

Neonicotinoiden: Een ramp in wording

Dr. Ir. H.A. (Henk) Tennekes

Wageningen, 11 december 2012



„Knowing what I do, there would be no future peace for me if I kept silent...“

Rachel Carson

- Henk Tennekes graduated from the Agricultural University of Wageningen, The Netherlands in 1974 and performed his Ph.D. work at Shell Research in Sittingbourne in the UK.
- He worked at the German Cancer Research Centre in Heidelberg from 1980-1985, where renowned pharmacologist and oncologist Hermann Druckrey became his mentor.
- He was Chief Toxicologist at a Swiss CRO from 1985-1992 and has worked as an independent consultant in toxicology since 1992



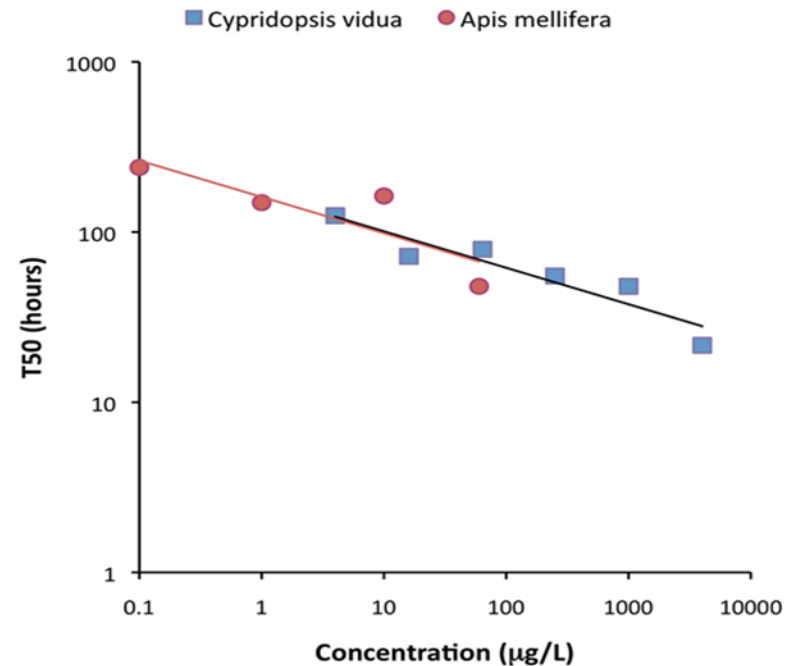
Ontdekking en Paradigma Verschuiving

De Dosis-Werking Relaties van Genotoxische Carcinogenen en Neonicotinoiden lijken opvallend veel op elkaar

Sánchez-Bayo F. 2009. *Ecotoxicology* 18: 343-354

Tennekes, H.A. (2010) *Toxicology* 276, 1–4.

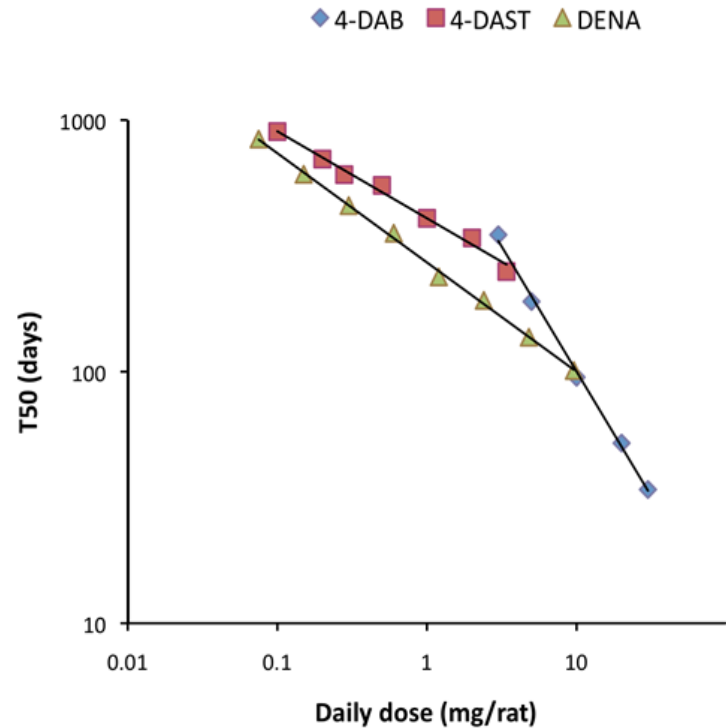
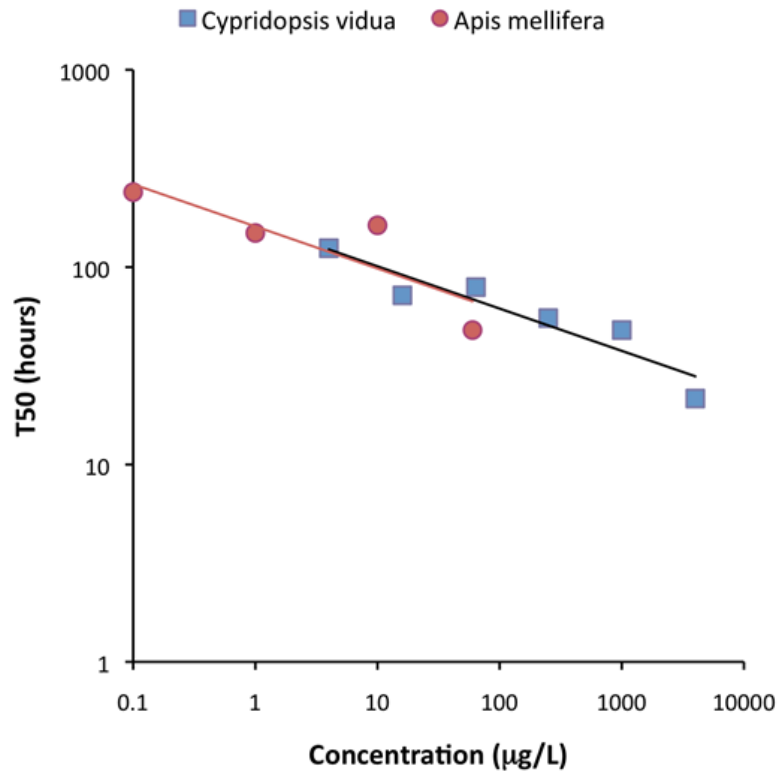
- In 2009, Henk Tennekes discovered that the dose response characteristics of the toxicity of widely used neonicotinoid insecticides to arthropods were strikingly similar to those of genotoxic carcinogens



De Dosis-Werking Relaties van Genotoxische Carcinogenen (rechts) en Neonicotinoiden (links) lijken opvallend veel op elkaar

Druckrey-Küpfmüller Vergelijkingen $C \times T50^n = \text{constant}$, waarbij $n \geq 1$

Tennekes, H.A. (2010) Toxicology 276, 1–4.



Neonicotinoiden Vergiftigen Niet-Doelwit Insecten

- Neonicotinoid insecticides that are currently in use are water soluble (hydrophilic) and permeate the whole plant
- Advantage:
Application rates are much lower than for traditionally used insecticides
- Disadvantage:
Non-target insects such as honey bees or butterflies that collect pollen or nectar from the crop are poisoned



Letale Effecten van Imidacloprid bij Honing Bijen

De giftigheid wordt enorm versterkt door de tijd

Suchail S, Guez D, Belzunces LP, 2001. Environ. Toxicol. Chem. 20: 2482-2486
Tennekes HA, Sánchez-Bayo F, 2012. J. Environment. Analytic Toxicol. S4- 001

- The *lower* the exposure concentration, the *longer* the time period up to a lethal effect, the *lower* the lethal dose
- The Dose : Response Relationship is a Druckrey-Küpfmüller Equation

$$\ln T50 \text{ (hrs)} = 5.11 - 0.22 \ln C \text{ (}\mu\text{g. L}^{-1} \text{ or kg}^{-1}\text{)}$$

or

$$C \times T50^{4.5} = \text{constant}$$

Concentration C ($\mu\text{g/L}$)	Time to Effect T50 (hours)	Lethal Dose ($\mu\text{g/L} \times \text{hours}$)
57	48	2,736
37	72	2,664
10	173	1,730
1	162	162
0.1	240	24



Letale Effecten van Imidacloprid op *Cypridopsis vidua*

De giftigheid wordt enorm versterkt door de tijd

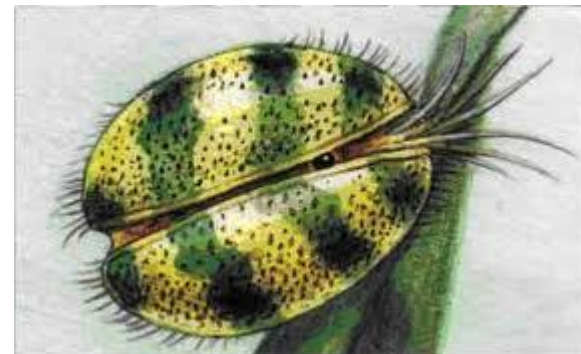
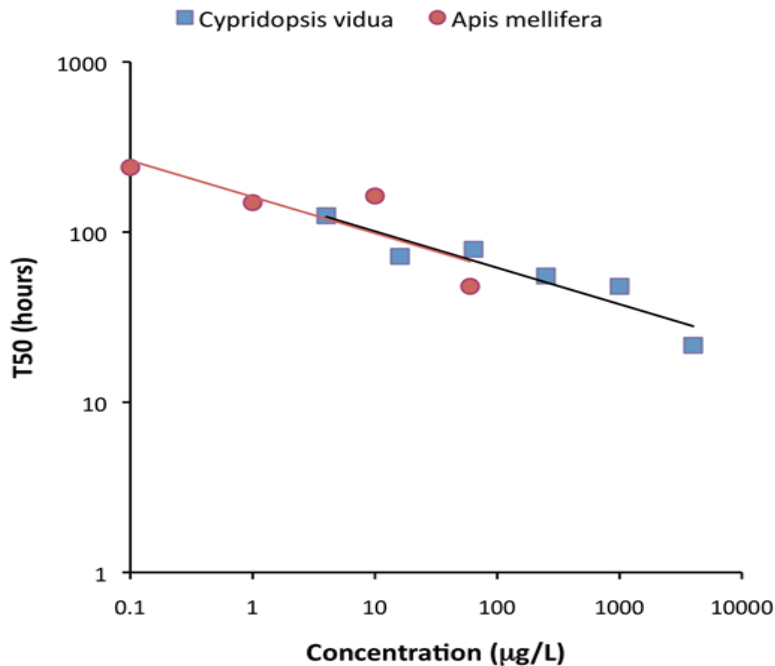
Sánchez-Bayo F. 2009. *Ecotoxicology* 18: 343-354

Tennekes HA. 2010. *Toxicology* 276, 1-4.

Tennekes HA, Sánchez-Bayo F. 2012. *J. Environment. Analytic Toxicol.* S4- 001

- The *lower* the exposure concentration, the *longer* the time period up to a lethal effect, the *lower* the lethal dose

Concentration (µg/L)	Time to Effect (days)	Lethal Dose (µg/L x days)
4,000	0.9	3,600
250	2.3	575
64	3.3	211.2
4	5.2	20.8

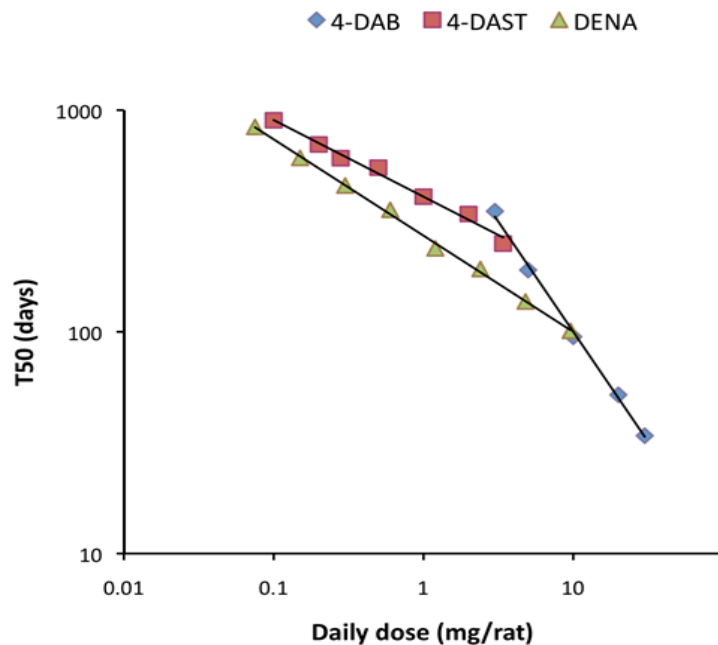


Inductie van Lever Kanker In Ratten Met Diethylnitrosamine

De giftigheid wordt enorm versterkt door de tijd

Druckrey, H., Schildbach, A., Schmaehl, D., Preussmann, R., Ivankovic, S., 1963. Arzneimittelforsch. 13, 841–851

- The *lower* the exposure concentration, the *longer* the time period up to a carcinogenic effect, the *lower* the carcinogenic dose

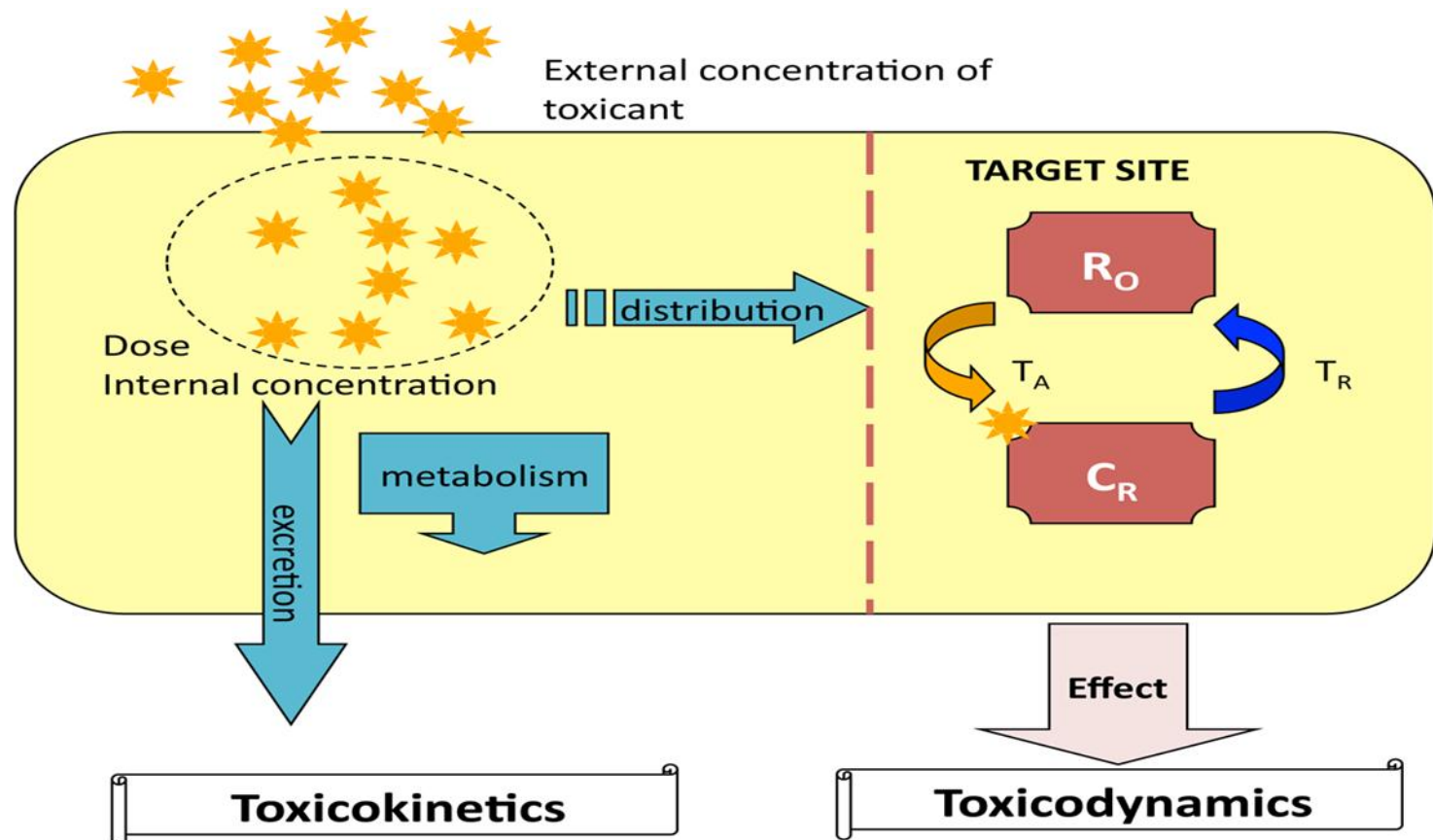


Daily Dose (mg/kg)	Time to Effect (Days)	Carcinogenic Dose (mg/kg)
9,6	101	963
1,2	238	285
0,3	457	137
0,075	840	64



Dosis-Werking Relaties Worden Bepaald Door De Reversibiliteit Van De Receptor Binding

At the target site (CNS), imidacloprid molecules bind to critical receptors and produce a toxic effect. The value of the time constant for dissociation (T_R), which determines the reversibility of receptor binding, is the critical variable that determines the nature of the dose : effect relationship

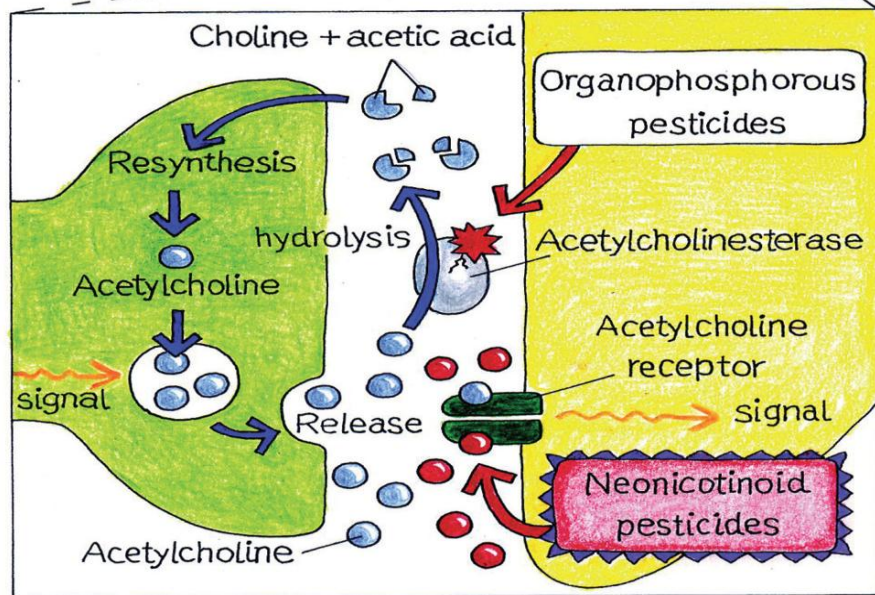
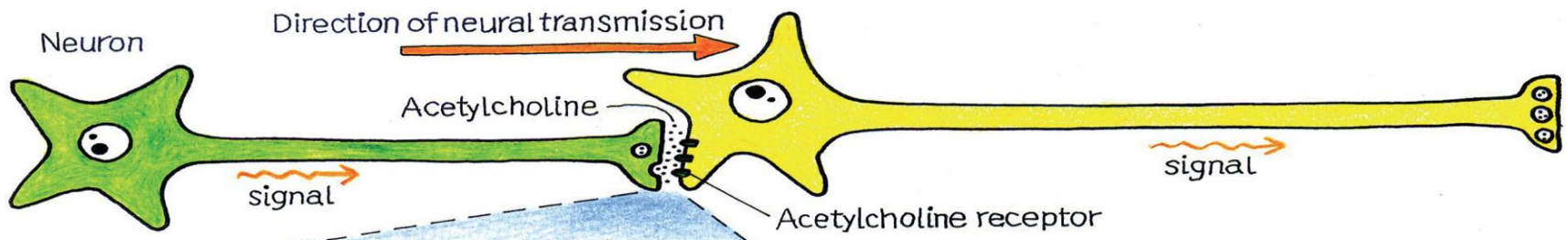


Volgens producent Bayer berust het werkingsmechanisme van Neonicotinoiden op onomkeerbare receptor binding: „Their Mode Of Action Derives From **Virtually Irreversible Blockage Of Postsynaptic Nicotinic Acetylcholine Receptors**“

Abbink, J. (1991) Pflanzenschutz-Nachrichten Bayer, Serial ID-ISSN 0340-1723C.

Neonicotinoid / Organophosphorous pesticides disrupt the neural transmission

Neural transmission mechanism through acetylcholine



Humans and insects cannot live unless the neural transmission functions normally. Neurotransmitters such as acetylcholine and glutamic acid are important substances that carries out this neural transmission.

Organophosphorous pesticides block acetylcholinesterase (hydrolytic enzyme of acetylcholine) and make the neural transmission stay on. It has the same effect as dangerous toxic nerve gas such as the Sarin.

Neonicotinoids bind with acetylcholine receptors, and become "false-neurotransmitters", where neural transmission switch will turn on even if there is no acetylcholine present.

Irreversibele receptorbinding kan tot enorme versterking van de werking leiden

Druckrey, H. & Küpfmüller, K. (1949).

Dosis und Wirkung. Beiträge zur theoretischen Pharmakologie, Editio Cantor GmbH, Freiburg im Breisgau

Tennekes, H.A. (2010) Toxicology 276, 1–4.

- If receptor binding happens to be virtually irreversible, the concentration of bound receptors C_R would be proportional to the integral of the imidacloprid concentration at the target site C over time:

$$C_R \sim \int C dt \quad (1)$$

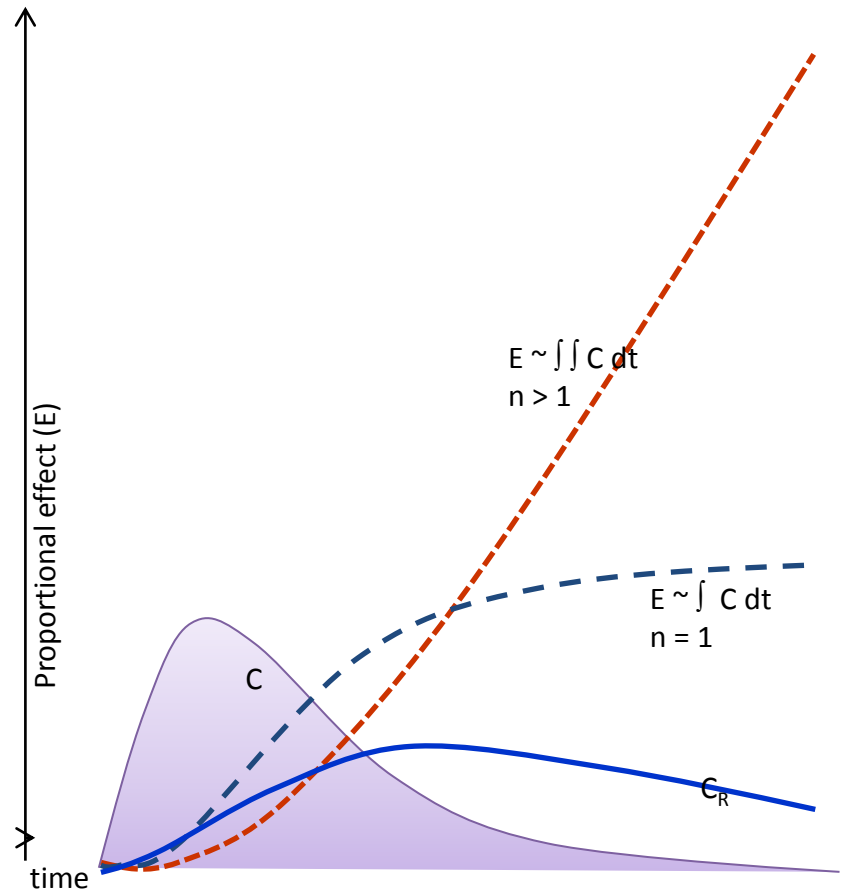
- If the subsequent effect would happen to be irreversible as well (e.g. perturbations of cognitive functions), the effect E would be proportional to the integral of the concentration of bound receptors C_R over time:

$$E \sim \int C_R dt \quad (2)$$

- So, in cases of irreversible receptor binding and an irreversible effect, the effect E would be proportional to the double integral of the imidacloprid concentration at the target site C over time, as the combination of eq. (1) and (2) shows:

$$E \sim \int \int C dt \quad (3)$$

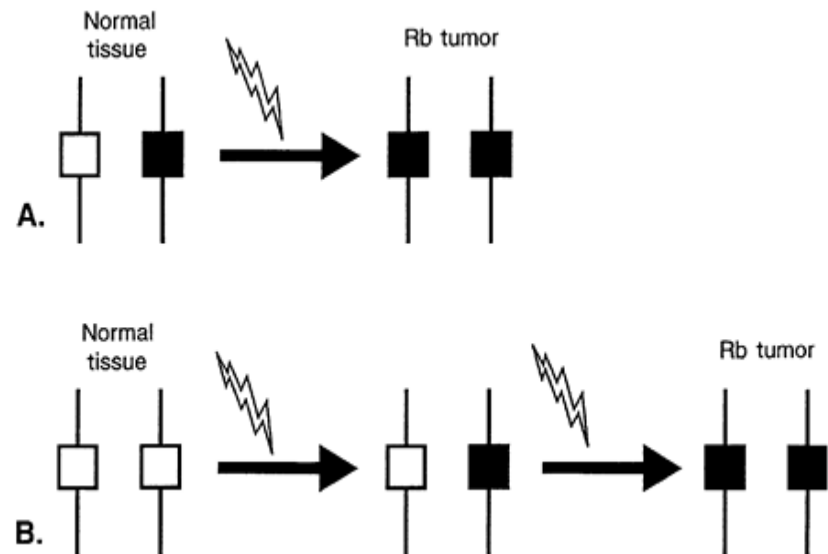
- This explains the imidacloprid dose : response relationship where exposure time reinforces the effect, as seen for genotoxic carcinogens



Een veilige dosis is voor Genotoxische Carcinogenen niet definieerbaar

Knudson AG (1971) Mutation and cancer: statistical study of retinoblastoma Proc Natl Acad Sci U S A. 68(4):820-3

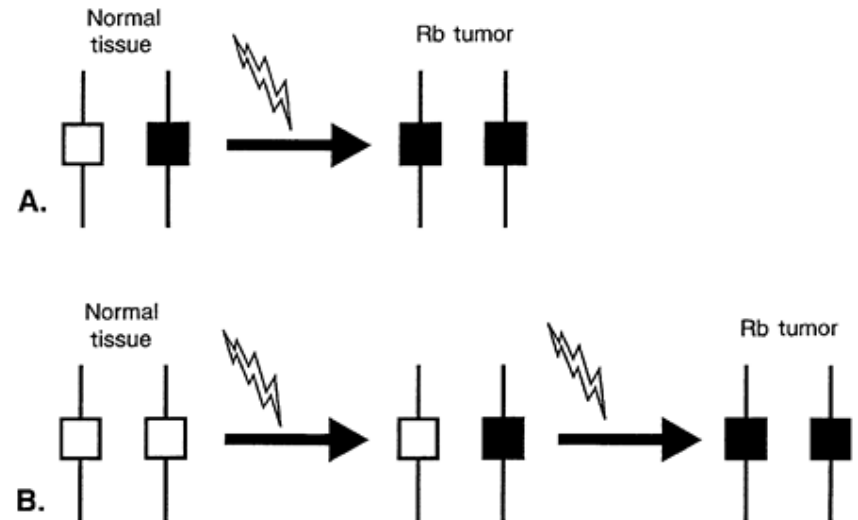
- “one hit” could cause a mutation and eventually result in cancer
The retinoblastoma (Rb) protein is a tumor suppressor protein that is dysfunctional in many types of cancer
- Mutated Rb can be inherited. The mutated gene is recessive
- Should a cell sustain only one mutation in the other Rb gene all pRb proteins in that cell would be ineffective



Risico Analyse van Genotoxische Carcinogenen

EPA, 2005. Guidelines for Carcinogen Risk Assessment, EPA/630/P-03/001F, pp. 1–166

- For genotoxic carcinogens it is now commonly accepted to apply the regulatory default based on the assumption that if “one hit” could cause a mutation and eventually result in cancer, then any exposure level could be associated with a finite cancer probability. With this in mind, the U.S. EPA evaluates carcinogens using a low-dose, linear model



Dosis facit venenum

Het centrale paradigma van de traditionele risico-analyse staat op losse schroeven

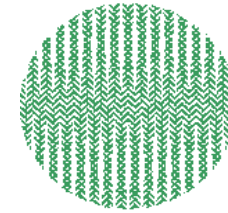
Toxicology: The learning curve. Nature, October 2012

- Risk assessors typically look for adverse effects of a compound over a range of high doses and, from there, extrapolate downwards to establish health standards — always assuming, like Paracelsus, that chemicals toxic at high doses are much less risky at lower, real-world levels.
- On the basis of conventional high-dose testing, **regulators have set maximum acceptable levels that assume all doses below that level are safe.**



De ontdekking van Luc Belzunces

S. Suchail, D. Guez, and L. P. Belzunces (2001) Environ Toxicol Chem. 20:2482-6



INRA

Institut National de la Recherche Agronomique

- Luc Belzunces, a bee researcher at INRA (the French agricultural research institute) in Avignon published “Discrepancy between acute and chronic toxicity induced by imidacloprid and its metabolites in *Apis mellifera*” [Environ Toxicol Chem. 20(11):2482-6]
- He found an acute lethal dose of imidacloprid of only 40 nanogram per bee, much less than most other insecticides. However, his big discovery was that the lethal dose from chronic exposure to imidacloprid was 4,000 times less, “Ingesting 1 picogram a day was enough to kill a bee within 10 days”, he told INRA magazine (June 2009). “ Moreover, imidacloprid degrades into 6 metabolites, some of which are even more toxic.”
- He said that the capacity to measure very small traces of imidacloprid in pollen now shows that **the concentration is in the range of microgrammes per kg (parts per billion) of pollen and that this constitutes a risk for bees.**

Het risico van imidacloprid voor honingbijen wordt onderschat

Suchail S, Guez D, Belzunces LP, 2001. Environ. Toxicol. Chem. 20: 2482-2486

Bonmatin JM et al., 2007. Environmental fate and ecological effects of pesticides. Pp. 827-834

Mullin CA et al, 2010. PloS One 5, e9754

- **Druckrey-Küpfmüller Equation**

$\ln T50 \text{ (hrs)} = 5.11 - 0.22 \ln C \text{ (}\mu\text{g. L}^{-1} \text{ or kg}^{-1}\text{)}$

or

$C \times T50^{4.5} = \text{constant}$

- **The concentrations of imidacloprid detected in nectar or pollen cause lethal effects in honey bees within a week !!**

Food Source	Imidacloprid Content C ($\mu\text{g}/\text{kg}$ or ppb)	Expected Time to Effect (T50) (Days)
Nectar	1	6.9
	3	5.4
Pollen	0.7	7.5
	10	4.2

De neonicotinoiden zijn een voorbeeld van onderschatting van het daadwerkelijke risico door de traditionele risico-analyse

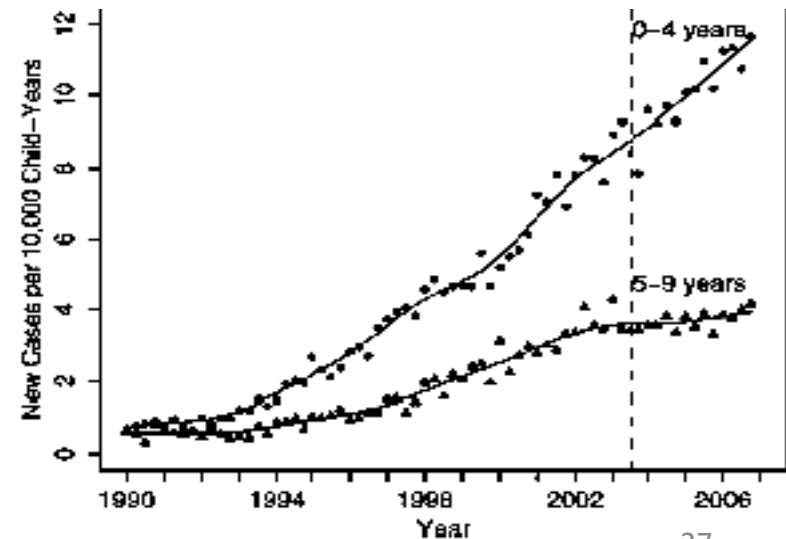
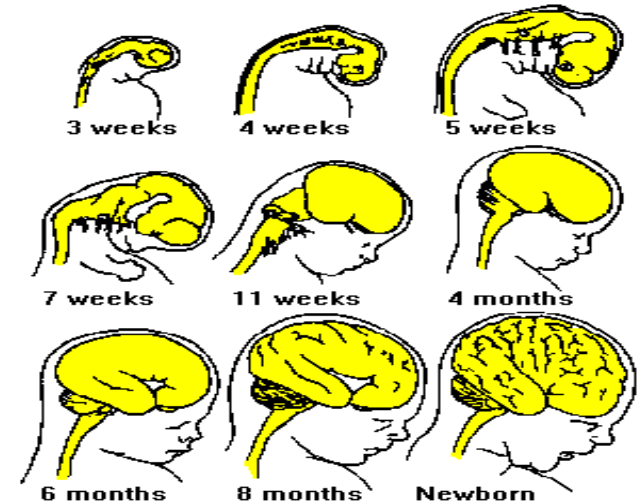


- The traditional approach to toxicity testing is to consider dose (concentration)-effect relationships at arbitrarily fixed exposure durations which are supposed to reflect 'acute' or 'chronic' time scales.
- This approach measures the proportion of all exposed individuals responding by the end of different exposure times.
- Toxicological databases established in this way are collections of endpoint values obtained at fixed times of exposure.
- As such these values cannot be linked to make predictions for the wide range of exposures encountered by humans or in the environment.
- An increasing number of researchers are using a variant of the traditional toxicity testing protocol which includes time to event (TTE) methods.
- This TTE approach measures the times to respond for all individuals, and provides information on the acquired doses as well as the exposure times needed for a toxic compound to produce any level of effect on the organisms tested.
- Consequently, extrapolations and predictions of toxic effects for any combination of concentration and time are now made possible.

Neonicotinoiden kunnen de ontwikkeling van een kind negatief beïnvloeden, met name de ontwikkeling van hersenen

Kimura-Kuroda J et al. (2012) PLoS ONE 7(2): e32432. doi:10.1371/journal.pone.0032432

- Neonicotinoids as well as nicotine directly act on mammalian nAChRs which regulate critical aspects of brain maturation during the prenatal, early postnatal, and adolescent periods
- Perinatal exposure to nicotine is a known risk factor for sudden infant death syndrome, low-birth-weight infants, attention deficit/hyperactivity disorder (ADHD), autism
- The Graph on the Right →:
The rise of autism in California since the introduction of the neonicotinoid insecticides in the early 1990s



A Generation in Jeopardy

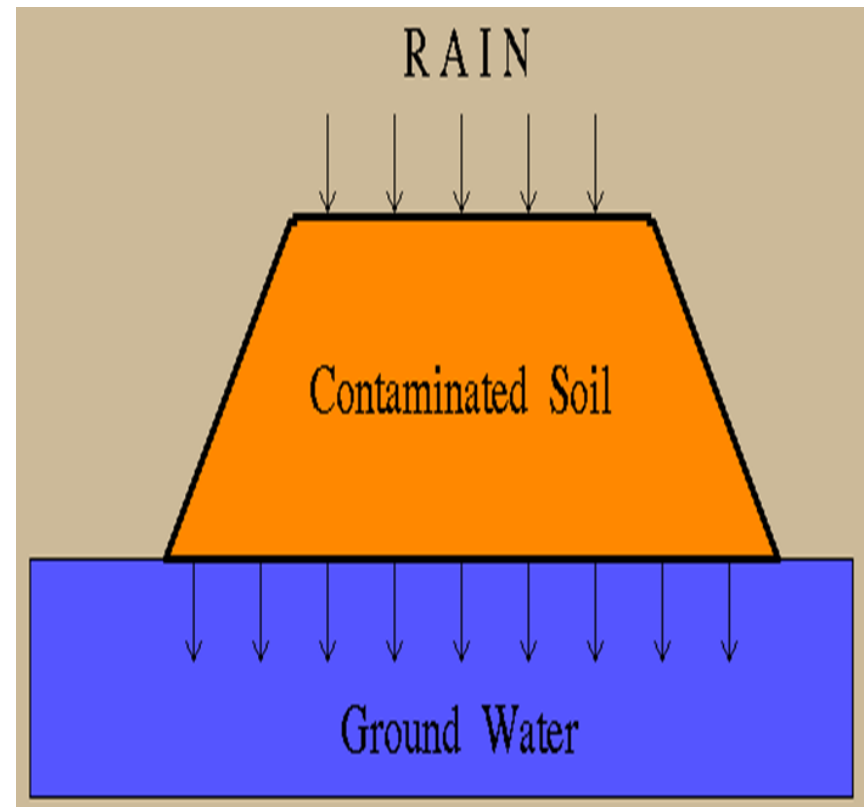
How pesticides are undermining our children's health & intelligence

PESTICIDE ACTION NETWORK NORTH AMERICA , OCTOBER 2012



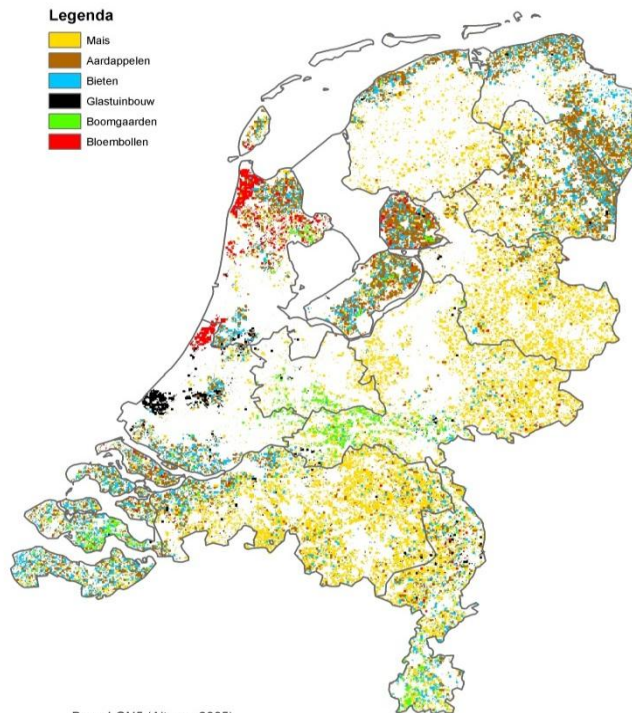
Neonicotinoiden worden uit- en afgespoeld in grond- en oppervlaktewater

- Not only are neonicotinoids water soluble and mobile in soil, they are also quite persistent in soil and water.

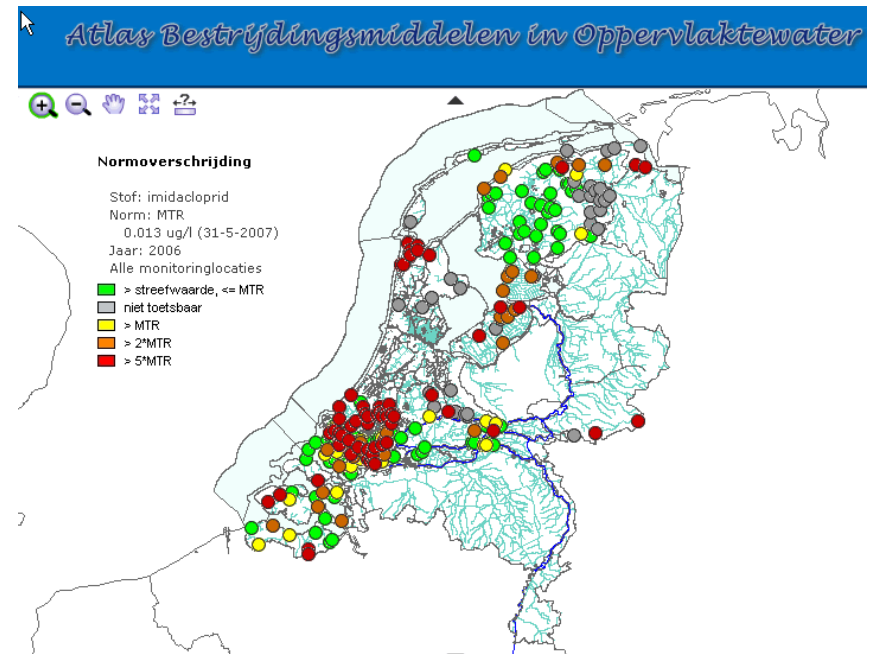


Het neonicotinoïde insecticide Imidacloprid verontreinigt het Nederlandse oppervlaktewater sinds 2004

Red dots (right hand side) : **Maximum Permissible Risk Level (MRL) Exceeded At Least Five Times**
In 2005, MRL Exceeded 25,000 Times at Noordwijkerhout (Flower Bulb Cultivation Area)

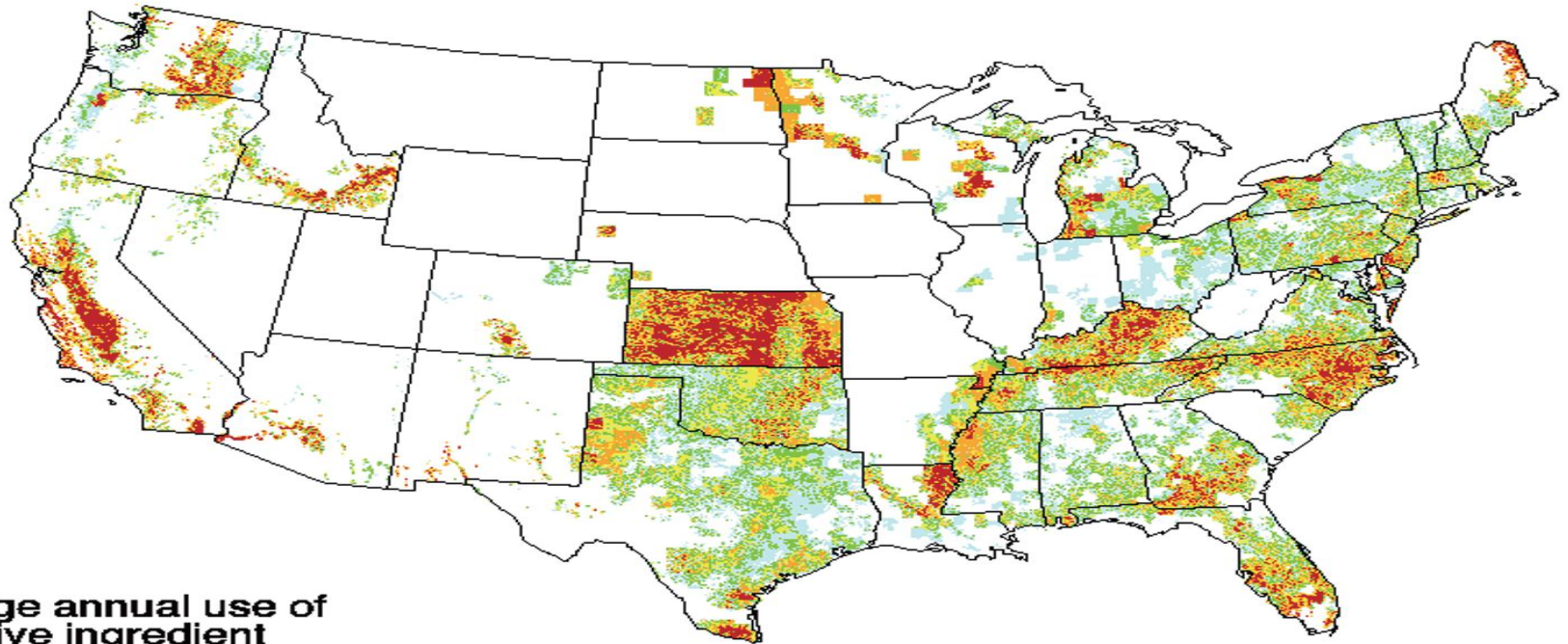


Bron: LGN5 (Alterra, 2005)

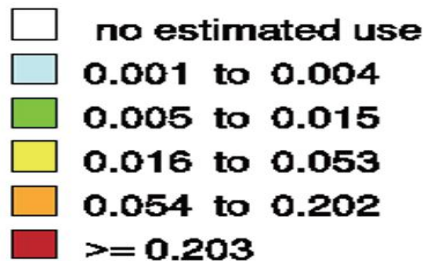


Het gebruik van Imidacloprid in de Amerikaanse landbouw in 2002

US Geological Survey National Water-Quality (NAWQA) Program



average annual use of
active ingredient
per square mile of agricultural
land in county)

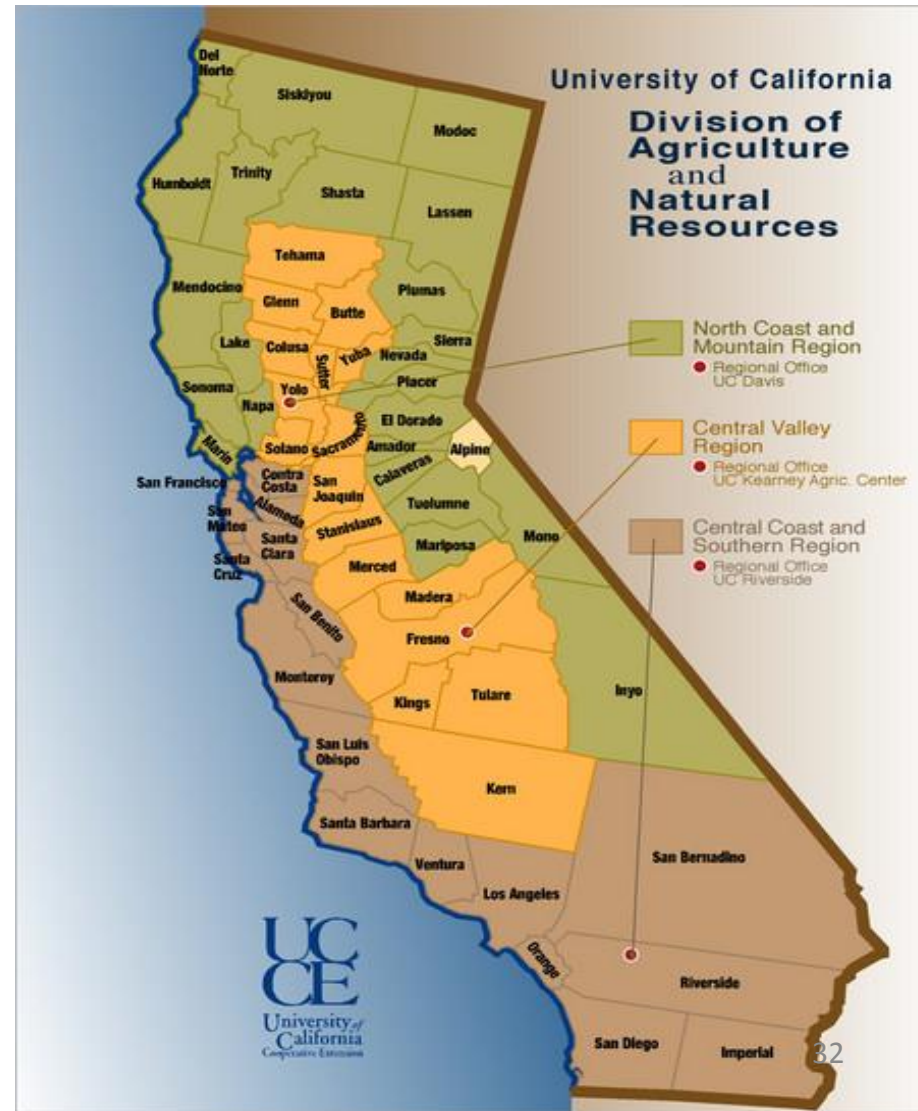


Crops	Total pounds applied	Percent national us
sorghum	95355	26.36
potatoes	59336	16.40
tobacco	43392	11.99
lettuce	35573	9.83
cotton	18147	5.02
grapes	17093	4.72
tomatoes	15211	4.20
citrus fruit	13295	3.68
apples	11268	3.11
pecans	10001	2.76

Ook in landbouwgebieden in Californië verontreinigt Imidacloprid het oppervlaktewater

K Starner and KS Goh (2012) Bulletin of Environmental Contamination and Toxicology DOI: 10.1007/s00128-011-0515-5

- 75 surface water samples from three agricultural regions of California were collected and analyzed for contamination with imidacloprid
- Imidacloprid was detected in 67 samples (89%);
- Concentrations exceeded the U.S. Environmental Protection Agency's (EPA) chronic invertebrate Aquatic Life Benchmark of $1.05 \mu\text{g/L}$ (micrograms per liter) in 14 samples (19%).



Neonicotinoiden verspreiden zich door het milieu

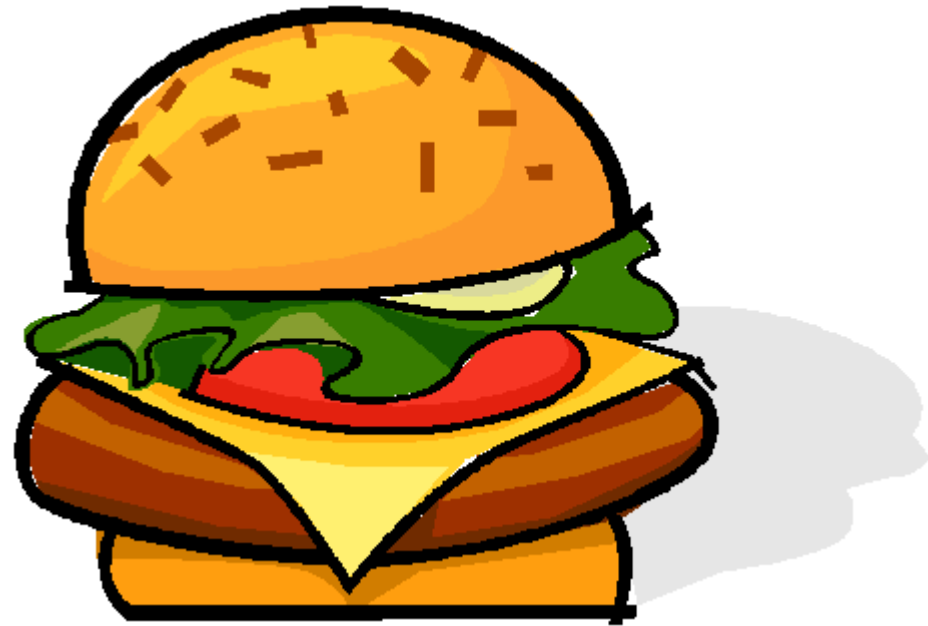
- Imidacloprid is diffusing through the environment in California and the Netherlands, killing or debilitating non-target insects and possibly other arthropods, and by doing so progressively reducing invertebrate prey for higher organisms



Van een Big Mac naar een kaal broodje

May Berenbaum (Entomologist, University of Illinois) NZZ Folio 07/01 - Theme: Käfer und Co

- A McDonald's Big Mac burger in an insect-free world would have no meat, no lettuce, no cheese, no pickle, no onion, and no ketchup; basically, it would be a McBun.



Onze kleding hangt voor een groot gedeelte van insecten af

May Berenbaum (Entomologist, University of Illinois) NZZ Folio 07/01 - Theme: Käfer und Co

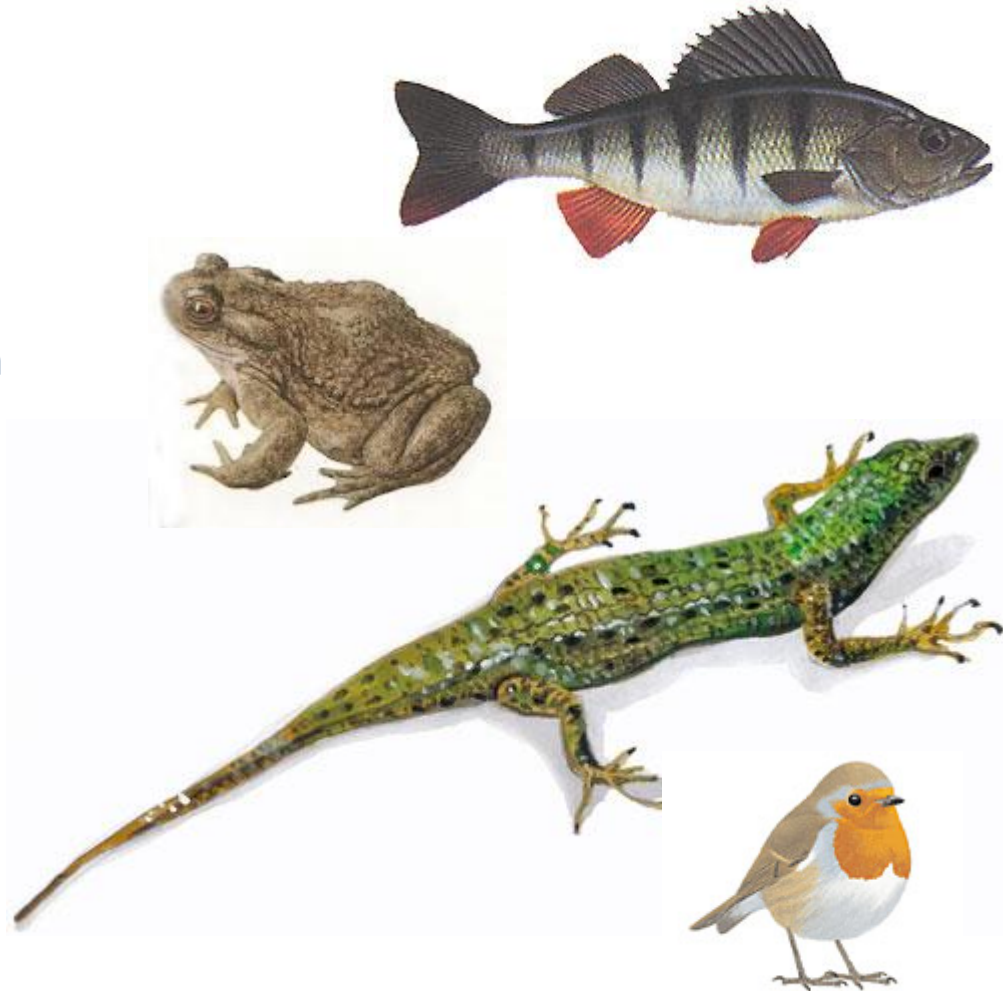
- The **cotton** plant is insect – pollinated
- **Wool** and **leather** come for the most part from sheep and cattle that have eaten insect-pollinated legumes in their diet.
- **Silk**, of course, is a natural fiber produced directly by an *insect*— *Bombyx mori*, the Japanese silkworm



Vele gewervelde dieren zijn afhankelijk van insecten

May Berenbaum (Entomologist, University of Illinois) NZZ Folio 07/01 - Theme: Käfer und Co

- Approximately 40 to 90% of the diet of **freshwater fish** consists of insects
- Among the **amphibians**, frogs, toads, and salamanders depend on insects; about 75% of the diet of the common toad is made up of insects
- Among the **reptiles**, insects are the food of choice for lizards, chameleons, green glass snakes, and horned toads.
- About one-third of the diet of **game birds and songbirds** are insects and their relatives



Rotkehlchen

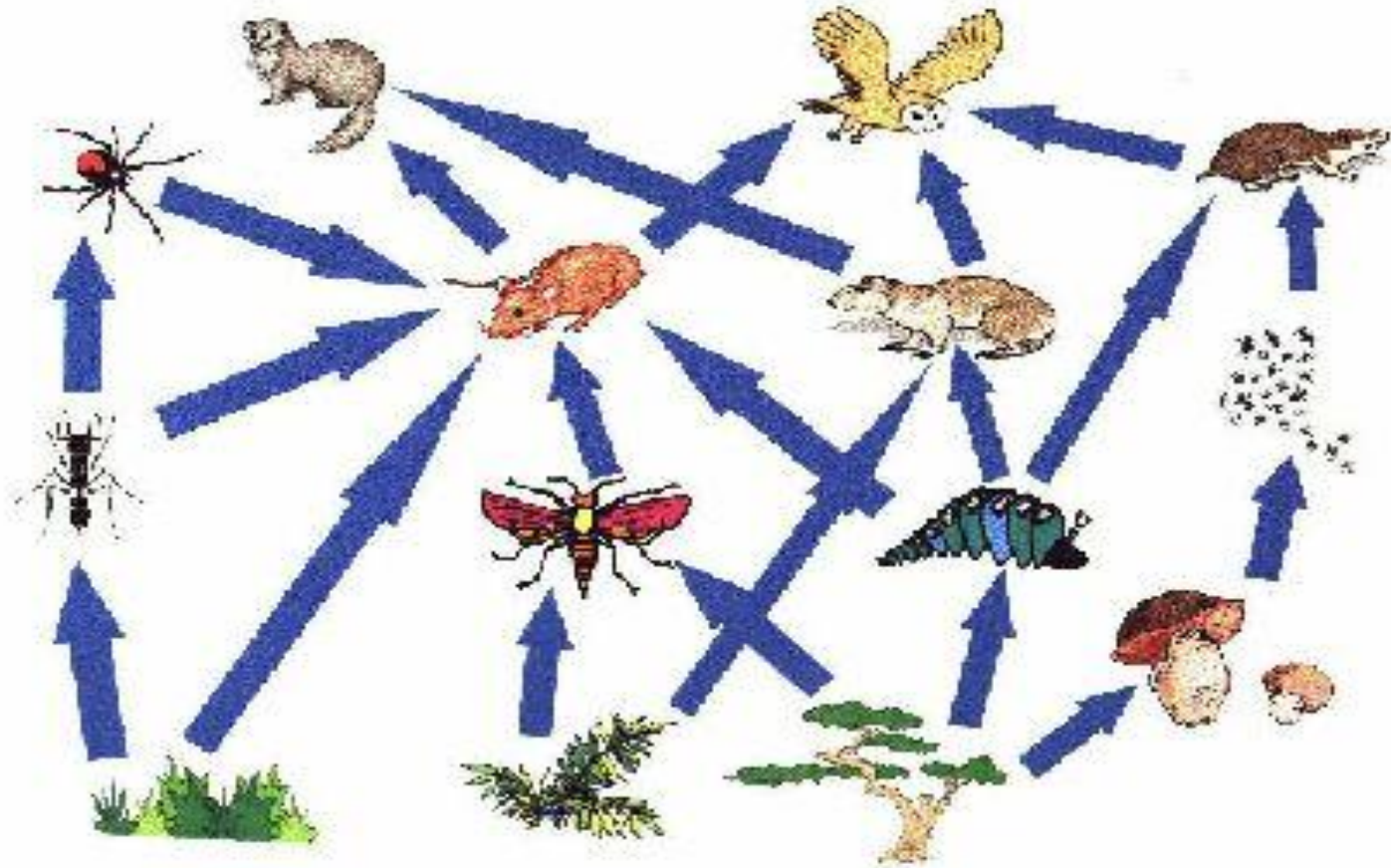
Veel zoogdiersoorten zijn afhankelijk van insecten

May Berenbaum (Entomologist, University of Illinois) NZZ Folio 07/01 - Theme: Käfer und Co

- spiny anteaters, duck-billed platypuses, opossums, cuscuses, caenolestid rat opossums, bandicoots, marsupial moles, hedgehogs, moles, tenrecs, solenodons, shrews, most bats, anteaters, armadillos, pangolins, some mice, and raccoons all consume insects on a regular basis.
- Even among the primates, our closest relatives, insect-eating is the norm; lemurs, aye-eyes, lorises, tarsiers, marmosets, and several of the great apes are to various degrees entomophagous.
- Both gorillas and chimpanzees fashion sticks into tools to help them extract termites and ants from their nests.



Zijn er op dit moment aanwijzingen dat neonicotinoïden de voedselketen breken?



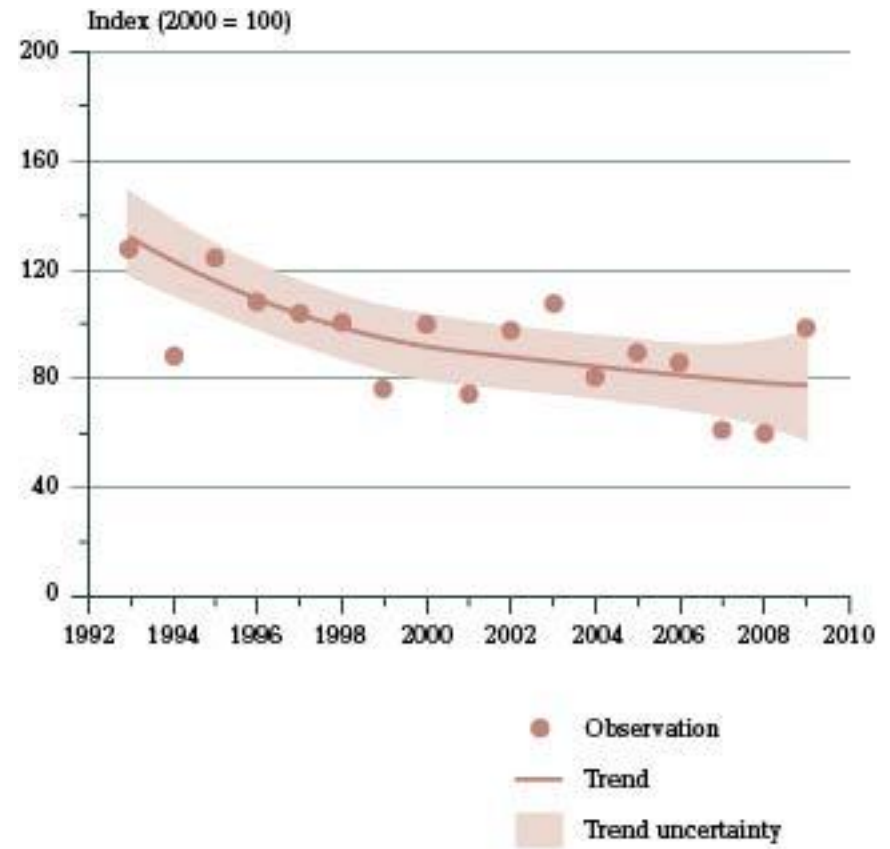
Recent onderzoek toont aan dat insecticiden in de intensieve akkerbouw een negatief effect hebben op de biodiversiteit van wilde planten, kevers en broedvogels

F. Geiger et al. (2010) Basic and Applied Ecology 11, 97-105

- “In a Europe-wide study in eight West and East European countries, we found important negative effects of agricultural intensification on wild plant, carabid and bird species diversity.
- Of the 13 components of intensification we measured, use of insecticides and fungicides had consistent negative effects on biodiversity.
- Insecticides also reduced the biological control potential “



De vlinderstand heeft in Nederland een dieptepunt bereikt



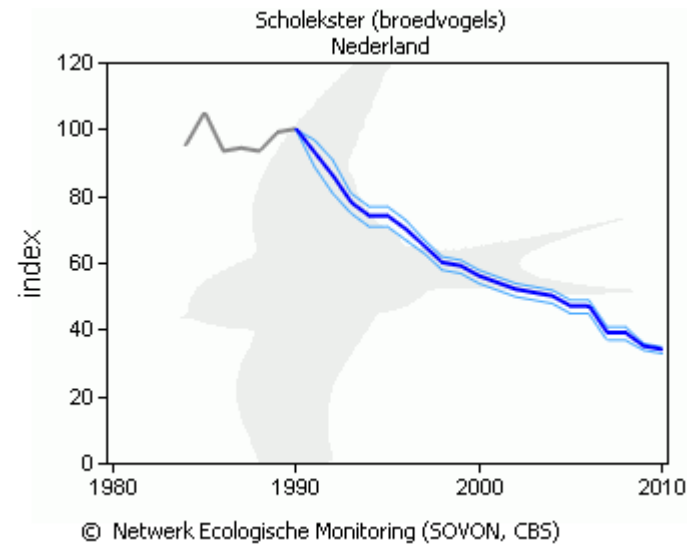
Source: NEM (Vlinderstichting, CBS)

CBS/ju00w/1386
www.compendiumvoordalesomgeving.nl

De achteruitgang van weidevogels in Nederland

Scholekster

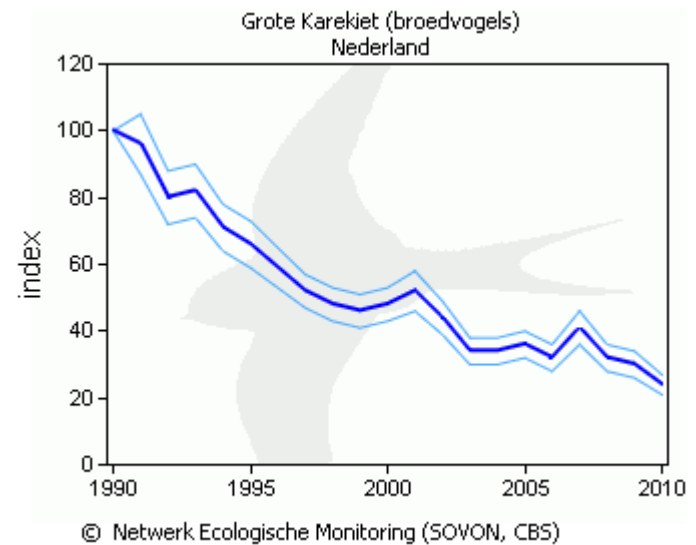
Een karaktersoort van de Noordzeekust dreigt binnen afzienbare tijd uit te sterven



De achteruitgang van moerasvogels in Nederland

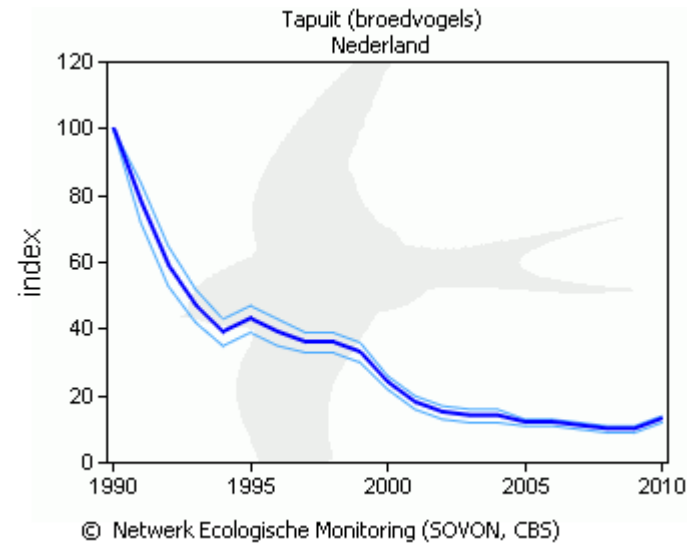
Grote Karekiet

Deze vogelsoort is zo goed als verdwenen uit het Reeuwijkse Plassengebied



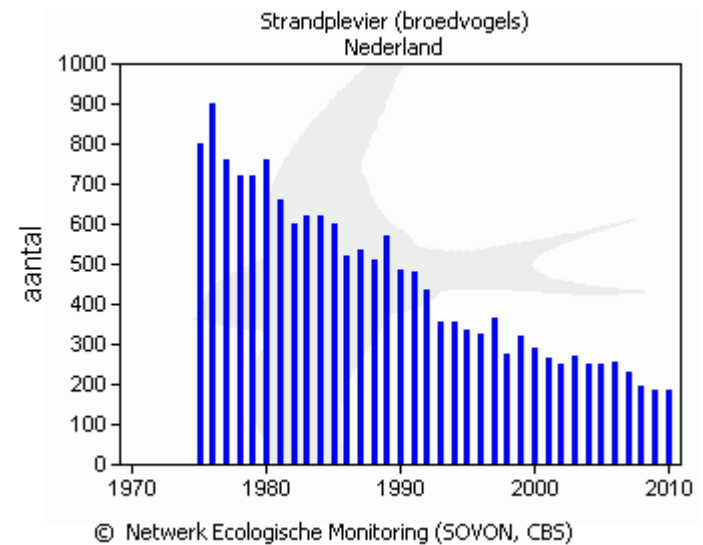
De achteruitgang van heidevogels in Nederland

Tapuit



De achteruitgang van kustvogels in Nederland

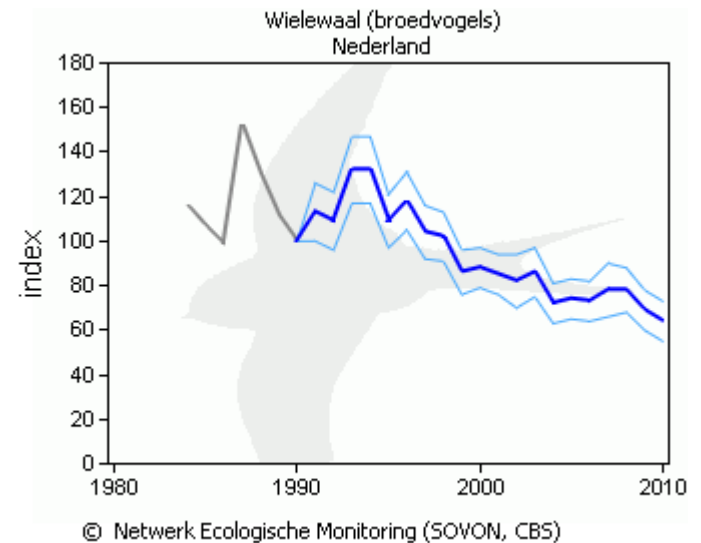
Strandplevier



De achteruitgang van bosvogels in Nederland

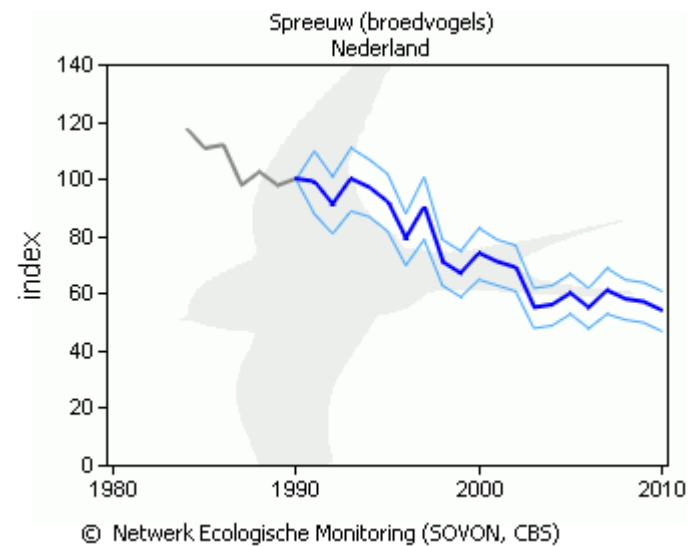
Wielewaal

Kom mee naar buiten allemaal dan zoeken wij de Wielewaal



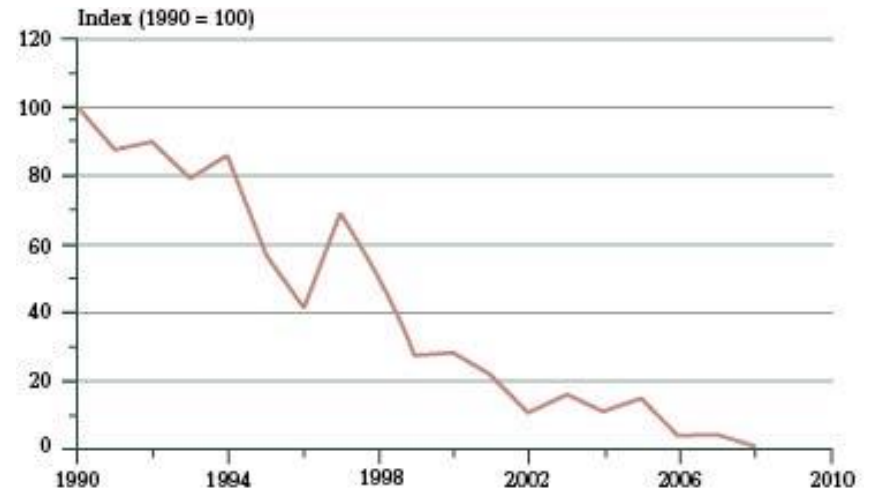
De achteruitgang van vogels in woongebieden in Nederland

Spreeuw



De achteruitgang van akkervogels in Nederland

Grauwe Gors

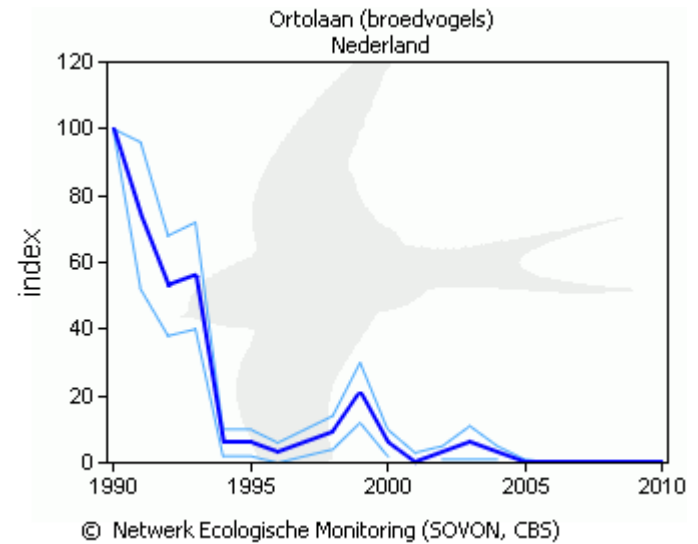


Source: NEM (SOVON, CBS)
CBS/nov09/1389
www.compendiumvoordelastofomgeving.nl

De achteruitgang van akkervogels in Nederland

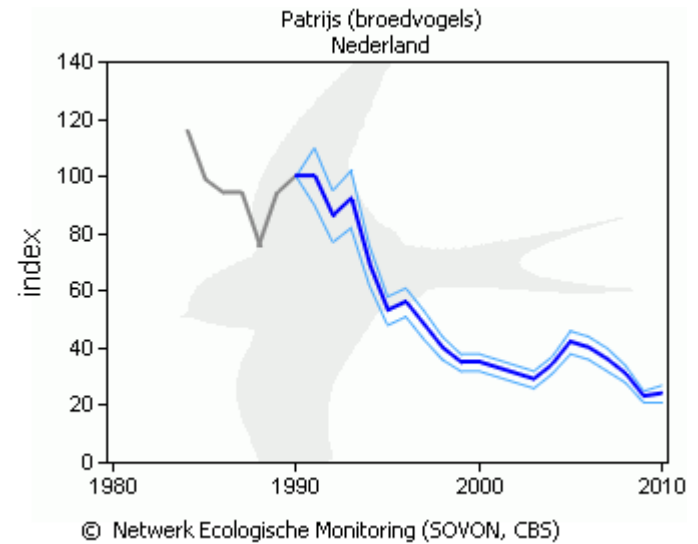
Ortolaan

Eén van de mooiste karaktersoorten van het oude cultuurlandschap op de hoge zandgronden



De achteruitgang van akkervogels in Nederland

Patrijs



Neonicotinoiden veroorzaken Immuun Suppressie

R Mason, H Tennekes, F Sánchez-Bayo, P Uhd Jepsen. *Journal of Environmental Immunology and Toxicology* 2012; X:XX-XX (in press)

- There is experimental evidence of immune suppression in bees and fish by neonicotinoids
- There have been outbreaks of infectious diseases in honey bees, bumble bees, fish, amphibians, bats and birds in the past two decades
- The disease outbreaks started in countries and regions where neonicotinoid insecticides were used for the first time, and later they spread to other countries

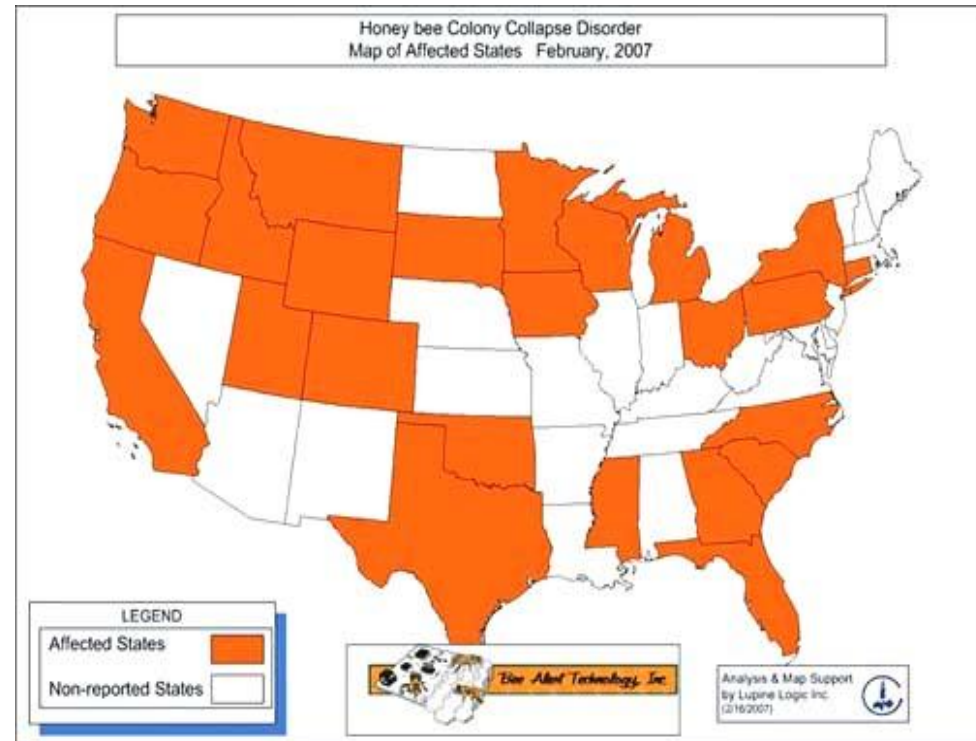


Bijensterfte staat in verband met infecties en immuun suppressie

Cédric Alaux et al. Environ Microbiol. (2010) 12(3): 774–782

Pettis, JS et al. (2012) Naturwissenschaften DOI 10.1007/s00114-011-0881-1

- Neonicotinoids are weakening the insects' immune systems, and thus allowing infections to spread through a hive
- One thing common to bee colonies that go on to collapse is a greater variety and higher load of parasites and pathogens than other colonies



De achteruitgang van hommelse soorten staat in verband met infecties

Cameron, S.A. et al. (2011) Proc. Natl Acad. Sci. USA 108, 662-667

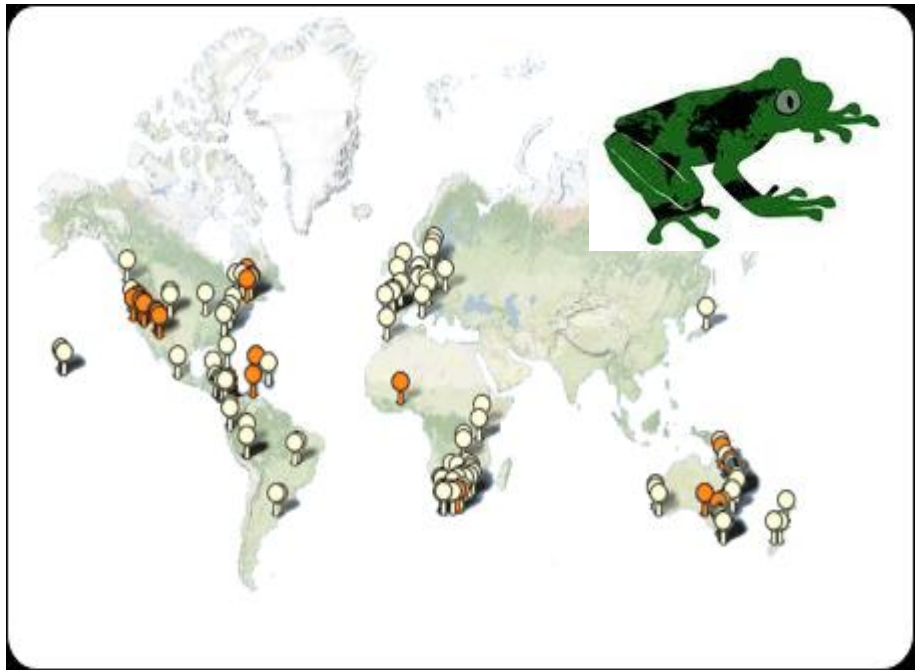
- Comparing results with museum records of bumble bees showed that the relative abundances of four species had declined historically by up to 96%. Geographical ranges had contracted by 23-87%, some within the past two decades.
- Those species that had declined had significantly higher infection levels of the pathogen *Nosema bombi*
- Exposure to neonicotinoid insecticides is likely to have occurred and may have weakened immune systems, such that they became more susceptible to pathogens



De achteruitgang van de amfibieën staat in verband met infecties

Symposium held at the Zoological Society of London: 20/21 November 2008. Halting the global declines in amphibians.
Research & Practice

- Two species of once common frogs that had inhabited the thousands of lakes and ponds in California's Sierra Nevada are being wiped out by ***chytridiomycosis***
- Exposure to small doses of neonicotinoid insecticides is likely to have occurred and may have weakened the amphibian immune systems, such that they became more susceptible to pathogens



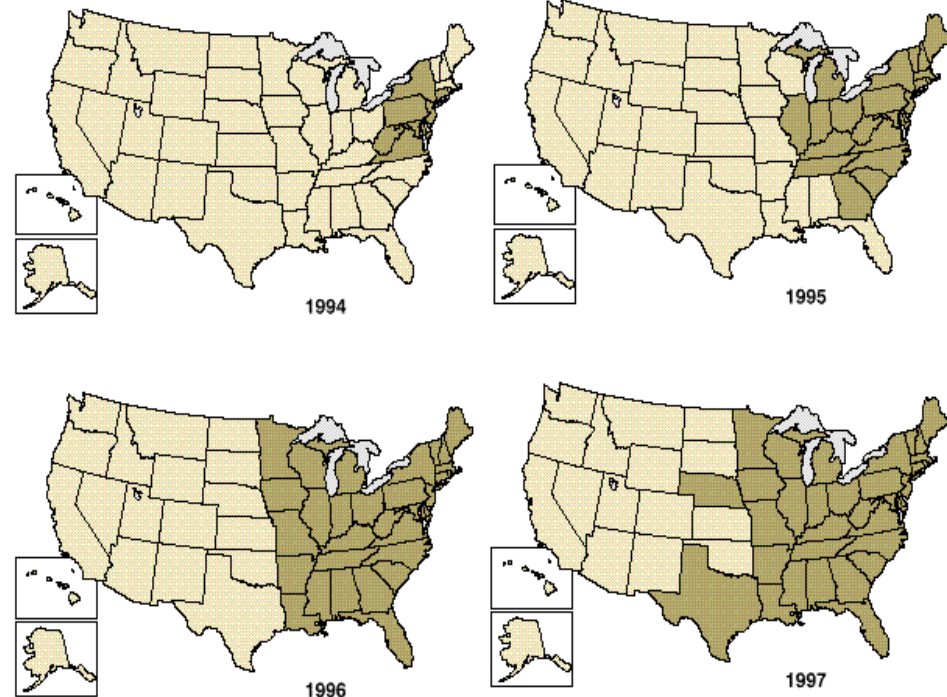
De achteruitgang van de Mexikaanse roodmus staat in verband met infecties

Fischer JR, Stallknecht DE, Luttrell P, et al. Emerg Infect Dis 1997; 3(1):69-72.



- A mycoplasmal conjunctivitis was first reported in wild house finches (*Carpodacus mexicanus*) in February 1994 in suburban Washington, DC.
- It was identified as ***Mycoplasma gallisepticum***, a pathogen of poultry that had not previously been associated with wild songbirds.
- In the first three years it killed an estimated 225 million finches. There was a dramatic spread of disease to house finches in the mid-West and South East

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EXPLANATION
Spread of house finch conjunctivitis
■ States where disease has been detected

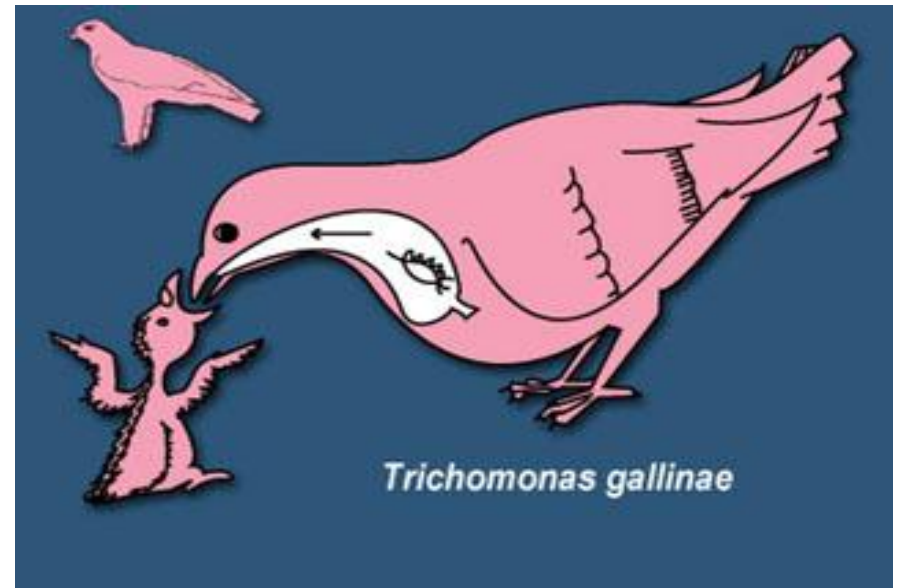
Reported geographic spread of house finch inner eyelid inflammation (conjunctivitis) since the initial 1994 observation. (Data adapted from reports in the scientific literature and personal communications between the National Wildlife Health Center and other scientists.)

De achteruitgang van de groenling en de vink staat in verband met infecties

Robinson RA, Lawson B, Toms MP, et al. PLoS One 2010; 5(8):e12215.

Lawson B, Malnick H, Pennycott TW, et al. Vet J 2011; 188(1):96-100

- In Europe epidemics caused by a variety of novel pathogens in wild birds began in early 2000
- Greenfinch (*Carduelis chloris*) numbers in Europe have been devastated by infections with ***Trichomonas gallinae***, a protozoal organism which invades the bird's crop and mucosal lining of the beak. Deaths started in the UK around 2005
- At the same time, chaffinches (*Fringilla coelebs*) appeared in gardens with white, crusty growths on their legs and feet caused by a ***papilloma virus***. The mortality is said to be about 20%, so the disease kills more slowly than with the Greenfinch *Trichomonas* infections



De achteruitgang van de merel staat in verband met infecties

Friedrich-Loeffler-Institute. Federal Research Institute for Animal Health. News 16/09/2011

- In September 2011, mass deaths of Blackbirds (*Turdus merula*) were reported in the Rhine-Neckar area of Germany
- The Bernhard-Noct Institute for Tropical Diseases and the Friedrich-Loeffler Institute examined four birds and confirmed that it was the tropical **Usutu Virus** from Africa
- It was first seen in Austria in 2001, followed by reports from Italy, Hungary and Switzerland. In birds it first causes apathy, then signs of a central nervous system disorder, with unnatural movements of the head
- An estimated 300,000 blackbirds were killed by the disease





Samenvatting

- Neonicotinoid insecticides act by causing **virtually irreversible blockage of postsynaptic nicotinic acetylcholine receptors (nAChRs)** in the central nervous system of insects.
- The damage is cumulative, and with every exposure more receptors are blocked. In fact, **there may not be a safe level of exposure.**
- The nAChRs play roles in many cognitive processes and neonicotinoids account for worker bees neglecting to provide food for eggs and larvae, and for a breakdown of the bees' navigational abilities. **Very small quantities of neonicotinoid insecticides are sufficient to cause collapse of bee colonies**
- Food residues of **neonicotinoids may adversely affect human health, especially the developing brain**
- **Neonicotinoid insecticides** are persistent and mobile in soil, soluble in water and stable to breakdown by water at neutral pH, and - as a result of these properties - the compounds **may leach from soils.**
- **Major contamination of surface water with imidacloprid** has been detected in the Netherlands and in California
- Consequently, **high concentrations of imidacloprid have been diffusing through the environment**, killing or debilitating non-target insects and other arthropods, **decimating invertebrate prey for higher organisms.** Moreover, **imidacloprid causes immune suppression in bees and freshwater fish and may be at the root of global wildlife declines**
- Breaking one link on the food chain means that all of the **higher organisms above that link are in threat of extinction**

Conclusie

Een ramp in wording - Neonicotinoiden breken de voedselketen

- **Invertebrate-dependent bird species in the Netherlands have been declining on a massive scale in recent times, in all kinds of habitats** (grasslands, marshes, heathlands, at the coast, woodlands, settlements, farmlands):
- *Skylark, Yellow Wagtail, Oystercatcher, Black-tailed Godwit, Northern Lapwing, Common Redshank, Meadow Pipit, Willow Tit, Spotted Flycatcher, Wood Warbler, Pied Flycatcher, Wood Nuthatch, Willow Warbler, Marsh Tit, Grey-faced Woodpecker, Wryneck, Common Crossbill, Golden-Oriole, Northern House Martin, Barn Swallow, Common Swift, Starling, House Sparrow, Common Redstart, Great Reed Warbler, Bearded Tit and Spotted Crake*
- Ground and surface water contamination with persistent insecticides that cause irreversible and cumulative damage to aquatic and terrestrial (non-target) insects must lead to an environmental catastrophe.
- The data presented here show that **an environmental catastrophe is actually taking place before our eyes**, and that

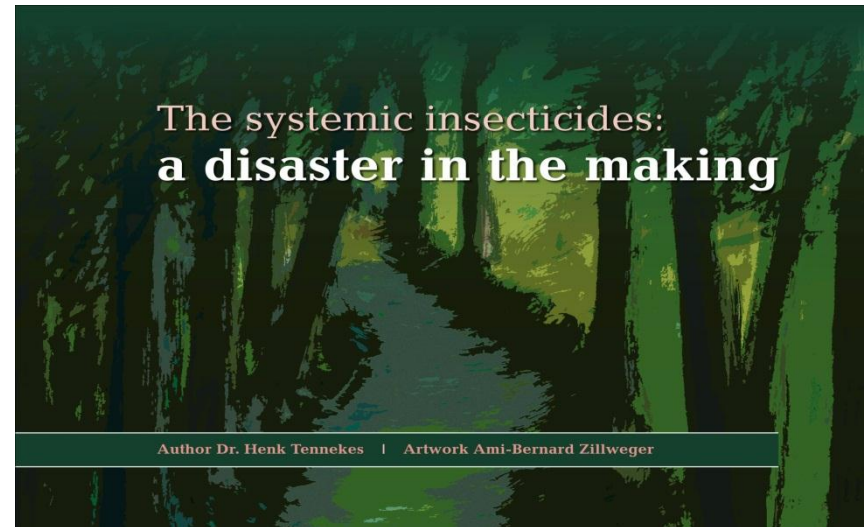
IT MUST BE STOPPED



„Knowing what I do,
there would be no future peace for me if I kept silent...”

Rachel Carson

- Realising the dire consequences of environmental pollution with neonicotinoid insecticides, Henk Tennekes decided to write a book to warn the general public about an impending environmental catastrophe



German Edition of 'A Disaster in the Making'

Preface by Professor Hubert Weiger, Chairman, *Friends of the Earth Germany*

German Translation: Sven Buchholz Tomas Brückmann Patricia Cameron



Das Ende der Artenvielfalt: **Neuartige Pestizide töten Insekten und Vögel**

Autor: Dr. Henk Tennekes | Illustrationen: Ami-Bernard Zillweger

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