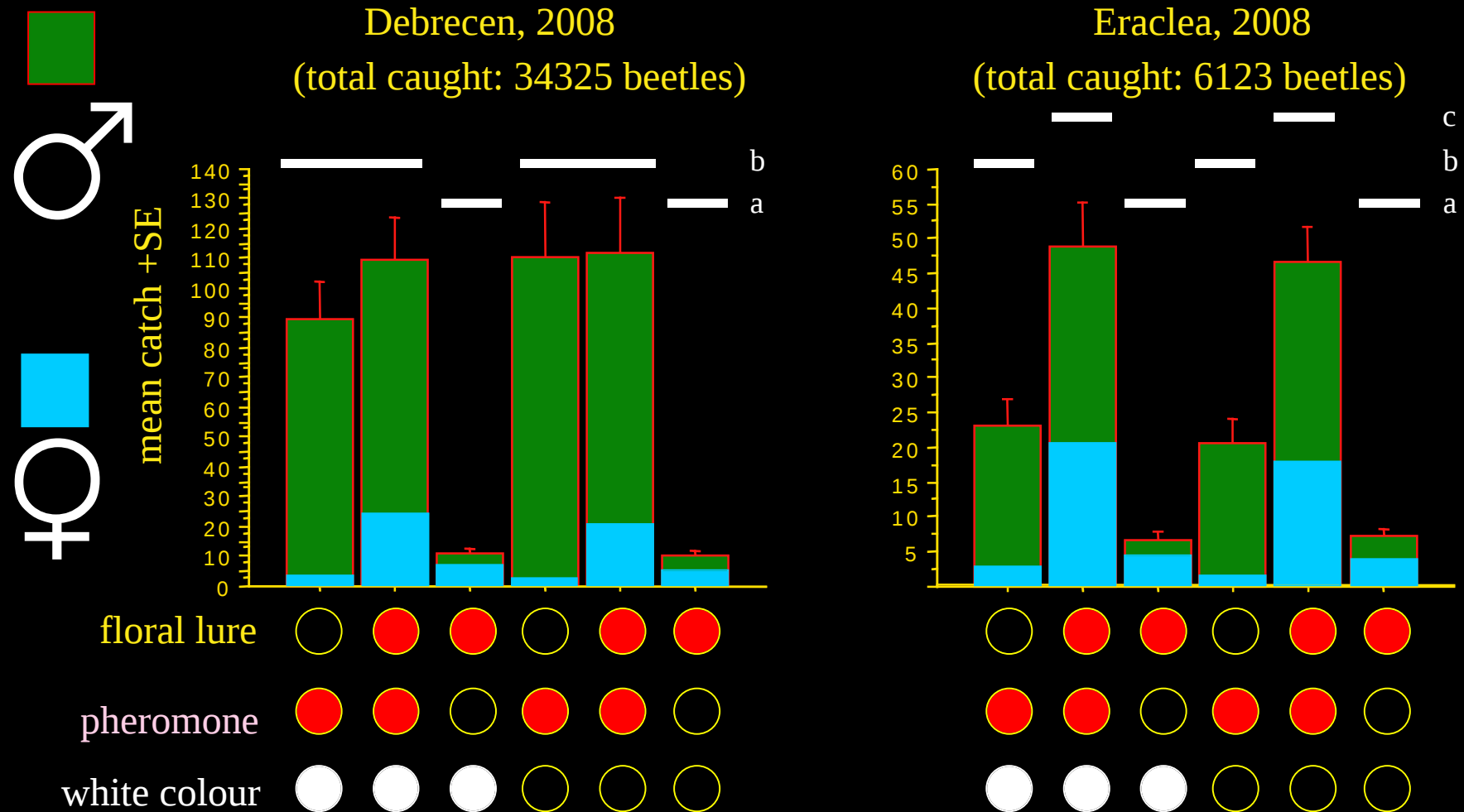
Most female specimens were caught in traps with both floral AND pheromonal baits



(After Tóth M. et al., in preparation)

Efficient click beetle traps for both sexes?

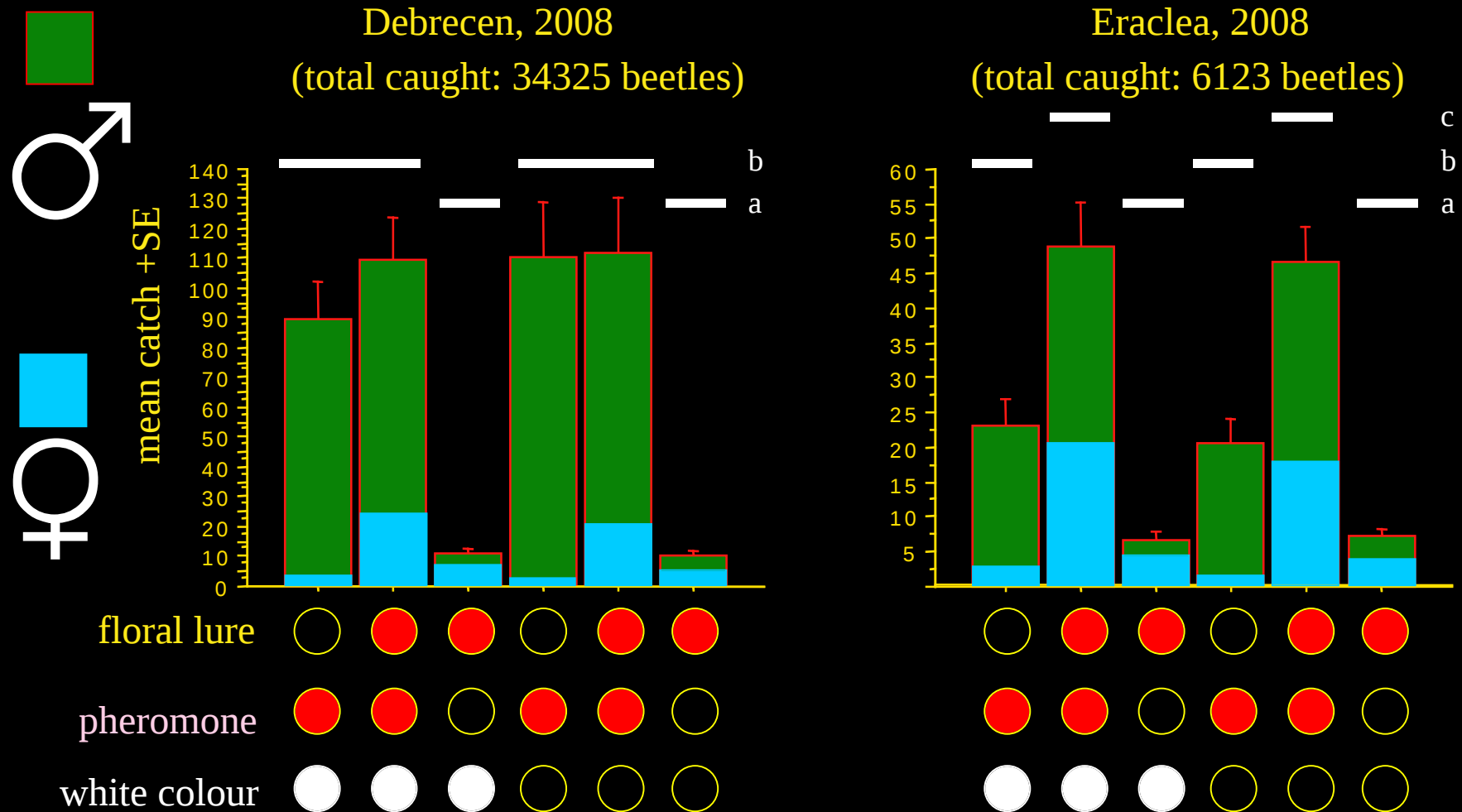
A similar phenomenon (that the presence of the pheromone increases the effect of floral bait on females) is unusual with sex pheromones



(After Tóth M. et al., in preparation)

Efficient click beetle traps for both sexes?

The phenomenon is frequently reported with aggregation pheromones, so elaterid pheromones may have to be reclassified.



(After Tóth M. et al., in preparation)

Acknowledgements

Scientists cooperating in
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Toshova, T. (Bulgaria)

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Yatsynin, V.G. (Russia)