Climex modeling for spatial expansion of Asian hornet, Vespa velutina



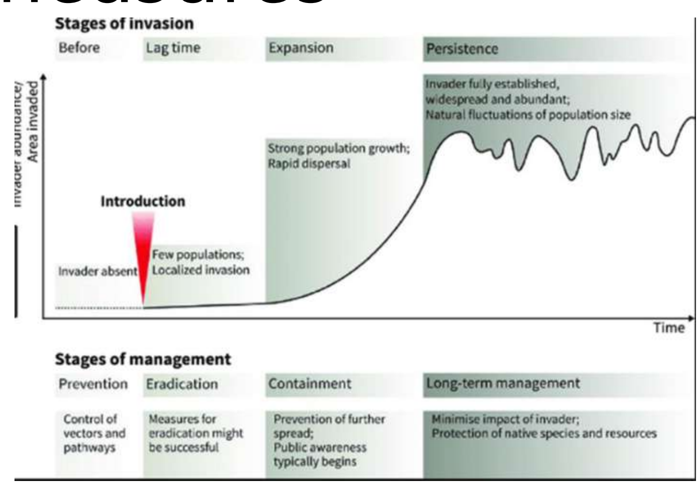

Chuleui Jung, Seongbin Bak, Jeongjun Park

Plant Medicals, Andong National University, Korea
Kyoungsang National University, Korea

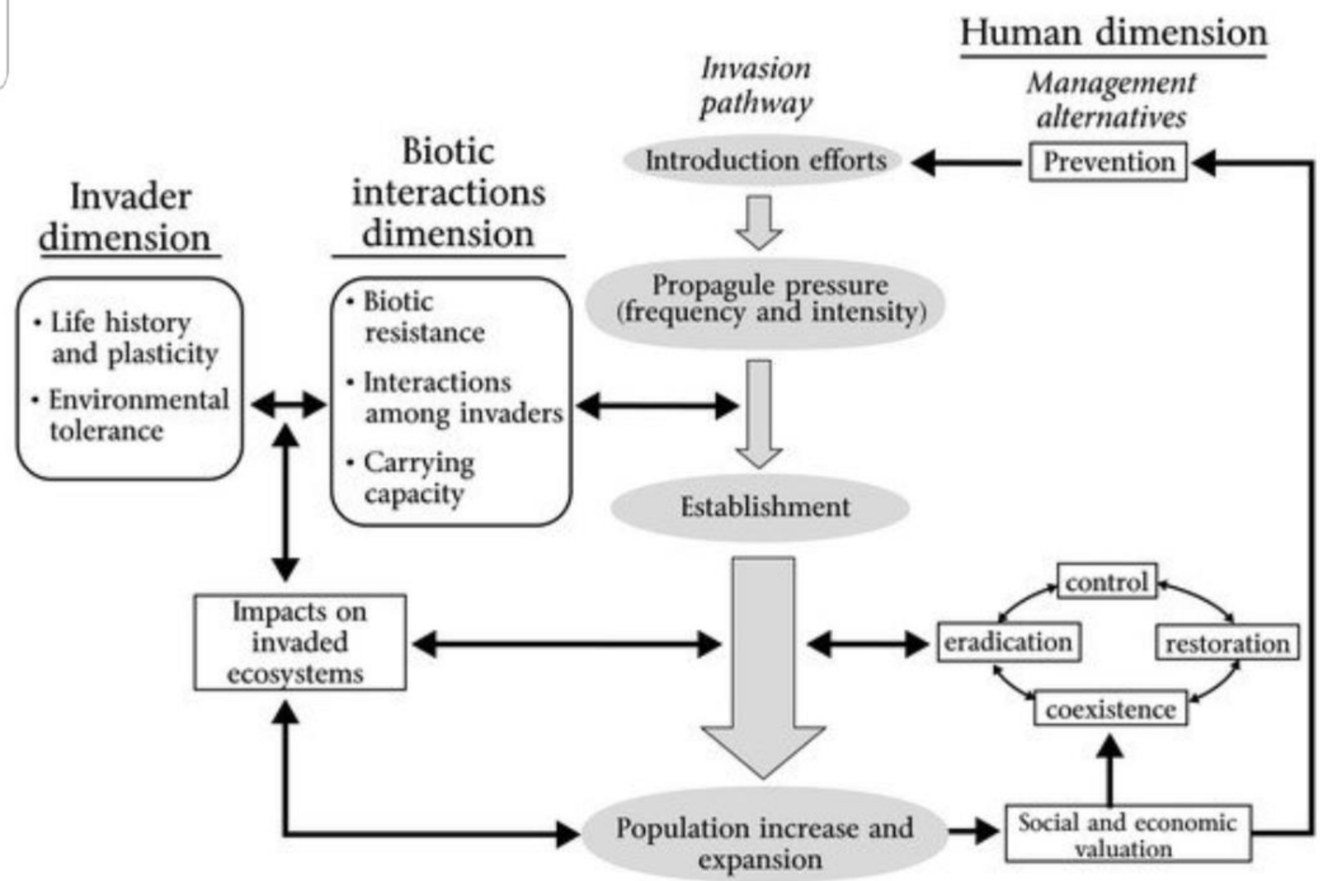
Biological Invasion

- Alter biotic community and ES functions
- Significant ecological, socio-economic consequences

- Stepwise responses and measures
  - Prevention
  - Eradication
  - Containment/Suppression
  - Management



Complex interaction



Honeybee / pest into Korea

A.mellifere 1910s?

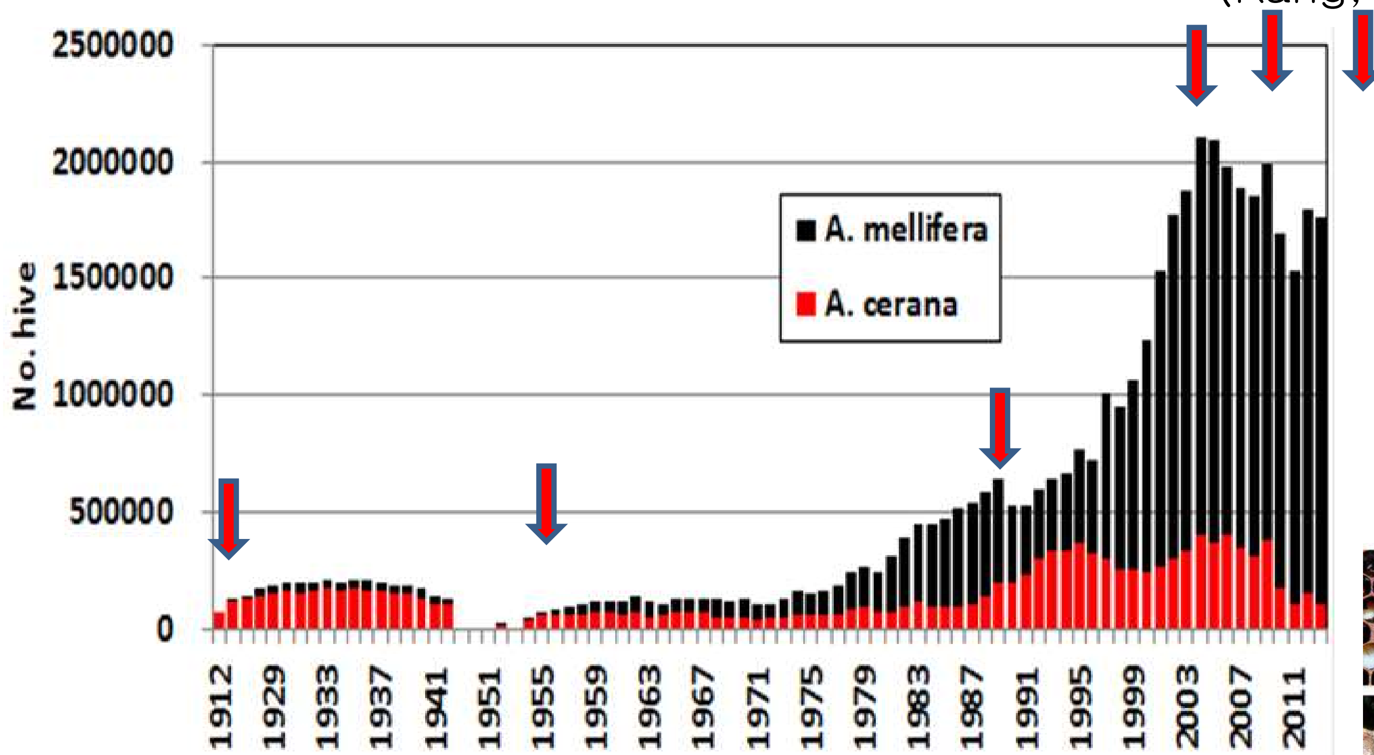
Varroa shifting from Ac to Am 1950s

Tropilaelaps from China, 1993

Vespa velutina 2003 → 2008
(Kim, talk)

Sac brood virus 2009

Small hive beetle 2016
(Kang, talk, Noor-Poster)

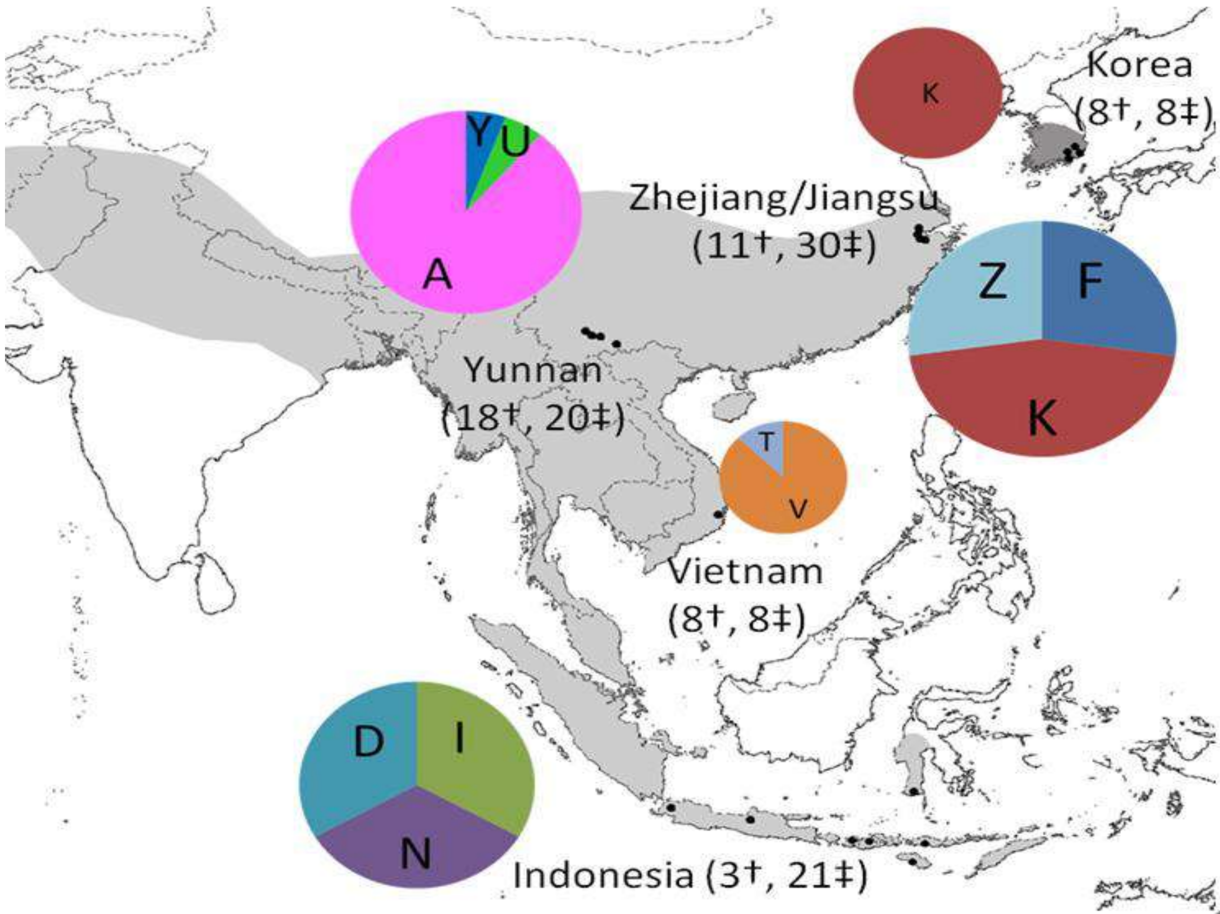


Invasion of Hornet into Korea

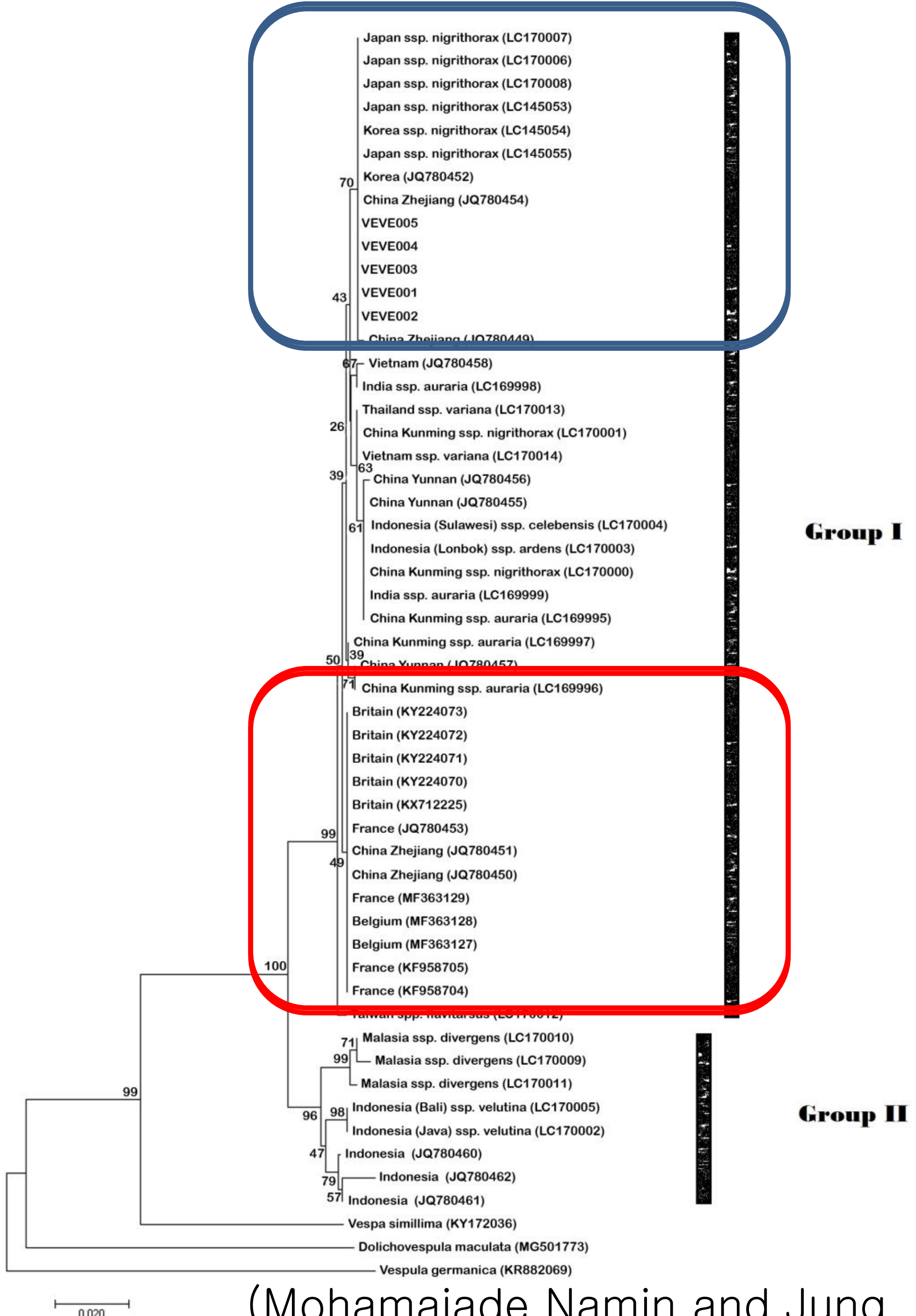
2003

Vespa velutina nigriothoax Buysson, 1905

Origin of invasion

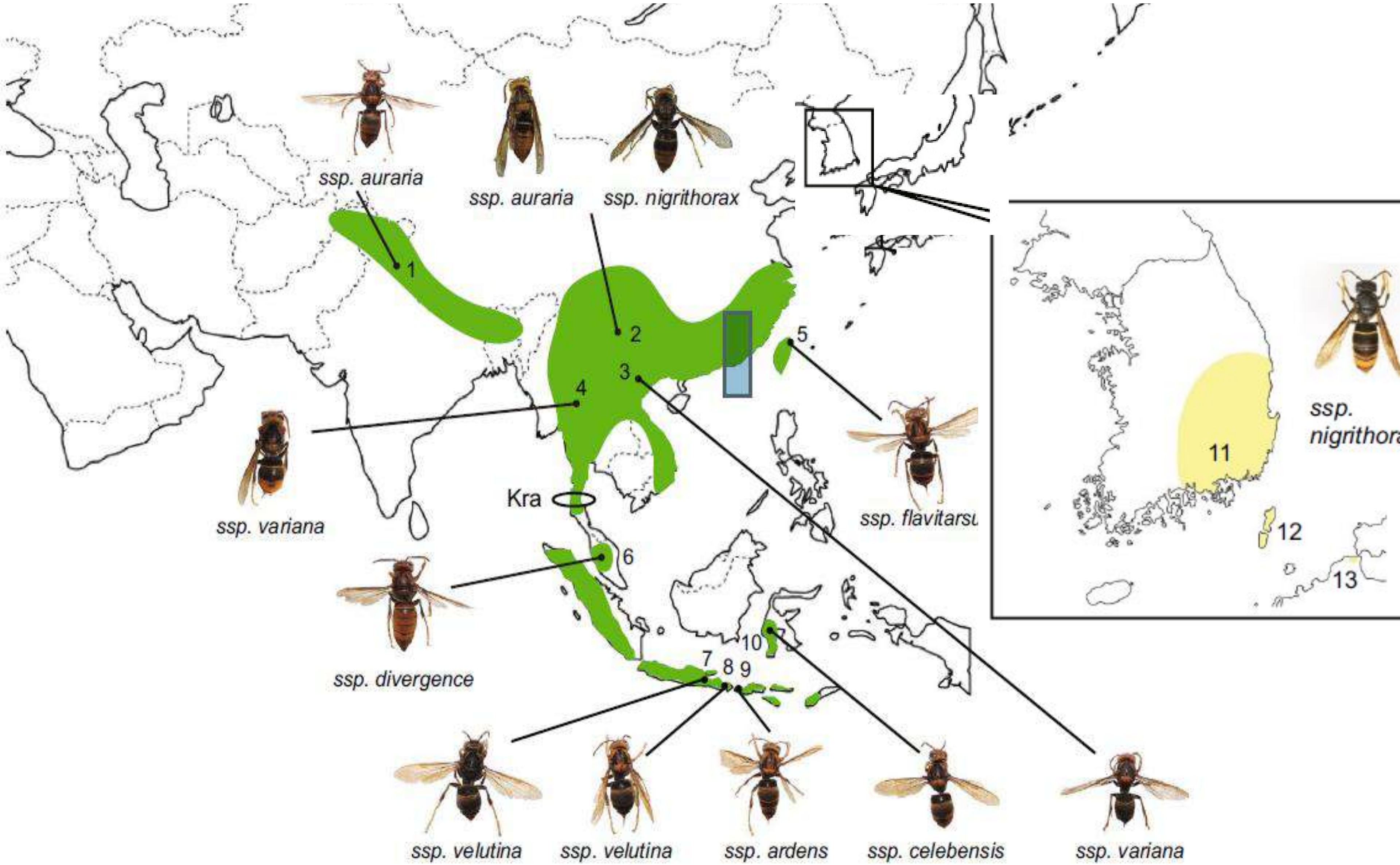


<Arca, … Jung, … Villement…, 2015. Biological Invasion
mt COI haplotype distribution



(Mohamajade Namin and Jung, in Prep)

International distribution of Velutina



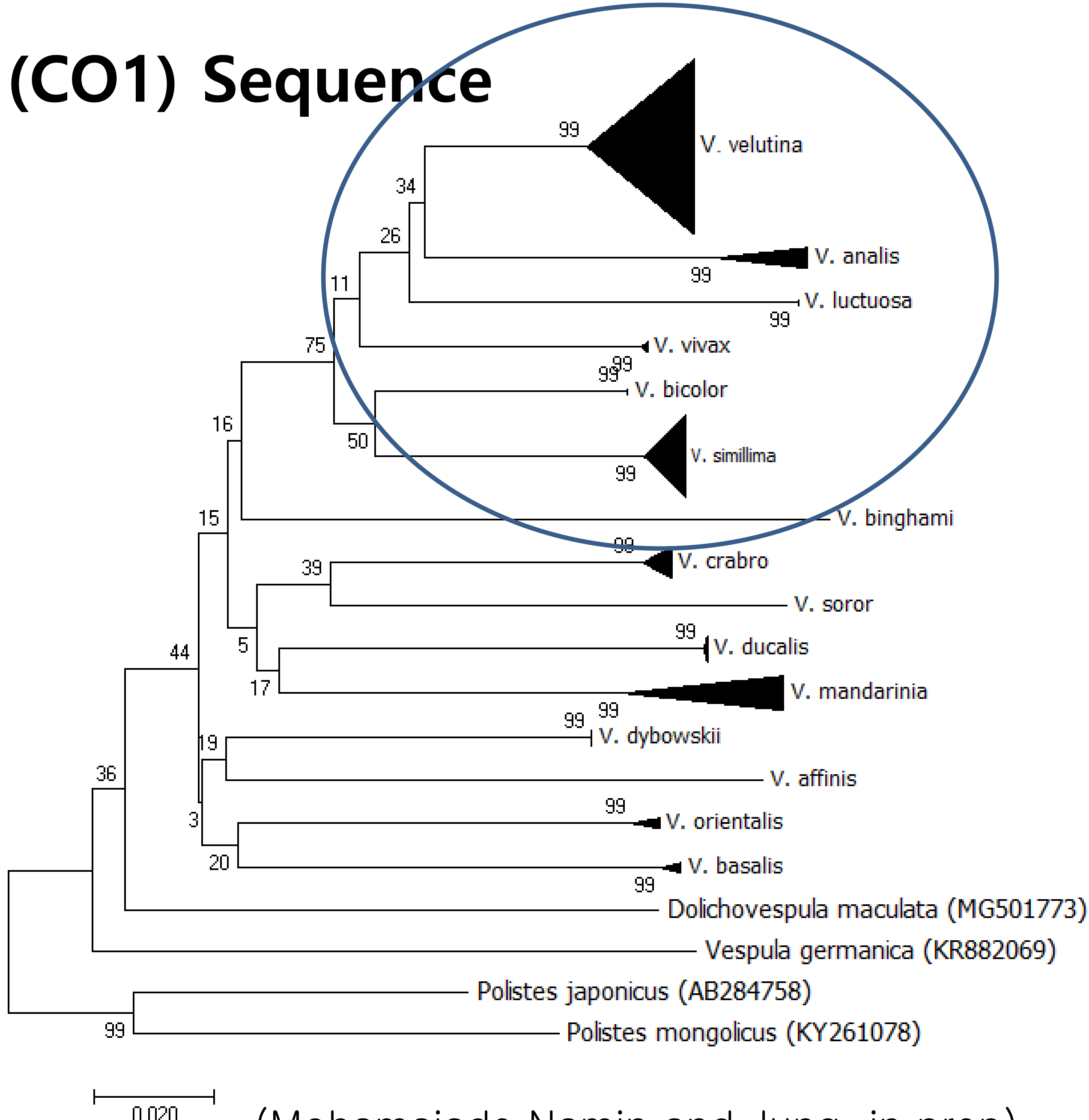
Increase of biodiversity ?

Hymenoptera : Vesidae : *Vespa* 9(sub) species ➔ 10 speies

	Species		Korea name	Note
Vespa	***analis parallela*** Andre, 1884		좀말벌	
	binghami du Buysson, 1905	Nocturnal	큰홀눈말벌	Notcturnal
	crabro crabroniformis Smith, 1852	Europe, Asia	등무늬말벌	Kim et al., 1994
	c. flavofasciata Cameron, 1903		말벌	
	ducalis Smith, 1852		꼬마장수말벌	
	dybowskii Andre, 1884		검정말벌	
	mandarinia Cameron, 1852	Giant hornet	장수말벌	
	simillima simillima Smith, 1868		털보말벌	
	s. xanthoptera Cameron, 1903		황말벌	
	velutina nigrithorax Buysson, 1905	Invasive	등검은말벌	

Jung et al. 2008, J. Korean Apic.

Mt DNA (CO1) Sequence variation



(Mohamajade Namin and Jung, in prep)

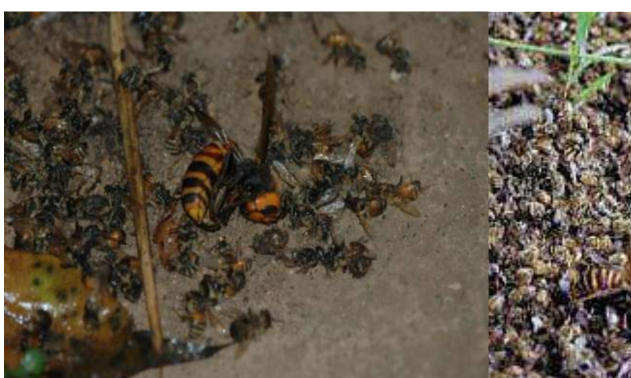
Economic threat to beekeeping; 107.5 m$/yr

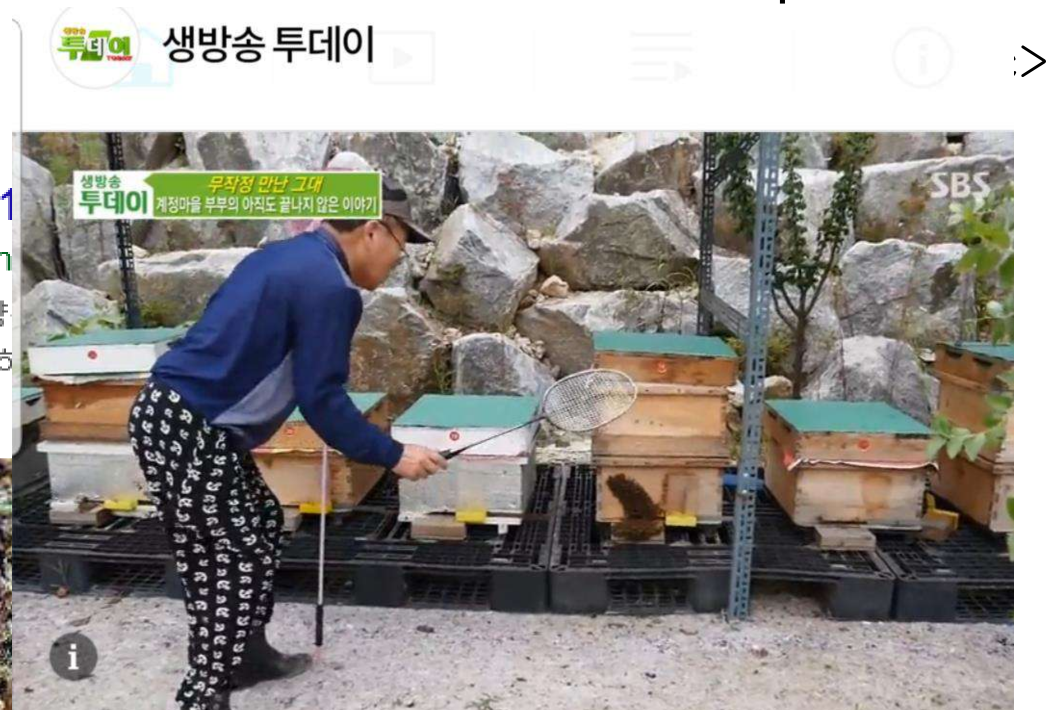
Labor: 40000 ind.x50,000Wx100dx50%=100 m$

Colony loss 30% ➔ 7.5 m$

Honey reduction 30% ➔10 m$

양봉산업, 등검은말벌 피해액 1
www.chuksannews.co.kr/news/article.h
2018. 12. 28. - [축산신문 전우중 기자] 양
적인 피해액이 연간 약 1천750억원에 달하





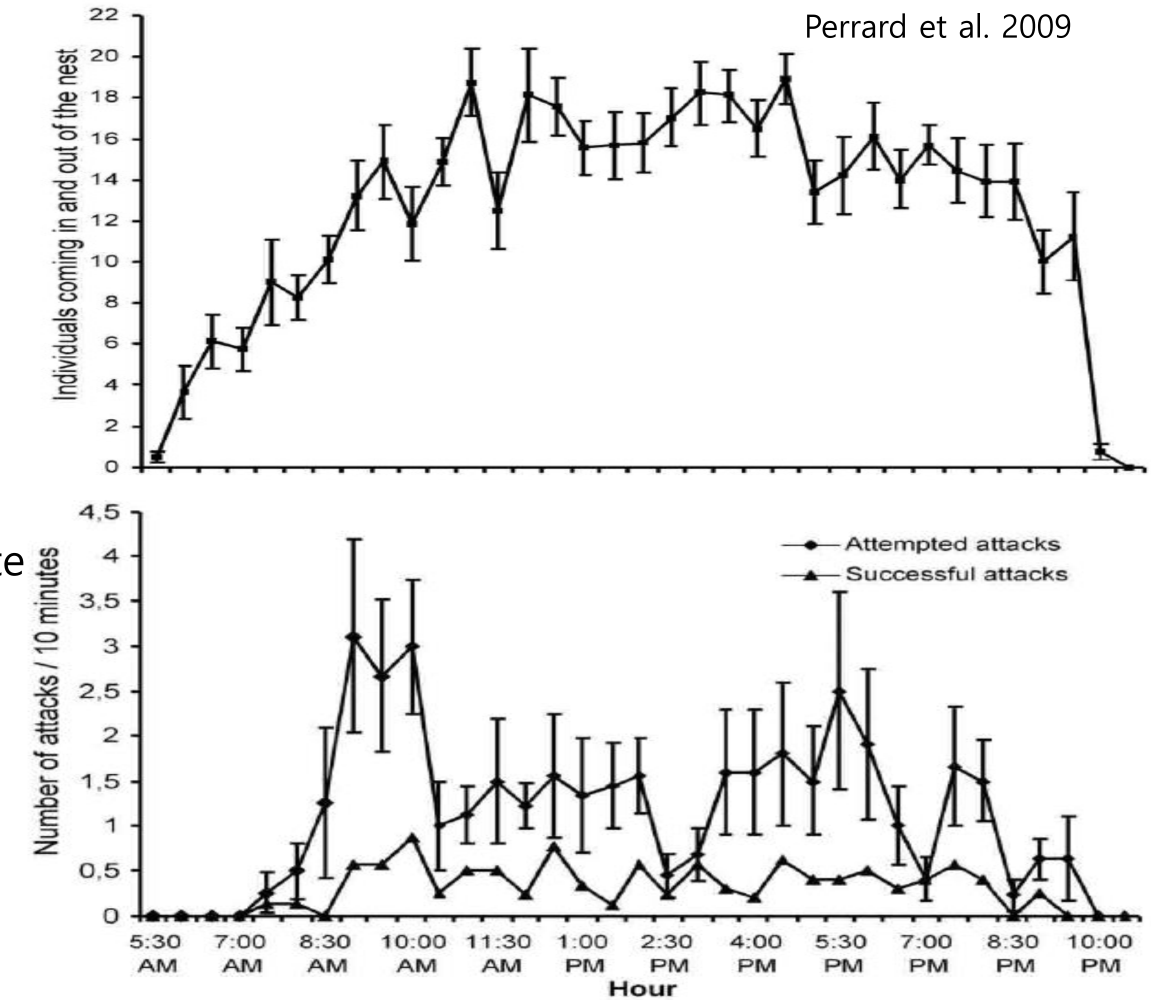
계정마을 양봉꾼 할아버지, 배드민턴 채로 말벌 사냥!
▶ 2,848 · 2017.01.30 22:30


2011


2011 12 4

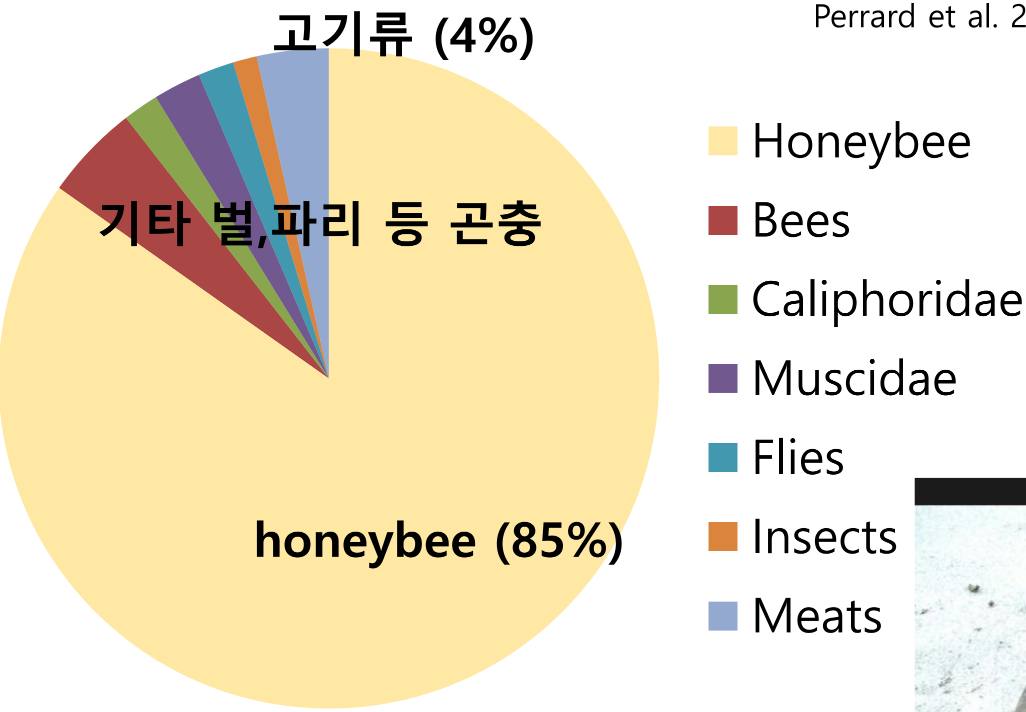
Activity
:

Honeybee attack rate

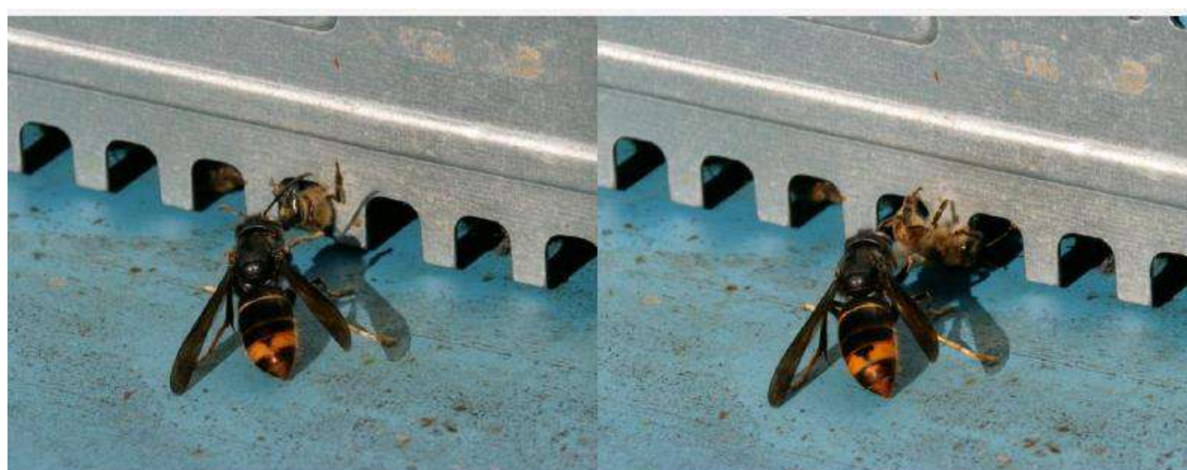


Honeybee Diet preference

Perrard et al. 2009



Netting



Maybe prevent entry
But
Bees are not foraging

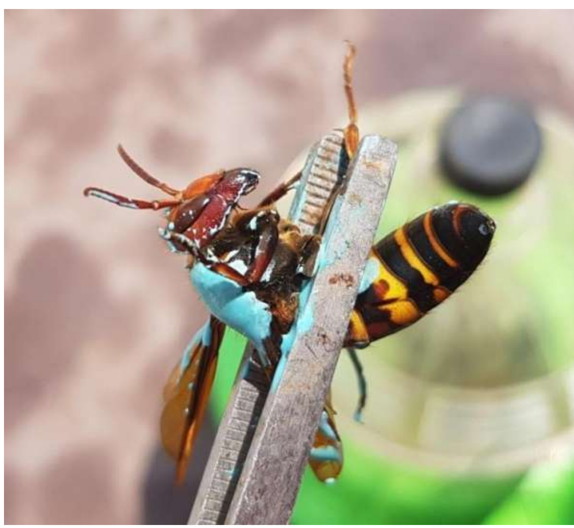
Mass trapping

- Spring queens
- Summer workers
- ???
- Trap design, color, lure

Chemical control

- Selection of pesticide important
- contact, exposure method
- Target? Immature? Adults?
- human, environmental concerns 제고

IGR ?



https://blog.naver.com/sungoig1/221336610104 안경강의 금주양봉관리

Appl Entomol Zool (2017) 52:361–368

Table 1 Pesticides added to baits to control *Vespula* wasps in published studies

Chemical	Sp[a]	Conc.[b]	Bait	Effect[c]		Country, State
Acetamiprid	P	0.05%	Canned fish or chicken cat food	–	High repellency	USA, California
Amidinohydrazone	P	0.50%	Canned tuna cat food	+	Reduction after 1 month	USA, Hawaii
Avermectin	P	0.01%	Canned tuna cat food	+	Reduction after 7 weeks	USA, Hawaii
Bifenthrin	P	0.05%	Canned fish or chicken cat food	+	Dose-dependent repellency	USA, California
Boric Acid	P	1%	Canned tuna cat food	–	Little reduction	USA, Hawaii
Chlordane	P	1%	Cooked horse meat	++	Colony collapse	USA, California
	V	1%	Cooked horse meat	++	Colony collapse	USA, California
Chlorfenapyr	P	0.05%	Canned fish or chicken cat food	+	Site-dependent reduction	USA, California
Chlorpyrifos	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Argentine
Diazi[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	USA, Hawaii
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	USA, California
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible], Hawaii
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] California
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] California
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Hawaii
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]ine
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]alia, Tasma[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]A, Hawaii
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	USA, California
	[illegible]	[illegible]	[illegible] meat	++	[illegible] After 2 weeks	USA, California
	V	0.10%	Sardine	++	99.7% Reduction in 300 ha	New Zealand
	V	0.10%	Protein-based commercial bait	++	93% Reduction in 4 days	New Zealand
	V	0.10%	Chicken-based commercial bait	++	80% Reduction within 113 m	New Zealand
Hydramethylnon	G	2%	Fresh and dried beef	+	54% Reduction after 72 h	Argentine
Imidacloprid	P	0.05%	Canned fish or chicken cat food	–	High repellency	USA, California
Indoxacarb	P	0.05%	Canned fish or chicken cat food	+	Site-dependent reduction	USA, California
Mirex	P	1%	Canned fish cat food	++	Colony collapse	USA, California
Permethrin	G	0.30%	Fresh and dried beef	–	No reduction	Argentine
Sodium monofluoroacetate	G, V	0.001–1%	Canned sardine cat food	++	89% Reduction at 1% after 2 days	New Zealand
	V	1%	Canned sardine cat food	++	82% Nest reduction	New Zealand
Spinosad	P	0.05%	Canned fish or chicken cat food	–	High repellency	USA, California
Sulfluramid	G, V	0.25–1.0%	Canned sardine cat food	++	90% Reduction after 10–12 days	New Zealand
	V	1%	Sardine	–	No reduction	New Zealand

Carbamate,
Clothianidin (세시미),
Permethrin

Establishment after invasion

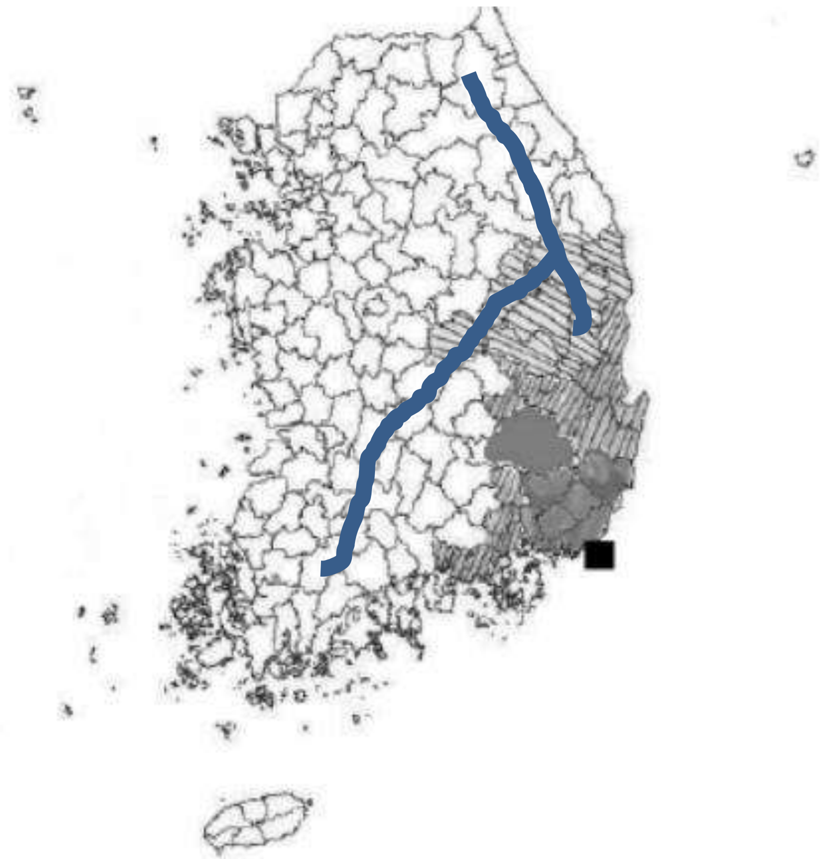


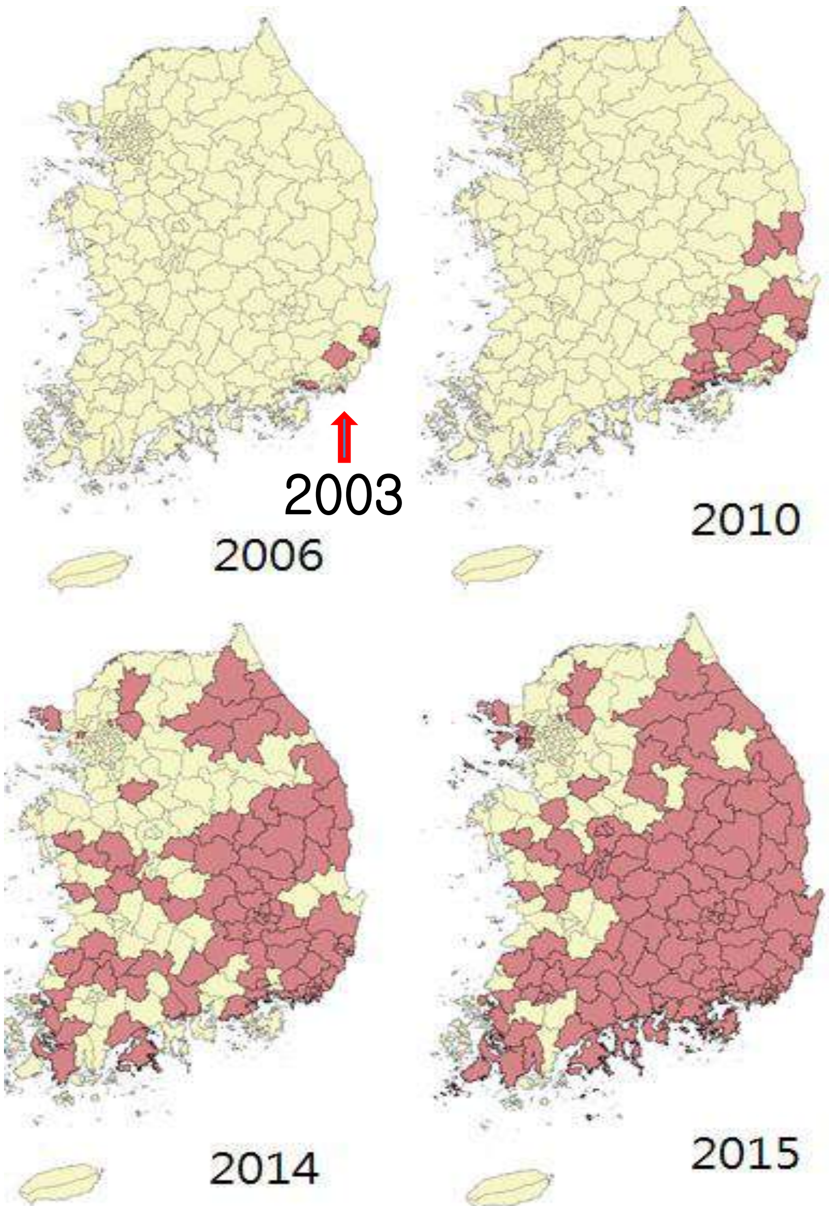
Fig. 2. Distribution of *Vespa velutina* in Korea after invasion into Busan port in 2003 (Occurrence was confirmed by sampling or circumstantial evidences; ■ point of invasion, violet gray color until 2008, red color in 2009, /// in 2010 and \\\ in 2011).

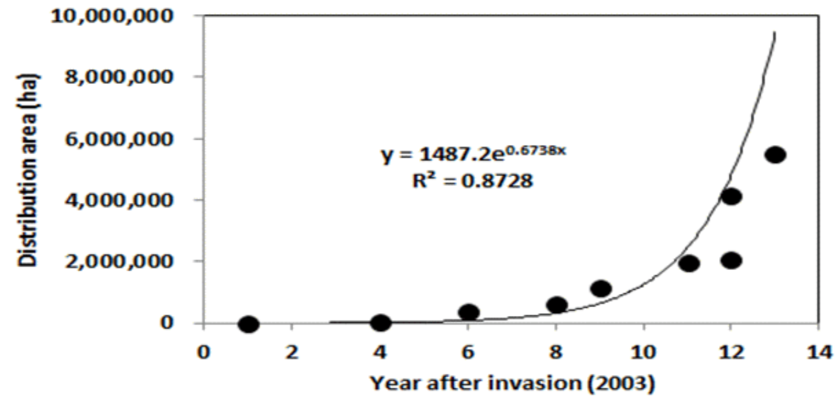
Table 1. Outlines of the history of invasion of *Vespa velutina* into Korea and France and its spread

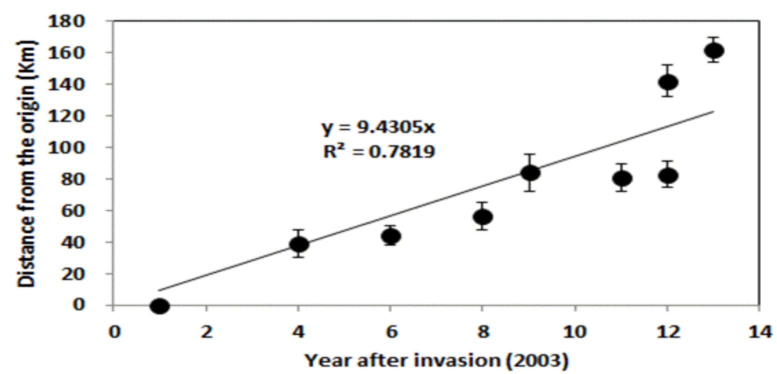
	Korea	France
Location of invasion	Busan port	Aquitaine
Year of invasion	2003	2004
Rate of spread (km/yr)	12.4±6.77	67.3±25.43
Maximum rate of spread (km/yr)	26.4	154.5
Maximum distance (km)	211	577
Number of other Vespa species	9	1

Jung, 2012 J. Apic.

Distribution expansion after invasion







Range expansion pattern
Area / Distance

Park and Jung, 2016 J Apic

Habitat suitability ?

- Population increase
- Spread

- Predicting potential suitable habitat
  - MaxEnt : maximum entropy approach
  - Climex : Bioclimatic niche model

Simulation using CLIMEX

Prediction map

Climex modeling
- Weather data
- Biological data

Climatic parameterization for distribution

Simulation with climate change scenario (RCP 8.5)

Validation with current distribution (GI, EI)

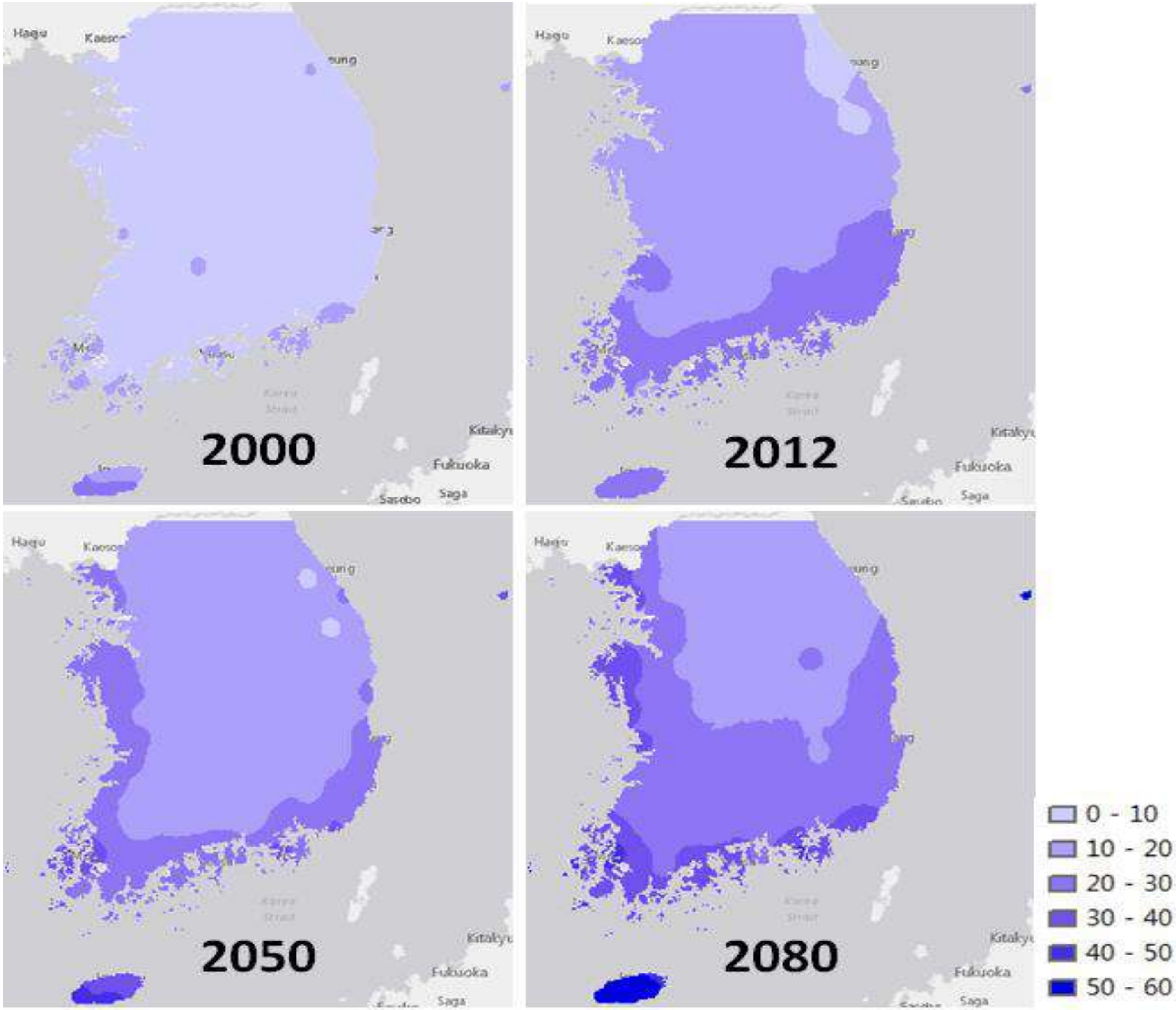
Prediction of future Distribution

Climatic parameterization for distribution

Table 1. Parameters used in CLIMEX for *Vespa velutina nigrithorax* in Korean environment

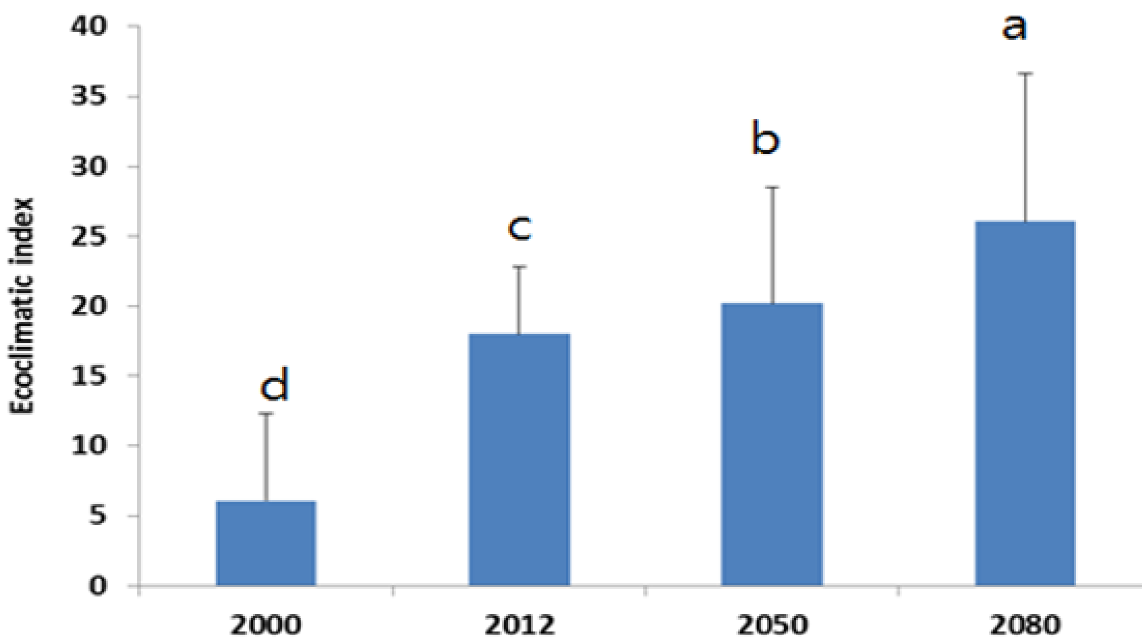
Moisture index	SM0 0.2	SM1 0.6	SM3 1.5	SM4 2.5
Temperature index	DV0 10	DV1 18	DV2 26	DV3 31
Light index Diapuase index		Indices are not applied in model		
Cold stress	TTCS 0	THCS 0	DTCS 10	DHCS -0.00014
Heat stress	TTHS 32	THHS 0.0035	DTHS 0	DHHS 0
Dry stress	SMDS 0.15	HDS -0.008		
Wet stress	SMWS 2.5	HWS 0.002		
Cold-dry stress Cold-wet stress Hot-dry stress		Indices are not applied in model		
Hot-wet stress	TTHW 28	MTHW 0.8	PHW 0.03	
DayDegree >DV0	DV0 10	DV3 31	MTS 7	
DayDegree >DVCS	DVCS 10	*DV4 100	MTS 7	
DayDegree >DVHS	DVHS 31	*DV4 100	MTS 7	
DayDegree per Generation	PDD 462			

Simulation result



Simulation result

Establishment Index

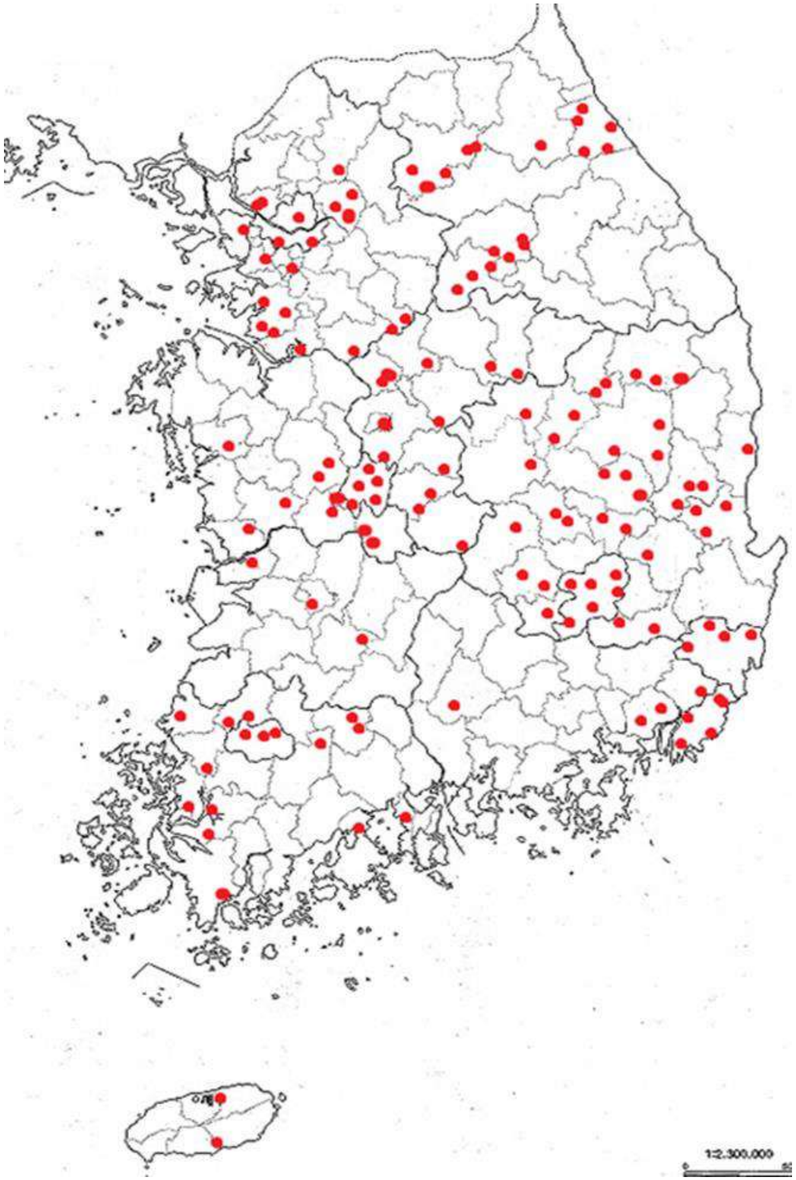


EI increase as climate change scenario

More suitable for establishment

GI the same pattern

Validation with field data

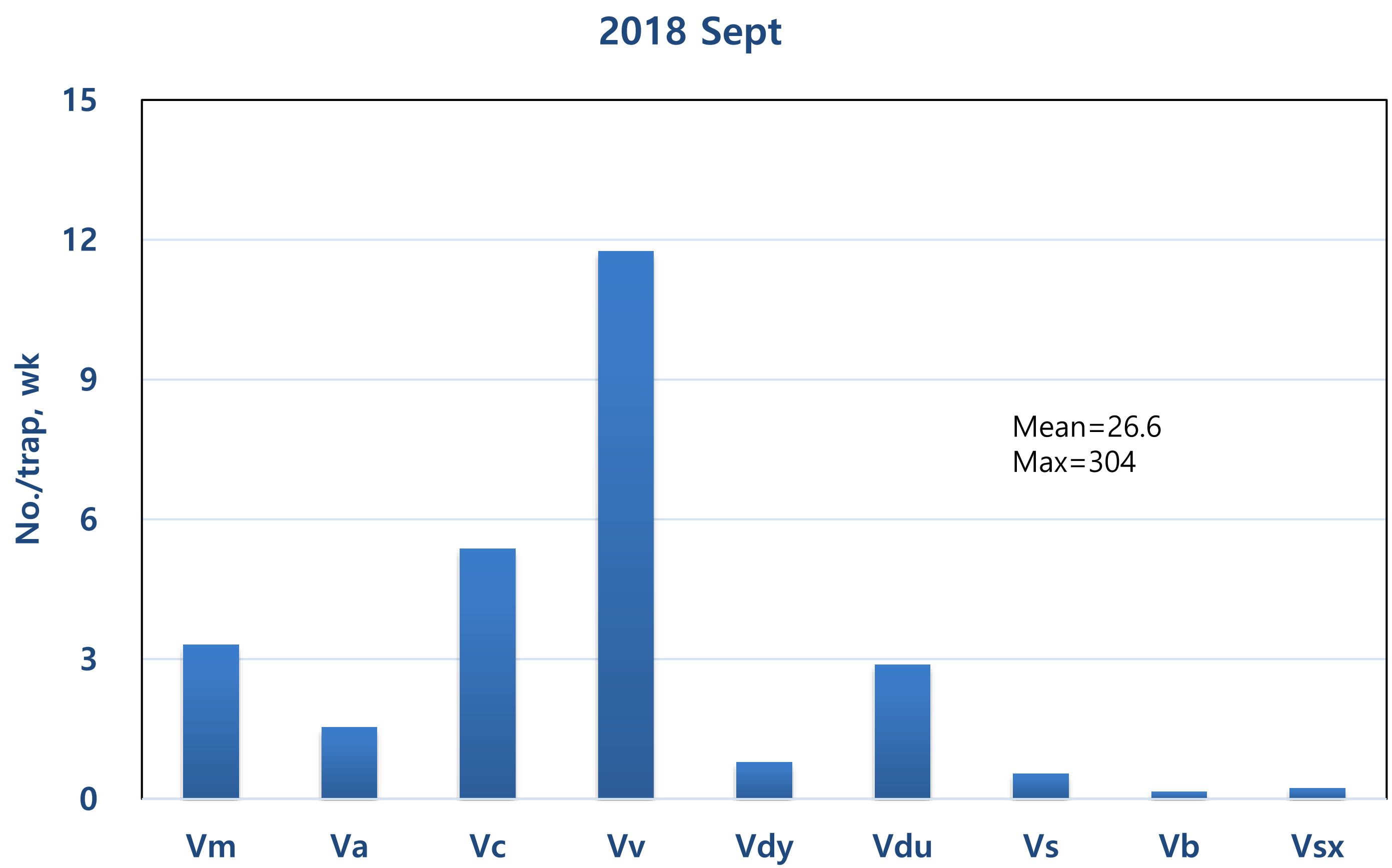


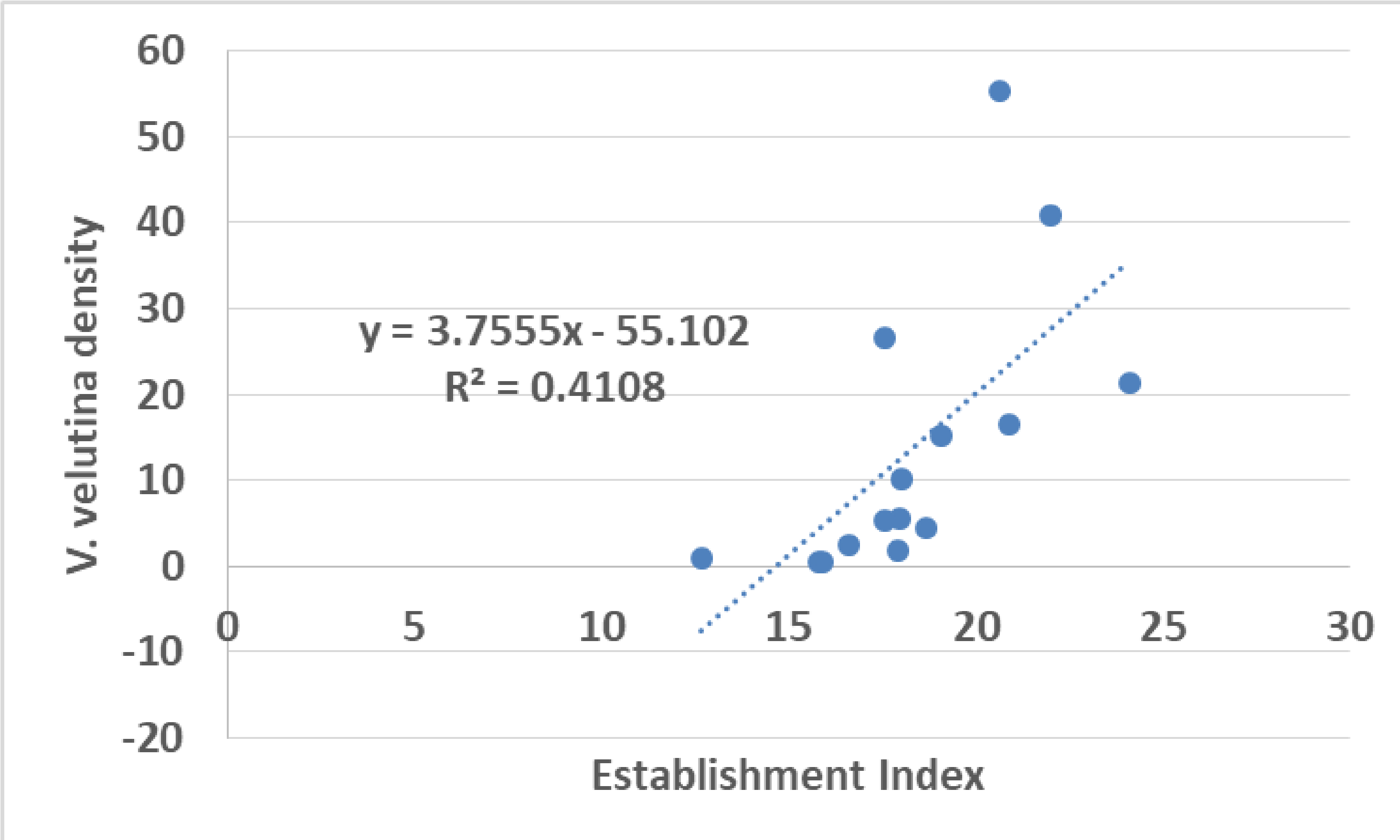
283 locations

Trap catches during Sep-Oct

Pooled into provinces

Vv data regression to the predicted


2018 Sept
15
12
9
6
3
0
No./trap, wk
Mean=26.6
Max=304
Vm
Va
Vc
Vv
Vdy
Vdu
Vs
Vb
Vsx



Significant relationship b/w predicted vs observed

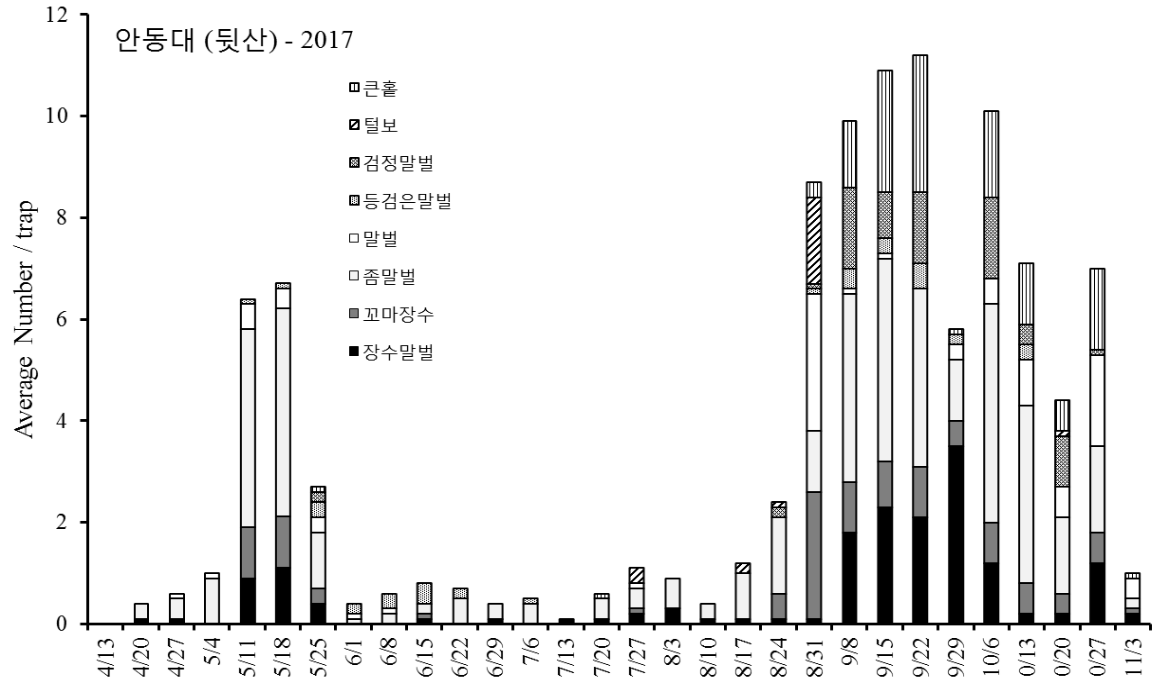
Summary

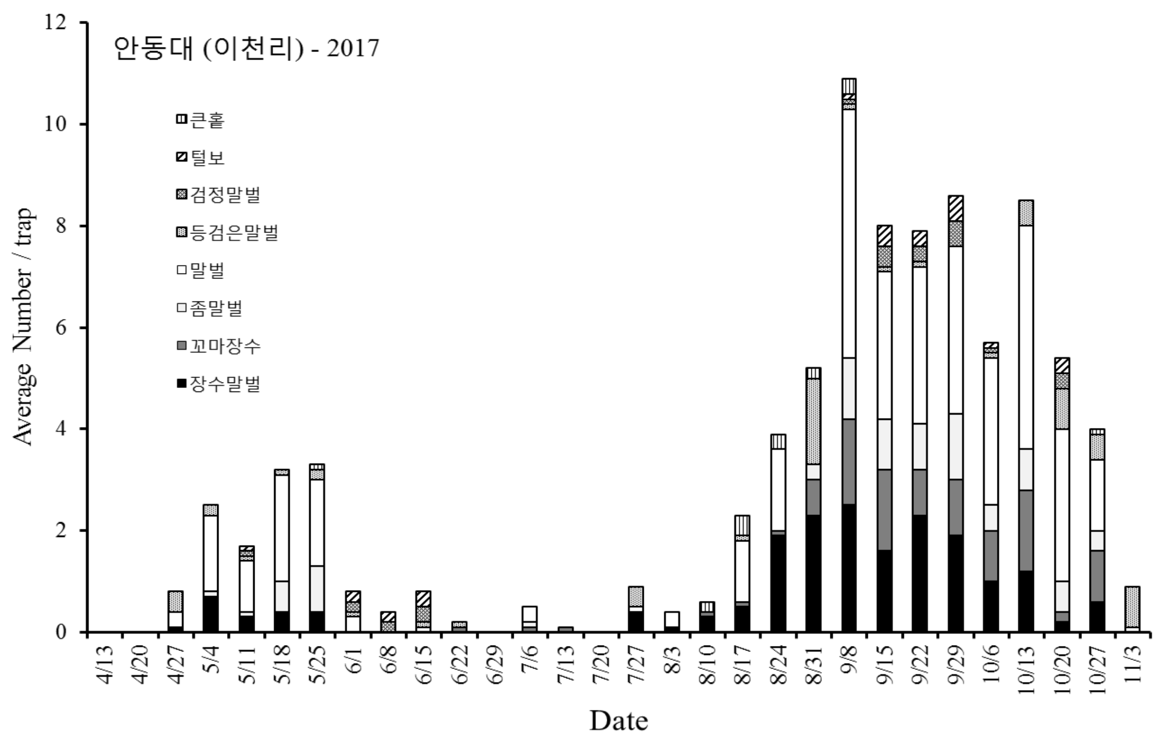
- Climex modeling could represent current distribution and predict future distribution

- Korean peninsula is becoming more suitable for Vv establishment
- Expansion potential high

- Efficient monitoring can help understanding complex interaction with native hornets

Field observation 2017



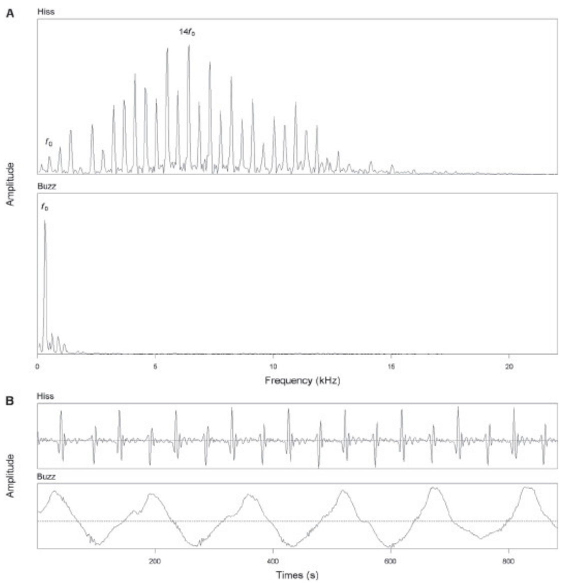


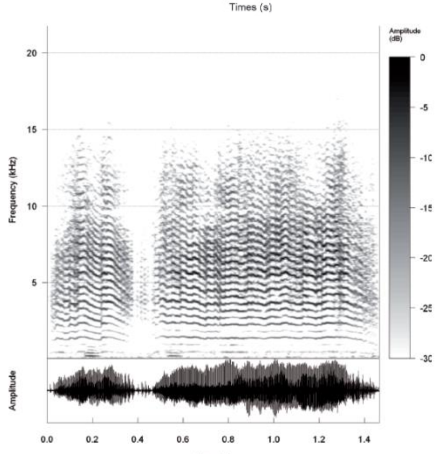
Automated Hornet alert system

Apidologie 39 (2008) 468–474

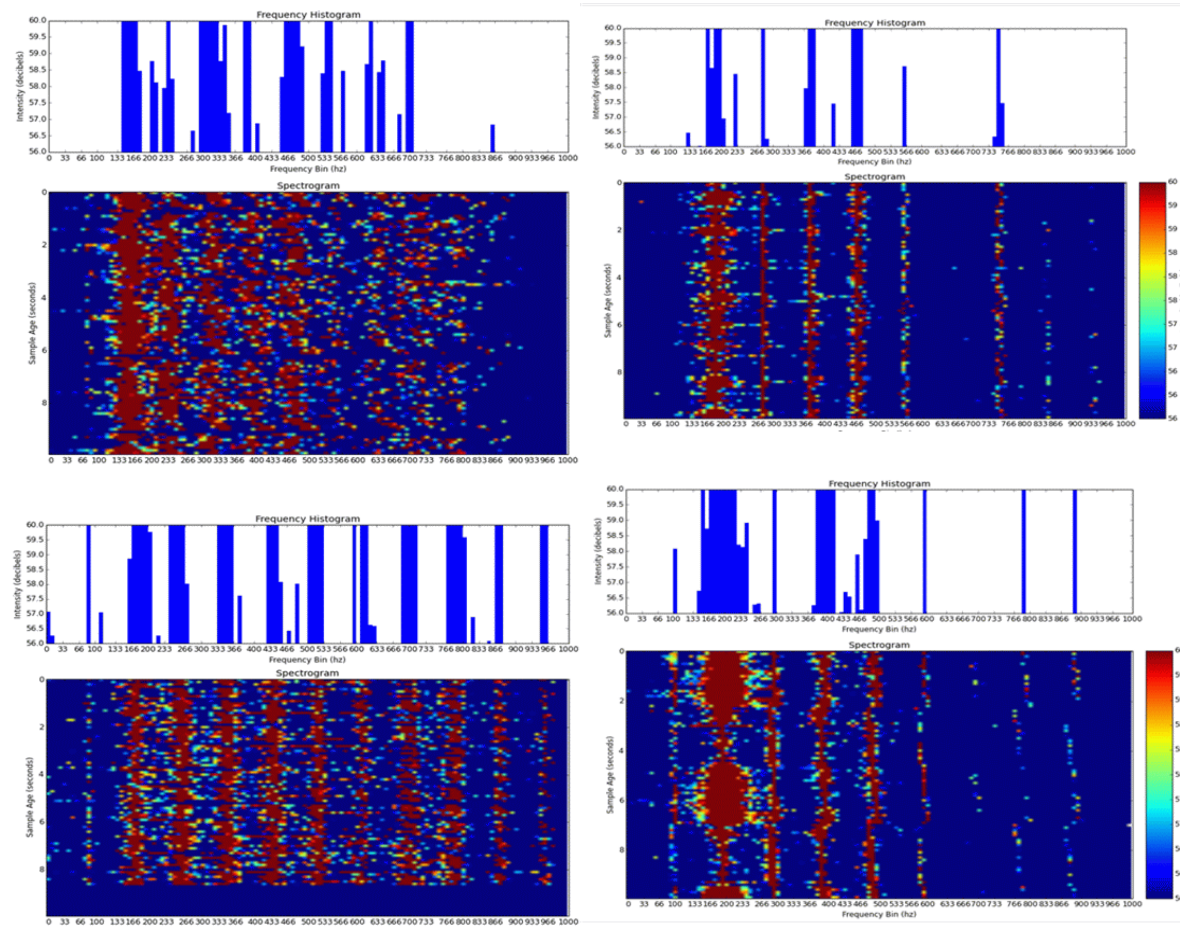
High frequency sounds produced by Cyprian honeybees *Apis mellifera cypria* when confronting their predator, the Oriental hornet *Vespa orientalis**

Alexandros PAPACHRISTOFOROU[1], Jérôme SUEUR[2], Agnès RORTAIS[3], Sotirios ANGELOPOULOS[4], Andreas THRASYVOULOU[1], Gérard ARNOLD[3]





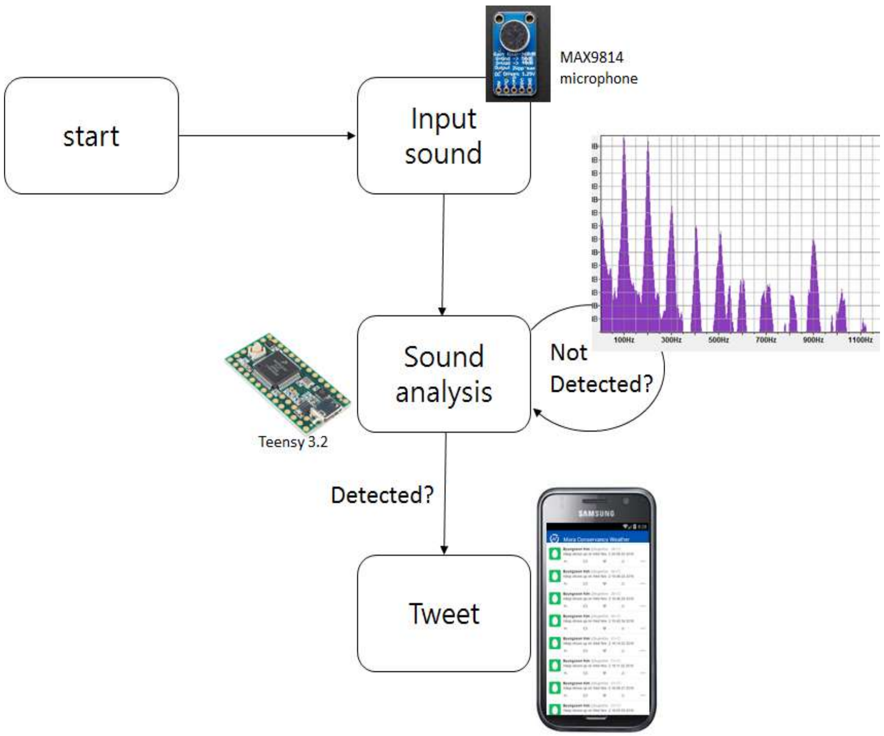
Wing beat frequency profiling



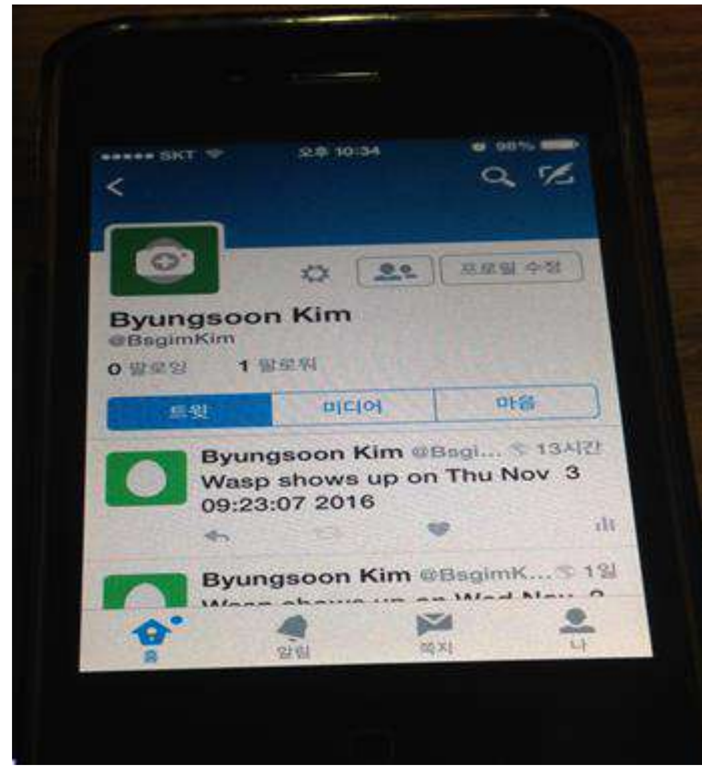
장수말벌

등검은말벌

Automated Hornet alert system



System design

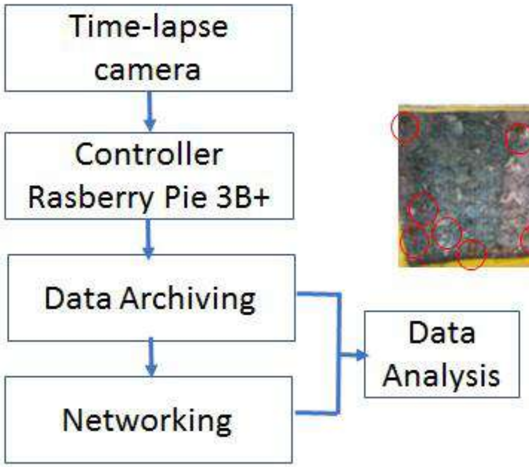


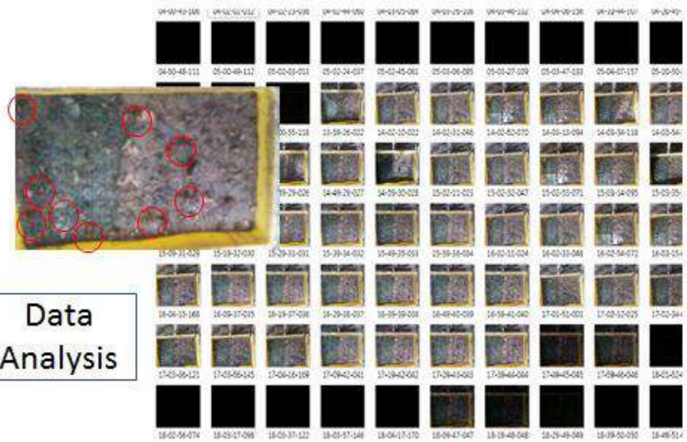
Wireless networking

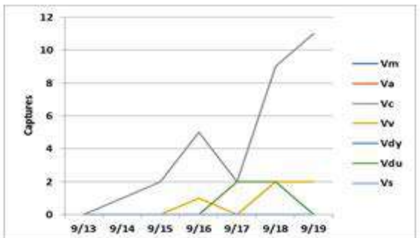
Kim, Jung, 2016

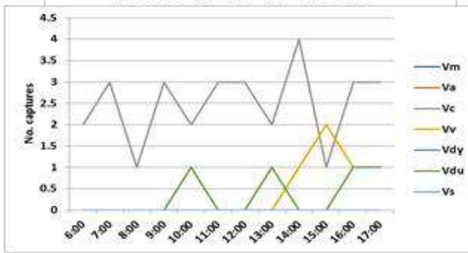
Automated monitoring : AI learning

Design of Automated MOnitoring System of Vespa hortnet (DAMOS Vespa)

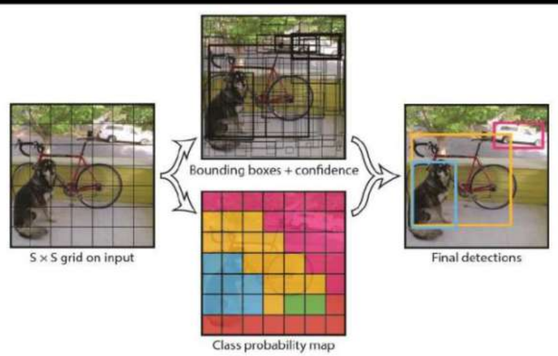








Structure of Yolo Network



Confidence Score: $Pr(Object) * IOU^{truth}_{pred}$ **Conditional Class Probability**: $Pr(Class_i|Object)$

$$
\begin{aligned}
ClassSpecificConfidenceScore &= ConditionalClassProbability * ConfidenceScore \\
&= Pr(Classi|Object) * Pr(Object) * IOU^{truth}_{pred} \\
&= Pr(Classi) * IOU^{truth}_{pred}
\end{aligned}
$$

테스트 결과 (class별 10개, 별도의 test data)

2000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	9(0.9)	1(0.1)	0(0)
유럽말벌	0(0)	0(0)	10	0(0)
꼬마장수말벌	3(0.3)	0(0)	0(0)	7(0.7)

4000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	9(0.9)	1(0.1)	0(0)
유럽말벌	0(0)	0(0)	10(1)	0(0)
꼬마장수말벌	3(0.3)	0(0)	0(0)	7(0.7)

실제값
예측값
TP

6000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	10(1)	0(0)	0(0)
유럽말벌	0(0)	0(0)	10(1)	0(0)
꼬마장수말벌	1(0.1)	0(0)	2(0.2)	7(0.7)

8000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	10(1)	0(0)	0(0)
유럽말벌	0(0)	0(0)	10(1)	0(0)
꼬마장수말벌	3(0.3)	0(0)	1(0.1)	6(0.6)

10000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	10(1)	0(0)	0(0)
유럽말벌	0(0)	0(0)	10(1)	0(0)
꼬마장수말벌	2(0.2)	0(0)	0(0)	8(0.8)

12000weights

	장수말벌	등검은말벌	유럽말벌	꼬마장수말벌
장수말벌	10(1)	0(0)	0(0)	0(0)
등검은말벌	0(0)	10(1)	0(0)	0(0)
유럽말벌	0(0)	0(0)	10(1)	0(0)
꼬마장수말벌	3(0.3)	0(0)	1(0.1)	6(0.6)

For human predation

	V.v	Vm	Vb	Vv	
		Brood		L	P
Total AAs	37.91	36.78	28.05	47.15	53.85
SFAs	5.58	6.19	5.35	5.71	5.12
MUFAs	4.57	5.88	5.55	5.32	4.80
PUFAs	1.38	8.06	11.24	0.64	0.59
Total FAs	11.53	20.12	22.15	11.67	10.51

(Ghosh et al. submitted)

기후변화 민감한 생물종 분포 보면 농업생태계 보인다

2018.11.12. 15:05

Agroecosystem climate change indicator (2018, 11)

 2003년 부산항을 거쳐 우리나라에 들어온 '등검은말벌'은 빠르게 퍼져 전국 모든 농업생태계에서 높은 비율로 관찰되고 있다. 농업진흥청 제공

Invasive species level 1

Min. Environ. (2019, 8)

Lab members: former and current

Kim Dongwon
Kang Moonsu
Jung Seongmin
Hong Seokmin
Lee Daekyoung
Bak Seongbin
Tekalign B.
Delgerma Ul.
Saeed Mohamazaeda
Sampat Ghosh
V.B Meyer-Rochow

Fundings

RDA
MoE
NRF
Gyeongbuk Province
Andong city
Beekeepers coop.
Syngenta

Collaborators

Beekeepers
Ba다 Hyun
Lee Heungsik
Villemante
Tan Ken