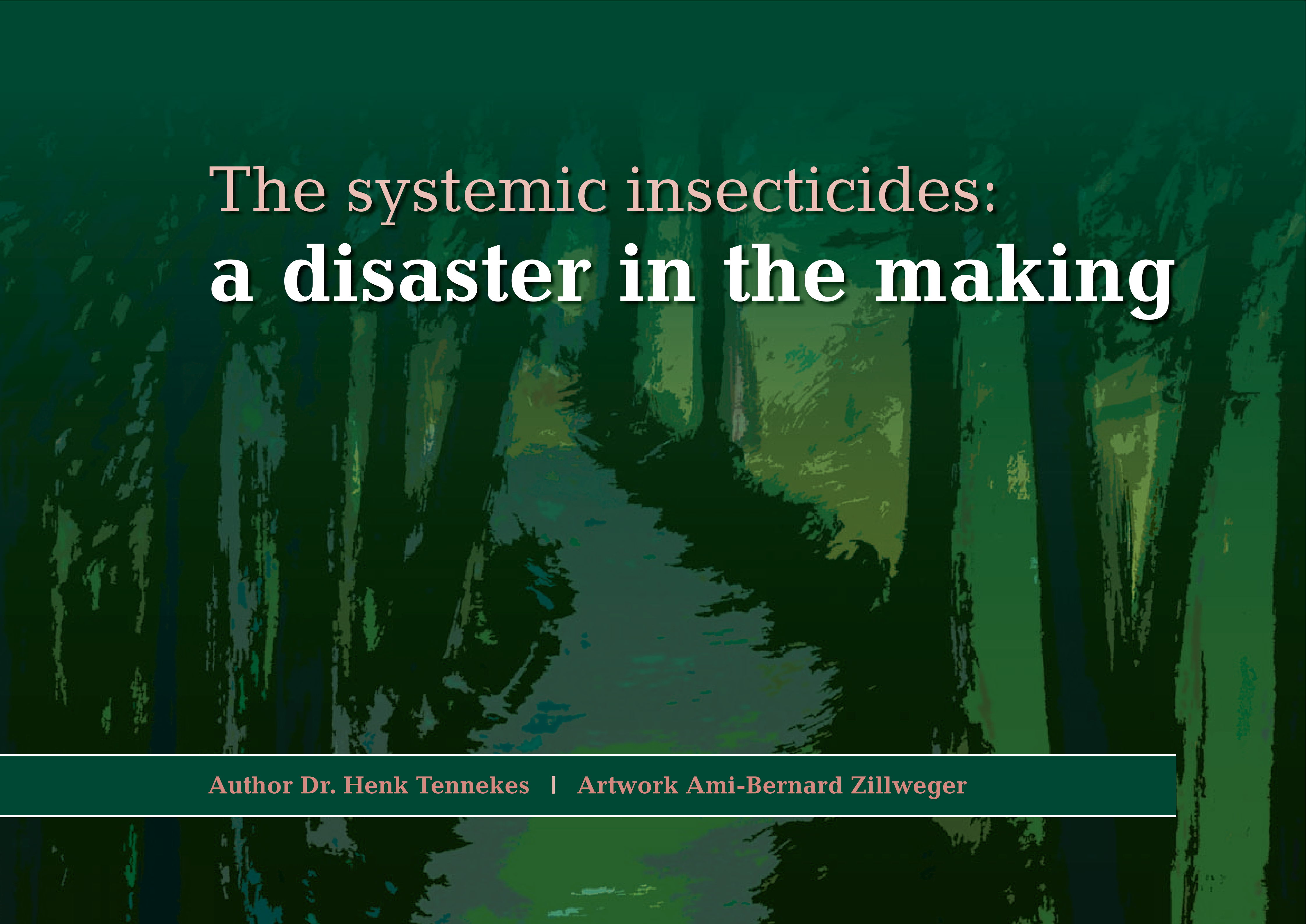

The systemic insecticides: **a disaster in the making**

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The Netherlands, under controlled conditions in

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by the SCGM, Certificate Number SCGM-DI:2010.01.11

The systemic insecticides:
a disaster in the making

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ISBN/EAN: 978-90-79627-06-6

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Preface

An ecological crisis threatens to bring global agriculture to a standstill. Bees, the number one insect pollinator on the planet, are dying at an alarming rate. In parts of China farmers are already forced to pollinate by hand. Many believe that pests, such as the varroa mite, are at the root of this devastation, but recent French studies indicated that these pests struck particularly hard in areas where a new class of insecticides, the so-called neonicotinoids, were being used. Neonicotinoids are revolutionary because they are put inside seeds, and permeate the whole plant because they are water soluble, which is why they are called *systemic* insecticides. Any insect that feeds on the crop dies. The neonicotinoids may seem ideal insecticides because application rates are much lower than for older, traditionally used insecticides, but, unfortunately, there are catastrophic disadvantages as well.

Any bee or butterfly that collects pollen or nectar from the crop is poisoned. Neonicotinoids bind *irreversibly* to critical receptors in the central nervous system of insects. The damage is cumulative. The French *Comité Scientifique et Technique* concluded in 2003 that neonicotinoids were implicated in a mass die-off of the bee population. In 2008, Germany banned seed treatment with neonicotinoids after bee keepers had suffered a severe decline linked to the use of the neonicotinoid insecticide clothianidin in the Baden-Württemberg region of Germany.

The second catastrophic disadvantage of neonicotinoids is their potential to leach from soils. Soil acts as a major sink for bulk of the pesticides used in agriculture and public health programs. Pesticides may cause problems when they seep out of storage or are washed out of the soil into waterways and groundwater. The chemicals are then diffused through the environment and may affect marine and bird life. Neonicotinoids are prone to cause such problems because not only are they water soluble and mobile in soil, they are also quite *persistent* in soil and water. Not surprisingly, the widely used neonicotinoid insecticide imidacloprid has caused major contamination of Dutch surface water since 2004.

"It is not my contention that chemical insecticides must never be used. I do contend that we have put poisonous and biologically potent chemicals indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm."

Rachel Carson
Silent Spring (1962)

Ground and surface water contamination with persistent insecticides that cause irreversible damage to non-target insects is an environmental disaster in the making. The excessive imidacloprid levels noted in surface water of western Dutch provinces with intensive agriculture have already been associated with insect decline and a dramatic decline of common grassland birds. Graham White, an environmental author who keeps bees in the Scottish Borders, recently wrote: "We are witnessing an ecological collapse in all the wildlife that used to live in fields, hedgerows, ponds and streams. All the common species we knew as children are being wiped from the face of the countryside."

Henk Tennekes
Zutphen, September 2010

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The use of neo-nicotinoid insecticides

The 2005 insecticide sales figures for Germany[1] (Table 1) show that the neo-nicotinoid insecticide **imidacloprid**, which was introduced in 1991, is now widely used. This compound is highly toxic to honey bees, persistent in soil, and has high leaching potential[2]. Imidacloprid may be washed out of the soil into waterways and groundwater[3]. The chemical is then diffused through the environment. Other neo-nicotinoid insecticides, such as **clothianidin** and **thiamethoxam**[4], have similar properties.

Table 1. Quantities and properties of insecticides sold in Germany in 2005

Insecticide	Sales in 2005 (tonnes)	Acute (48h) LD50 honey bee in ng bee $^{-1}$		Soil degradation	Leaching potential
Dimethoat	100 - 250	120	(contact)*	non-persistent	low
Methiocarb	100 - 250	230	(contact)	non-persistent	low
Imidacloprid	25 - 100	3.7	(oral)	**persistent**	**high**
Methamidophos	25 - 100	220	(oral)	non-persistent	transition state
lambda-Cyhalothrin	25 - 100	38	(contact)	non-persistent	low
Pirimicarb	10 - 25	4000	(oral)	moderately persistent	transition state
Alpha-Cypermethrin	10 - 25	33	(contact)	moderately persistent	low
Beta-Cyfluthrin	10 - 25	1	(contact)	non-persistent	low
Delthamethrin	2.5 - 10	1.5	(contact)	non-persistent	low
Clothianidin	2.5 - 10	4	(oral)	**very persistent**	**high**
Thiacloprid	2.5 - 10	17320	(oral)	non-persistent	low
Thiamethoxam	2.5 - 10	5	(oral)	**moderately persistent**	**high**
Dichlorvos	2.5 - 10	290	(oral)	non-persistent	low
Chlorfenvinphos	2.5 - 10	550	(oral)	moderately persistent	transition state
Pirimiphos-methyl	2.5 - 10	220	(oral)	moderately persistent	low
Fenoxycarb	2.5 - 10	204000	(contact)	non-persistent	low
Carbosulfan	2.5 - 10	180	(oral)	non-persistent	low
Tefluthrin	2.5 - 10	280	(oral)	moderately persistent	low
zeta-Cypermethrin	2.5 - 10	2	(contact)	moderately persistent	low
Chlorpyrifos	< 1	59	(contact)	moderately persistent	low
Lambda-Cyhalothrin	< 1	38	(contact)	non-persistent	low

* *exposure route in parentheses*

[1] Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, D-38104 Braunschweig: Absatz an Pflanzenschutzmitteln in der Bundesrepublik Deutschland. Ergebnisse der Meldungen gemäss § 19 Pflanzenschutzgesetz für das Jahr 2005

[2] IUPAC FOOTPRINT Pesticides Properties Database

[3] S Gupta et al. Bull Environ Contam Toxicol (2002) 68: 502-508

[4] S Gupta et al. Bull Environ Contam Toxicol (2008) 80: 431-437

Contamination of Dutch surface water with imidacloprid

Table 2. **Imidacloprid contamination of Dutch surface water**

Location	Date of sampling	Imidacloprid concentration in water sample in ng/L	Factor above maximum acceptable limit (67 ng/L)	Geographical Coordinates (x, y)
Emmererfscheidenveen	05-04-2007	4,200	63	(263060, 536500)
Schagerbrug	10-09-2007	1,100	16	(110162, 534722)
Amsterdam	04-08-2004	6,000	90	(122624, 484495)
Noordwijkerhout	19-12-2005	320,000	4,776	(94800, 475440)
De Kwakel	12-05-2004	4,700	70	(110726, 470153)
Oude Wetering	19-03-2007	8,600	128	(103444, 470006)
Rijnsburg	09-08-2005	120,000	1,791	(90986, 469385)
Roelofarendsveen	16-04-2007	2,500	37	(102574, 467108)
Boskoop	23-06-2005	12,000	185	(108312, 456412)
Waddinxveen	15-03-2007	54,000	806	(101281, 450151)
Bleiswijk	27-09-2006	4,700	70	(95463, 449725)
Delft	05-11-2006	4,550	68	(85630, 449527)
Moerkapelle	14-06-2007	1,800	27	(98244, 449420)
Nieuwerkerk aan den IJssel	22-07-2004	35,000	522	(103222, 444796)
Bergschenhoek	26-04-2006	1,700	25	(94000, 444410)
Berkel en Rodenrijs	04-06-2006	2,190	33	(89257, 443578)
Zevenhuizen	26-04-2006	2,100	31	(97735, 443556)
Moordrecht	27-09-2006	3,500	52	(104451, 443547)
Midden-Delfland	13-08-2007	1,300	19	(82081, 440801)
Puttershoek	18-07-2007	3,500	52	(96466, 425574)
Nieuw-Beijerland	18-07-2007	3,700	55	(83816, 423786)
Mijnsheerenland	10-05-2007	3,700	55	(92655, 423433)
Goudswaard	18-07-2007	3,000	45	(79205, 420178)
Zuid-Beijerland	18-07-2007	2,000	30	(84983, 416989)
Numansdorp	15-05-2006	5,460	81	(90319, 416574)
Middelharnis	17-07-2007	1,500	22	(68183, 421759)

The use of imidacloprid in Dutch agriculture rose from 668 kg on 5,335 hectares in 1995 to 6,377 kg on 40,007 hectares in 2004[5]. Since 2004 major contamination of Dutch surface water with imidacloprid has been detected by the Water Boards[6], particularly in the western part of the country (Table 2). Imidacloprid is stable to breakdown by water at neutral pH and degrades with a half-life of 355 days in more basic solutions[7]. Thus, imidacloprid in surface water will diffuse through the environment, which may affect marine and bird life.

[5] Information provided by the Dutch Central Statistics Office (CBS), The Hague
[6] Information provided by the Dutch Water Boards
[7] National Pesticide Telecommunications Network (NPTN), Oregon State University, Corvallis, Oregon 97331-6502 – Imidacloprid Fact Sheet, October 1998

The potential toxicity to insects and other arthropods of Dutch surface water contaminated with imidacloprid

A 12 µL intake of Noordwijkerhout water excessively contaminated with imidacloprid at 320,000 ng/L (Table 2) would expose a honey bee to the acutely lethal dose (3.84 nanogram ~ acute (48h) LD50 for a honey bee, see Table 1). However, Suchail et al. (2001) reported that much lower imidacloprid concentrations (≥ 1,000 ng/L) killed honey bees within 8 days[8].

The 96-h lethal imidacloprid concentration (LC50) value for midges *(Chironomus tentans)* was determined to be 5,750 ng/L, but when the animals were continuously exposed for 28 days the LC50 value was much lower: 910 ng/L[9]. The product of exposure concentration (c) and exposure time (t) remained approximately constant, i.e. **c . t = constant**, indicating that the total lethal imidacloprid dose remained virtually the same under acute and chronic exposure conditions.

Such dose : response relationships are known as **Haber's rule** (the product of exposure concentration and duration produces a constant toxic effect), after the German chemist Fritz Haber who in the early 1900s characterized the acute toxicity of nerve gases used in chemical warfare[10]. Haber's rule was subsequently (in the 1940s) shown to apply to the carcinogenicity of 4-dimethylaminoazobenzene (4-DAB) in rats[11] (the time up to the appearance of liver cancer was found to be inversely proportional to the daily dose), which led to an important theoretical explanation of Haber's rule[12], as follows:

denoting the initial concentration of specific receptors that 4-DAB reacts with as R, the concentration of receptors that 4-DAB has reacted with as C_R, and the mean 4-DAB concentration at the site of action as C, the reaction kinetics in the case of a bimolecular reaction are:

$$dC_R / dt = K (R - C_R) C - C_R / T_R \qquad (1)$$

where K is the reaction constant for association and T_R the time constant for dissociation. Since the carcinogenic action of 4-DAB was *irreversible*, and $T_R \rightarrow \infty$, we obtain

$$dC_R / dt = K (R - C_R) C \qquad (2)$$

Now, assuming that up to the time of action $C_R \ll R$, which appears reasonable, then R remains practically constant, therefore

$$dC_R / dt = K R C \qquad (3)$$

Since the dose level was kept constant throughout the study, C probably remained constant as well. Integration yields

$$C_R = K R C t \qquad (4)$$

which is Haber's Rule.

[8] Suchail S et al. (2001). Environmental Toxicology and Chemistry 20, 2482–2486
[9] Stoughton SJ et al. (2008) Arch Environ Contam Toxicol 54:662-673
[10] Haber F (1924) Zur Geschichte des Gaskrieges. In Fünf Vorträge aus den Jahren 1920-1923, pp. 76-92. Julius Springer, Berlin
[11] Druckrey H (1943). Quantitative Grundlagen der Krebserzeugung. Klinische Wochenschriften 22: 532.
[12] Druckrey H and Küpfmüller K (1948) Quantitative Analyse der Krebsentstehung. Z Naturforschung 3b: 254-266

Thus, Haber's Rule points to *cumulative blockage of critical receptors*[13]. Indeed, imidacloprid is the first highly effective insecticide whose mode of action has been found to derive from almost complete and *virtually irreversible* blockage of postsynaptic nicotinergic acetylcholine receptors in the central nervous system of insects[14,15].

The British pharmacologist AJ Clark further expanded Haber's rule to characterise the action of a number of drugs, and pointed to an important additional aspect of Haber's Rule[16]:

$$(c - c_m)\,(t - t_m) = \text{constant} \quad (5)$$

where c_m = a threshold concentration, and t_m = a minimum time of response. Clark commented at the time:

"The formula ct = constant is indeed an impossible one in the case of drugs acting on biological material because it implies that an infinitely small concentration of a drug will produce the selected action in infinite time, and conversely that a sufficiently high concentration will produce an instantaneous effect. In some cases ct = constant gives an approximate fit, but this merely implies that ***c_m and t_m are so small as not to produce a measurable error****".*

So, an approximate fit of Haber's rule to the action of a compound indicates not only cumulative blockage of critical receptors but also that *the threshold concentration* (c_m) *is very small*. Haber's rule is characterised by a linear relationship (on logarithmic coordinates) between exposure concentration and median time to effect, such as cancer or mortality. Similar relationships have now also been demonstrated for the toxicity of imidacloprid to the freshwater ostracod *Cypridopsis vidua* and to the freshwater flea *Daphnia magna* as well as for the toxicity of thiacloprid to the freshwater amphipod *Gammarus pulex* and the dragonfly *Sympetrum striolatum*[17]. Sánchez-Bayo (2009) demonstrated that the relationship between the concentration of the neonicotinoid insecticides imidacloprid and thiacloprid in a medium (C) and the time to 50% mortality (T) of these exposed arthropods followed a hyperbolic curve described by the equation

$$T = a * C^{-b} \quad (6)$$

Accordingly, there was a linear relationship when the logarithms of the variables C and T were used

$$\ln T = a' - b \ln C \quad (7)$$

where a' is the intercept and b is the slope.

[13] Tennekes H et al. (2010) Hazard and Risk Assessment of Chemical Carcinogenicity Within a Regulatory Context. In: Cancer Risk Assessment, edited by Ching-Hung Hsu and Todd Stedeford, John Wiley & Sons, Inc. pp. 37-65
[14] Buckingham SD et al. (1997) The Journal of Experimental Biology 200: 2685-2692
[15] Abbink, J. (1991). The biochemistry of imidacloprid. Pflanzenschutz-Nachrichten Bayer (Germany, F.R.) Serial ID – ISSN: 0340-1723
[16] Clark, A. J. (1937). General pharmacology. In Handbuch der Experimentellen Pharmakologie (W. Heubner and J. Schuller, eds.), Vol. 4, pp. 123-142. Springer Verlag, Berlin/New York
[17] Sánchez-Bayo F (2009) Ecotoxicology 18:343-354

Equation (7) can be transformed to

$$C^{b}\,T = \text{constant} \qquad (8)$$

or

$$C\,T^{1/b} = \text{constant} \qquad (9)$$

Equation (9) is very similar to the Druckrey-Küpfmüller equation for the action of chemical carcinogens such as diethylnitrosamine (DENA)[13]

$$d\,t^{n} = \text{constant} \qquad (10)$$

where d= daily dose and t = exposure time to effect (cancer), and n = 2.3 in the case of DENA.

Similar to the dose-response characteristics of DENA, exposure time was found to reinforce the toxicity of imidacloprid and thiacloprid to the tested arthropod species. The C T product, which reflects the total dose required for a lethal effect, decreased with decreasing toxicant concentration C (Table 3). even though the times to 50% mortality T *increased* with decreasing toxicant concentration C. The value of the time exponent (1/b) in equation (9) was shown to be 4.65 and 1.31 for the toxicity of imidacloprid to *Cypridopsis vidua* and *Daphnia magna*, respectively, and 1.10 and 1.53 for the toxicity of thiacloprid to *Gammarus pulex* and *Sympetrum striolatum*, respectively (Sánchez-Bayo, 2009)[18, 19]. Suchail et al. (2001) also noted that at concentrations of 0.1, 1, and 10 µg of imidacloprid per liter, the total cumulated dose ingested by honeybees in chronic intoxication was about 60 to 6,000 times lower than the doses needed to produce the same effect in acute intoxication tests. **Thus, low environmental concentrations of these insecticides (that may not be acutely toxic) could be detrimental to many aquatic and terrestrial invertebrate species in the long term, in particular because these compounds are persistent in soil and stable to breakdown by water** (Table 1) **and their toxicity to invertebrates may be reinforced by exposure time.**

Nicotinic acetylcholine receptors (nAChRs) play roles in many cognitive processes. At sub-lethal doses imidacloprid can alter honey bee foraging and learning[20,21,22,23]. Imidacloprid has been detected at levels of 5.7 µg/kg in pollen from French hives[24] and foraging honey bees reduced their visits to a syrup feeder when it was contaminated with 3 µg/kg of imidacloprid[25]. Mayflies of the genera *Baetis* and *Epeorus* showed a reduction in reproductive success when exposed to concentrations of imidacloprid as low as 100 ng/L[26].

The evidence indicates that, in any case in the western part of the Netherlands (Table 2), high concentrations of imidacloprid are diffused through the environment, which may kill or debilitate insects and possibly other arthropods. There is supporting evidence. The number of butterflies in the Netherlands is presently at the lowest point ever recorded (Figure 1)[27], and the lowest numbers of butterflies are being recorded in the western part of the country (apart from the coastal dunes)[28].
The water beetle *Graphoderus bilineatus*, widely recorded in the Netherlands up to the 1980s, is now nearly extinct in the western

Table 3. **Mortality of Arthropods Induced by Neonicotinoid Insecticides (Sánchez-Bayo, 2009)**

Species	Chemical	Concentration (C) in µg.L^{-1}	Time to 50% mortality (T) in days	C x T product in µg.L^{-1}.days
Cypridopsis vidua	Imidacloprid	4	5.2	20.8
		16	3.0	48
		64	3.3	211.2
		250	2.3	575
		1,000	2.0	2,000
		4,000	0.9	3,600
Daphnia magna	Imidacloprid	250	384.7	96,175
		750	69.7	52,275
		2,220	18.6	41,292
		6,700	15.0	100,500
		20,000	18.4	368,000
		60,000	3.0	180,000
Gammarus pulex	Thiacloprid	99	63.6	6,296.4
		364	16.7	6,078.8
		988	6.5	6,422
		3,100	3.2	9,920
		9,520	0.9	8,568
Sympetrum striolatum	Thiacloprid	7.2	20.6	148.3
		8.0	17.2	137.6
		12.7	13.0	165.1
		113.3	3.2	362.6

[18] The effects of thiacloprid on *Simulium latigonium* reported by Sanchez-Bayo (2009) were not considered in view of a poor fit to the regression equation (7)
[19] Sánchez-Bayo F (2009) Ecotoxicology 18:343-354
[20] Guez D et al. (2001) Neurobiol. Learn. Mem. 76: 183-191
[21] Lambin M et al. (2001). Arch. Insect Biochem. Physiol. 48: 129-134
[22] Decourtye A et al (2004) Ecotoxicol. Environ. Saf. 57: 410-419
[23] Colin ME et al (2004) Archives of Environmental Contamination and Toxicology 47 (3): 387-395
[24] Chauzat MP et al. (2006) Apiculture and Social Insects 99(2): 253-262
[25] Yang EC et al (2008) Journal of Economic Entomology 101(6): 1743-1748
[26] Alexander AC et al. (2008) Freshwater Biology 53: 171-180
[27] van Swaaij CAM et al. (2009). Vlinders en libellen geteld. Jaarverslag 2008, Vlinderstichting (Butterfly Foundation), Wageningen & the Dutch Central Statistics Office (CBS), The Hague. Report No. VS2009.007
[28] van Swaay CAM et al (2006) Hotspots Dagvlinder Biodiversiteit, Rapport VS2006.016, De Vlinderstichting, Wageningen

province of South-Holland[29]. In a comprehensive appraisal of the impact of neonicotinoid insecticides on bumblebees, honey bees and other non-target invertebrates, Kindemba also concluded that significant negative impacts of imidacloprid on bees and other non-target insects occur at levels predicted to be present in the UK countryside (based on imidacloprid application rates approved for use in the UK)[30].

Figure 1.
The decline of day butterflies in the Netherlands since 1992.
Source: Netwerk Ecologische Monitoring (NEM)
[CBS (Dutch Central Statistics Office), Vlinderstichting (Butterfly Foundation)]

[29] Cuppen JGM (2005) De gestreepte waterroofkever *Graphoderus bilineatus* in Zuid-Holland. Stichting European Invertebrate Survey-Nederland, Leiden
[30] Kindemba V (2009) The impact of neonicotinoid insecticides on bumblebees, honey bees and other non-target invertebrates. Buglife Invertebrate Conservation Trust, UK

General environmental studies with imidacloprid

Neonicotinoid insecticides differ from conventional spray products in that they can be used as seed dressings or as soil treatments. When used as a seed dressing, imidacloprid will migrate from the stem to the leaf tips and eventually into flowers and pollen[31,32,33]. Imidacloprid has been detected on vegetation near corn fields sown with imidacloprid-dressed seeds[34].

Suppression of non-target arthropods by neonicotinoid insecticides under field conditions

A study conducted over 3 years on an experimental home lawn[35] revealed that three consecutive yearly imidacloprid applications to the same field plots suppressed numbers of total hexapods, *Collembola*, *Thysanoptera* and *Coleoptera* adults by 54-62%. Turfgrass-residue exposure of the carabid *Harpalus pennsylvanicus* to imidacloprid has caused neurotoxic effects, making them highly vulnerable to predation[36]. When applied directly to aquatic microcosms to simulate leaching from soils, imidacloprid was shown to be highly toxic to aquatic insects[37]. A single pulse contamination of mesocosms (designed to realistically mimic communities in small streams within the agricultural landscape) with the neonicotinoid insecticide thiacloprid to resulted in long-term alteration of the overall invertebrate community structure[38]. One species, the stonefly *Nemoura cinerea*, was affected at the lowest tested concentration, 100 ng/L, 70 times below the lowest known median lethal concentration (LC50). Nearly 5,000 historical and contemporary specimen records of stoneflies (*Plecoptera*) from Illinois demonstrated that this fauna is highly imperilled, boding poorly for aquatic insect communities in North America and elsewhere[39]. When applied as a systemic insecticide to trees by direct stem injections or by soil injections and drenches, imidacloprid may be indirectly introduced to aquatic systems via leaf fall or leaching. Imidacloprid at realistic concentrations in leaves can inhibit leaf litter breakdown through adverse effects on decomposer invertebrates[40]. When imidacloprid is applied as a systemic insecticide to the soil around trees it may cause adverse effects on earthworms[41]. Imidacloprid at realistic field concentrations in maple leaves had adverse effects on aquatic insects and earthworms[42]. A recent study indicates high toxicity of imidacloprid to the non-target terrestrial arthropod *Porcellio scaber*[43]. Imidacloprid affects isopods at similar exposure concentrations as insects.

[31] Bonmatin JM et al. (2005) Journal of Agricultural and Food Chemistry 53: 5336-5341
[32] Bonmatin JM et al. (2005) Environmental Chemistry Part V, 483-494
[33] Scientific and Technical Committee for the Multifactor Study of the Honeybee Apiaries Decline (2003) French Ministry of Agriculture, Paris.
[34] Greatti M et al. (2006) Bulletin of Insectology 59 (2): 99-103
[35] Peck DC (2009) Pedobiologia 52: 287-299
[36] Kunkel BA et al. (2001) Journal of Economic Entomology 94(1): 60-67
[37] Kreutzweiser DP et al. (2007) Ecotoxicology and Environmental Safety 68: 315-325
[38] Beketov MA et al. (2008) Science of the Total Environment 405: 96-108
[39] DeWalt Ree et al (2005) Ann. Entomol. Soc. Am. 98(6):941-950
[40] Kreutzweiser DP et al. (2009) Ecotoxicology and Environmental Safety 72: 1053-1057
[41] Kreutzweiser DP et al. (2008) Pest Manag Sci 64:112-118
[42] Kreutzweiser DP et al. (2008) J Environ Qual 37: 639-646
[43] Drobne D et al. (2008) Chemosphere 71: 1326 - 1334

The decline of invertebrate-dependent Dutch meadow birds

Monitoring data reveal significant changes in the number of meadow birds in the Netherlands[44]. The overall yearly decline has nearly quadrupled in recent years, i.e. from 1.2% in 1990-2000 to 4.6% since 2000. All meadow birds in the monitoring scheme (Skylark *Alauda arvensis*, Northern Shoveler *Anas clypeata*, Yellow Wagtail *Motacilla flava*, Oystercatcher *Haematopus ostralegus*, Black-tailed Godwit *Limosa limosa*, Northern Lapwing *Vanellus vanellus*, Common Redshank *Tringa totanus*, Meadow Pipit *Anthus pratensis* en Tufted Duck *Aythya fuligula*) are declining since 2000. Songbirds like Skylark, Meadow Pipit and Yellow Wagtail declined up to 30% from year to year in some regions which may lead to a population drop of 75% in only five years. **Particularly alarming is the steep decline of meadow birds in the western peat land of the Netherlands (with an overall annual decline of 13% since 2000)**.

An abundance of insects and other invertebrates is crucial for reproductive success and survival of Dutch meadow birds[45] (Table 4).

Table 4. **Chick feeding habits for birds on Dutch grassland**

Species	Chick feeding habit
Northern Lapwing *Vanellus vanellus*	Ground-dwelling prey such as ground beetles (*Carabidae*) and earthworms (*Lumbricidae*) on the surface
Black-tailed Godwit *Limosa limosa*	Arthropods in the vegetation, in particular flies and midges (*Diptera*) and beetles (*Curculionidae*)
Common Redshank *Tringa totanus*	Similar to that of Black-tailed Godwit
Oystercatcher *Haematopus ostralegus*	Earthworms (*Lumbricidae*), the larvae of crane flies (*Tupilidae larvae*) and beetles (*Coleoptera*, mostly ground beetles *Carabidae*).
Skylark *Alauda arvensis*	Wasps, bees, and ants (*Hymenoptera*), beetles (*Coleoptera*), true bugs, flies and midges (*Diptera*, *Hemiptera*), spiders (*Araneae*) and insect larvae
Meadow Pipit *Anthus pratensis*	Flies and midges (*Diptera* comprising many crane flies *Tipulidae* and non-biting midges *Chironomidae*), *Pyralidae*, *Lycosidae*, wasps, bees, and ants (*Hymenoptera*) and spiders (*Aranea*)
Yellow Wagtail *Motacilla flava*	Flies and midges (*Diptera*), *Ephemeroptera*, grasshoppers, butterflies en beetles

[44] Teunissen W & Soldaat L (2006). Recente aantalontwikkeling van weidevogels in Nederland (Recent population changes of meadow birds in the Netherlands), De Levende Natuur (Living Nature) 107: 70-74

[45] Anoniem (2008) Ecologische kenmerken van weidevogeljongen en de invloed van beheer op overleving. Rapport DK nr 2008/090. Ministerie van Landbouw, Natuur en Voedselkwaliteit.

The Black-tailed Godwit used to flourish in the peat soil habitats in the western part of the Netherlands[46]. Invertebrates profited from enrichment of the soil with manure and fertilisers and earthworms (*Lumbricidae*), leatherjackets (*Tipulidae*), snails and other species were abundant. The combination of abundant food, at least for adult birds, and the soft peat soil (which is easily penetrated by the long bill of the Black-tailed Godwit) made the western part of the Netherlands a prime breeding habitat for the Black-tailed Godwit. Nearly 80% of the western Europe population of the Black-tailed Godwit, currently estimated at 80,000 pairs and by far the largest in Europe[47], breed in the Netherlands (Table 5). However, the key Dutch breeding population underwent a large decline from 120,000-135,000 in 1969, 85,000-100,000 in 1989-1991[48] to 62,000 in 2004[49]. Over the last 15-20 years, the important breeding populations in Germany, Poland and Belarus have been reduced by 50%[50] as well.

Table 5. The main breeding populations of the Black-tailed Godwit in Europe

Country	Breeding pairs	Breeding Population Data Quality§	Year(s) of the estimate
Netherlands	62,000	1	2004
Iceland†	18,750	1	1999 - 2003
Russia	13,000 - 30,000	1	1990 - 2000
Germany	6,000 - 7,300	2	1995 - 1999
Belarus	6,000 - 8,500	1	1997 - 2004
Poland	5,000 - 6,000	1	1995 - 2000
Ukraine	5,000 - 9,000	2	1990 - 2000

† *Limosa limosa islandica*; § 1: reliable quantitative data, 2: incomplete quantitative data. Source: European Commission (2007). Management Plan for Black-tailed Godwit 2007-2009. Technical Report-019-2007, Luxembourg Office for Official Publications of the EC

[46] Groen NM & Hemerik L (2002). Ardea 90 (2): 239-248
[47] European Commission (2007). Management Plan for Black-tailed Godwit 2007-2009. Technical Report-019-2007, Luxembourg Office for Official Publications of the EC
[48] Snow DW & Perrins CM (1998). The Birds of the Western Paleartic, Concise Edition ed., Volume 1 +2, Oxford University Press, Oxford
[49] Teunissen WA et al. (2005) Toelichting op de gruttokaart van Nederland 2004. SOVON Onderzoeksrapport 2005/4. SOVON Vogelonderzoek Nederland, Beek-Ubbergen
[50] Thorup O (2005) Waders Breeding in Europe 2000 – International Wader Studies 14, IWSA-UK

Evidence collected in the Wormer- and Jisperveld reserve in the western province of North-Holland (a 2200 ha soft peat wetland reserve with high water tables and restrictions in agricultural management) suggests that the decline of the Black-tailed Godwit may be caused by a lack of larger insects on which the chicks depend for their survival. **The decline of the number of breeding pairs of the Black-tailed Godwit in the Wormer- and Jisperveld reserve was 1% per annum from 2001 to 2004, 5% per annum from 2004 to 2006, and 22% in 2007**[51]. Insect sampling in early May 2007 (Black-tailed Godwit hatching) and the middle of May 2007 (when chicks need large quantities of large insects) showed that larger insects (> 4 mm) were in short supply in the middle of May[52]. This is consistent with evidence indicating that large carabid beetles (> 8 mm) associated with open, marshy or grassland habitats (including many agricultural habitats) have suffered the largest declines over the last 50 years[53]. This is probably due to changes in agricultural practices including intensification of the use of pesticides. In the Dutch breeding population of the Black-tailed Godwit, chick survival has decreased from 17-42% in the 1980s to 0-24% in 2003-2005, and reproductive success has declined rapidly from c. 0.7 chicks per pair per year in the 1980s to 0.1-0.4 chicks per pair per year in 2003-2005[54]. This is far below the threshold for a sustainable population.

[51] Vens N (2008). Broedvogelinventarisatie Wormer- en Jisperveld 2007. Vogelbeschermingswacht "Zaanstreek".
[52] Verhulst J et al. (2008). Voedselaanbod voor gruttokuikens in de Hollandse veenweidegebieden. Wageningen, Alterra, Alterra-rapport 1668, ISSN 1566-7197.
[53] Kotze DJ & O`Hara RB (2003) Species decline - but why? Explanations of carabid beetle (*Coleoptera*, *Carabidae*) declines in Europe. Oecologia 135:138-148
[54] Jensen FP et al. (2008). International Single Species Action Plan for the Conservation of the Black-tailed Godwit *Limosa limosa*, AEWA Technical Series No.XX. Bonn, Germany

The decline of invertebrate-dependent Dutch marsh birds

From 1970 to 1990, the populations of the insectivorous Great Reed Warbler *Acrocephalus arundinaceus* in France, Germany, Denmark, and the Czech Republic have declined by more than 50% and by 20% - 50% in Greece, Italy, and Switzerland[55,56], while key populations in Russia, Ukraine and Romania appear to be stable[57]. The Dutch population of the Great Reed Warbler has declined by 90% from 1960 to 1990 (from 5,000 breeding pairs in 1950-1960 to 400-550 in 1989-1991)[58], and continued to decline by 6% per annum since 1990[59,60]. The territories of a large Great Reed Warbler colony in the shallow Reeuwijk lakes (at 52°2′ N and 4°45′E in the Western part of the Netherlands, near Gouda), which originated from peat-digging in the 16th and 17th century, decreased from 90-100 in 1975, 40 in 1993, 20 in 1997, 14 in 2000, 8 in 2004 to just 6 in 2005[61,62]. The Reeuwijk polder is mainly used for agriculture and surplus water during wet periods is discharged via the Reeuwijk lakes to the Breevaart canal[63], which may expose insects in the Reeuwijk lakes to surface water contaminated with pesticides. Surface water analyses in the vicinity of the Reeuwijk lakes have revealed excessively high concentrations of imidacloprid and carbamates (carbendazim and propoxur) that are bound to be toxic to insects (Table 6). There is supporting evidence. Monitoring data for the characteristic dragonfly *Aeshna viridis* (a food source for the Great Reed Warbler) in the Reeuwijk lakes since 1998 indicate that this population is declining[64]. The populations of other dragonflies characteristic of peat bogs in the Netherlands, i.e. *Leucorrhinia pectoralis* (large white faced darter) and *Sympecma paedisca* are also in decline since the 1960s[65,66]. The Great Reed Warbler is one of the worst performers in the Dutch marsh bird protection programme which attempts to preserve 13 rare species[67].

The monitoring data show that while the populations of invertebrate-dependent species have declined even further since 1990, the populations of all fish-eating marsh bird species in the protection programme were stable or have grown in size (Table 7). The population increase of the insectivorous Bluethroat *Luscinia svecica* is possibly related to the survival benefits of biparental care and brood division after fledging[68].

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55 Cramp S (1992) The birds of the western Paleartic,4. Oxford University Press, Oxford
56 Hagemeijer WJM and Blair MJ (1997) The EBCC Atlas of European breeding birds: their distribution and abundance. T&AD Poyser, London
57 Tucker GM and Heath MF (1994) Birds in Europe: their conservation status. Birdlife International, Cambridge, UK
58 Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten:Grote Karekiet [A298]
59 Dijk AJ van et al. (2003). Kolonievogels en zeldzame broedvogels in Nederland in 2002. SOVON-monitoringrapport 2003/02. SOVON Nederland. Beek-Ubbergen
60 Dijk AJ van et al. (2009). Broedvogels in Nederland in 2007. SOVON-monitoringrapport 2009/01. SOVON Vogelonderzoek Nederland, Beek-Ubbergen
61 Heikoop L (2002) De Grote Karekiet (*Acrocephalus arundinaceus*) in het Reeuwijkse Plassengebied: ontwikkeling, biotoopeisen en beheersmaatregelen. Waardvogel 2002, nr 2. Natuur- en Vogelwerkgroep Krimpenerwaard
62 SOVON: Nieuws uit de provincie Zuid-Holland 2005/2 oktober & SOVON: Nieuws uit de provincie Zuid-Holland 2006/1 maart, SOVON Vogelonderzoek Nederland, Beek-Ubbergen, The Netherlands
63 Hoogheemraadschap van Rijnland (2010). Schoon water in de Reeuwijkse Plassen, www.rijnland.net
64 De Vries HH and Ketelaar R (2003) De groene glazenmaker in Zuid-Holland. Rapport VS2003.18, De Vlinderstichting, Wageningen.
65 Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Habitatrichtlijnsoorten: Gevlekte witsnuitlibel [H1042]
66 Kalkman VJ (2004) Noordse winterjuffer *Sympecma paedisca* (Brauer 1877), EIS-Nederland, Leiden
67 Anoniem (2000). Beschermingsplan moerasvogels 2000-2004. Directie Natuurbeheer. Ministerie van Landbouw, Natuurbeheer en Visserij. Wageningen.
68 Anthonisen K et al. (1997) The Auk 114 (4): 553-561

Fish as an alternative protein source to insects appears to enhance the survival prospects of marsh birds (Table 7). The Purple Heron *Ardea purpurea* is a documented case in point. The Dutch population of the Purple Heron rose by 160% from 270-280 pairs in 17 colonies in 1990 to 702 pairs in 25 colonies in 2008[69], and is recovering well from strong decline in the 1970s and 1980s caused by drought in the Sahel zone. The species now flourishes in peat soil polder habitats, and it was recently shown that its density in polders was related to the abundance of fish[70]. It is interesting to note in this context that the populations of fish-eating wetland birds such as Cormorant *Phalacrocorax carbo*[71], Great Crested Grebe *Podiceps cristatus*[72], Great Egret *Egretta alba*[73], Kingfisher *Alcedo atthis*[74], and Osprey *Pandion haliaetus*[75] have substantially increased in size in the Netherlands in the last two decades.

Table 6. **Insecticide contamination of surface water in the vicinity of the Reeuwijk lakes**

Location	Date of sampling	Compound	Concentration in water sample in ng/L	Factor above maximum acceptable limit	Geographical Coordinates (x, y)
Waddinxveen	18-05-2004	Imidacloprid	44,000	657	(101281, 450151)
	18-05-2004	Carbendazim	4,700	9	(101281, 450151)
	23-06-2004	Propopxur	710	71	(101281, 450151)
	13-07-2006	Imidacloprid	38,000	567	(101281, 450151)
	15-03-2007	Imidacloprid	54,000	806	(101281, 450151)
Nieuwerkerk a/d IJssel	23-08-2004	Carbendazim	23,000	46	(103222, 444796)
Boskoop	23-06-2005	Imidacloprid	12,000	179	(108312, 456412)
	19-08-2005	Carbendazim	12,000	24	(108312, 456412)
	26-04-2007	Imidacloprid	4,200	63	(108313, 456412)
	17-07-2007	Carbendazim	6,700	13	(108313, 456412)
	17-07-2007	Imidacloprid	4,800	72	(105888, 455853)

Maximum acceptable limits: imidacloprid 67 ng/L, carbendazim 500 ng/L, propoxur 10 ng/L. Source: Information provided by Dutch Water Boards

[69] SOVON: Broedvogels in Nederland in 2008, Monitoringrapport 2010/01. SOVON Vogelonderzoek Nederland, Beek-Ubbergen, The Netherlands
[70] Krijgsveld KL et al (2004) Kwaliteitseisen aan foerageergebieden van purperreigers in veenweiden. Bureau Waardenburg bv in opdracht van Alterra, Wageningen
[71] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Aalscholver [A017]
[72] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Fuut [A005]
[73] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Grote Zilverreiger [A027]
[74] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. IJsvogel [A229]
[75] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Visarend [A094]

Table 7. **Results of the Dutch marsh bird protection programme 1990 - 2008**

Species	Feeding habits*	National trend 1990 - 2008 (annual decrease/increase in %)ǂ	Habitat*
Northern Harrier *Circus cyaneus*	Mammals (particularly rodents), birds, reptiles, amphibians, and insects.	- 6%	Open wetlands, including marshy meadows
Great Reed Warbler *Acrocephalus arundinaceus*	Mainly insects, some fruits and berries outside breeding season.	- 6%	Aquatic vegetation emerging from shallow standing water
Bearded Tit *Panurus biarmicus*	Insects and other invertebrates in summer, seeds in late autumn and winter	- 2%	Reed by or often in fresh or brackish water
Spotted Crake *Porzana porzana*	Mainly small aquatic invertebrates and parts of aquatic plants	- 2%	Freshwater wetlands with dense cover of sedges and rushes, grass, etc.
Black Tern *Chlidonias niger*	In the breeding season: insects. Small fish and other aquatic creatures are also eaten	- 1%	Habitat with extensive, cover-providing, vegetation as well as open water
Savi's Warbler *Locustella luscinioides*	Mainly adult and larval arthropods, also snails	+ 1%	Fresh or brackish surface waters with extensive stands of reed
Great Bittern *Botaurus stellaris*	Predominantly fish, amphibians and insects, but also small birds and mammals	+ 2%	Large, wet reed beds with areas of open water
Bluethroat *Luscinia svecica*	Invertebrates, mostly insects. In autumn, also some seeds and fruits	+ 4%	Shrubby wetlands with woody vegetation.
Little Bittern *Ixobrychus minutus*	Very varied diet, including fish, frogs, spiders, small reptiles and birds	+ 5%	Fresh water with aquatic vegetation, forested margins of shallow lakes
Purple Heron *Ardea purpurea*	Fish, amphibians, insects (both grubs and adults)	+ 6%	Wetland habitat such as swamps, reed-beds, and lake shores
Eurasian Spoonbill *Platalea leucorodia*	Small fish, aquatic insects, shrimp and other invertebrates	+ 8%	Shallow, usually extensive waters of fairly even depth
Red-crested Pochard *Netta rufina*	Vegetarian. Green part of aquatic plants and grass, leaves, stems, roots and seeds	+ 20%	Lakes of fresh or brackish waters with abundant border vegetation
Black-crowned Night Heron *Nycticorax nycticorax*	Mainly fish, also amphibians, aquatic and terrestrial insects	+ 21%	Fresh, salt or brackish water, areas with aquatic vegetation

ǂ Source: Netwerk Ecologische Monitoring (NEM) [CBS (Dutch Central Statistics Office), SOVON Vogelonderzoek Nederland]
* Source: Soortenbank.nl, Dieren, planten en paddestoelen in Nederland, http://www.soortenbank.nl/over_deze_website.php

The decline of invertebrate-dependent bird species on Dutch heath land

The Dwingelderveld National Park, located in the province of Drenthe in the north-eastern part of the Netherlands, is a heath and woodland reserve of 3,700 hectares, with 1500 ha of wet heath land, which makes it the largest wet heath land in western Europe. Sjouke van Essen surveyed the ground beetles (*Coleoptera : Carabidae*) on 38 locations in the Dwingelderveld reserve in 1991 and 2008, in exactly the same manner, and observed a massive decline in the number of caught ground beetles, from 45,000 (94 species) in 1991 to 15,000 (79 species) in 2008[76]. Within the same period there was a dramatic decline of the insectivorous Whinchat *Saxicola rubetra* (from 35 pairs in 1989 to 6-14 pairs in 1998-2003) and Northern Wheatear *Oenanthe oenanthe* (from 33 pairs in 1993 to just 3 in 2003) in the Dwingelderveld reserve[77]. The populations of several invertebrate-dependent bird species observed on Dutch heath land, such as Northern Wheatear[78], Whinchat[79], Black Grouse *Tetrao tetrix*[80], Tawny Pipit *Anthus campestris*[81], Wryneck *Jynx torquilla*[82] and Red-backed Shrike *Lanius collurio*[83], have declined dramatically in recent decades. Black Grouse and Tawny Pipit are now more or less extinct in the Netherlands. In stark contrast, the Dutch population of the Stonechat *Saxicola torquata*[84] has actually increased in size. Feeding habits and reproduction characteristics of the Stonechat are very similar to those of Northern Wheatear, Whinchat, Wryneck, Red-backed Shrike, and Tawny Pipit, but the difference is the much longer breeding season of the Stonechat with a potential for rearing three broods (Table 8). The species in strong decline are trans-Saharan migrants that arrive later and can only raise two broods at maximum, sometimes just one, as in the case of the Red-backed Shrike (Table 8). A comparative analysis of the information held on 784 Stonechat and 669 Whinchats cards submitted to the BTO Nest Records scheme between 1936-1973 showed that the Stonechat had a potential annual productivity 2.7 times that of the Whinchat[85]. Overall losses for the Whinchat were higher than for the Stonechat within every stage of breeding except during laying. Although the Stonechat is highly susceptible to harsh winters, climatic changes in western Europe (leading to a higher frequency of mild winters) may well have enhanced the survival prospects of this species in recent years. The Tawny Pipit was considered extinct on the heath land of the Veluwe in 2004[86] and the Wryneck population of the Veluwe is also in strong decline. The heath lands of the Veluwe and Drenthe remain habitats for Northern Wheatear and Whinchat. Between 1990 – 2000 the Stonechat has even made a remarkable come-back to the heath lands of the southern provinces of North-Brabant and Limburg.

[76] Lustenhouwer I and Vermeulen R (2009) Wat loopkevers vertellen. Nationaal Park Dwingelderveld Informatiebulletin Veldspraak 13:11
[77] Ministerie Landbouw, Natuur en Voedselkwaliteit. Natura 2000 gebiedendocument- Natura 2000 gebied 30 - Dwingelderveld, November 2006
[78] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Tapuit [A227]
[79] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Paapje [A275]
[80] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Korhoen [A107]
[81] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Duinpieper [A255]
[82] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Draaihals [A233]
[83] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Grauwe Klauwier [A338]
[84] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Roodborsttapuit [A276]
[85] Fuller RJ & Glue (1977). The breeding biology of the Stonechat and Whinchat. Bird Study 24: 4, 215-228
[86] Turnhout, C. van (2005) Het verdwijnen van de Duinpieper als broedvogel uit Nederland en Noordwest-Europa. Limosa 78 (1), 1-14

Table 8. Feeding habits and reproduction of invertebrate-dependent bird species on Dutch heath land

Species	Feeding habits*	Reproduction*
Northern Wheatear *Oenanthe oenanthe*	Diet based chiefly on insects, also spiders, molluscs, and other small invertebrates, supplemented by berries. Normally locates prey visually, chiefly on ground or in low vegetation	In Britain and north-west Europe egg-laying starts from mid-April to June. In South and central Europe from early May to June. 1-2 broods. Clutch: 4-7 incubated in c. 13 days by female only
Whinchat *Saxicola rubetra*	Mostly insects and earthworms, often rather large, occasionally fruit. Feeding method varies with prey. Pursues ants, etc, on ground. Takes small *Diptera* and *Hymenoptera* from flowers, sometimes hovering to do so. Locates earthworms by probing in soft ground, throwing earth aside with bill once worm found.	Breeds May-July. 3-5 eggs, incubation 13 days tended by female only. There is a potential for rearing two broods
Tawny Pipit *Anthus campestris*	The Tawny Pipit feeds primarily on insects and other invertebrates, as well as some seeds. Its prey includes grasshoppers, dragonflies, butterflies, spiders, ants, flies, beetles, snails and termites. The Tawny Pipit typically forages on the ground, running and then pecking at prey, and only occasionally flying after it[87].	Breeding starts May-June in Western Europe, Clutch size 4-5 eggs incubated for about 12 days by female only.
Wryneck *Jynx torquilla*	Principally, and sometimes exclusively, ants, but also other insects. As ants make up the bulk of their diet, many sightings of Wrynecks are of the birds searching the ground or along stone walls in pursuit of their prey.	They lay up to ten pale grey-green – almost white – eggs during May, which are usually incubated by the female bird for 12 to 14 days. If food supplies are good, the birds may attempt a second brood during July and August.
Stonechat *Saxicola torquata*	*Coleoptera* (beetles), *Hymenoptera* (sawflies, ichneumon flies, bees, wasps and ants), terrestrial larvae (moth, sawfly, and beetle) and *Arachnida* (spiders and harvestmen) accounted for 81% of Stonechat nestling diet[88]. Locates terrestrial prey from elevated perch, then flies, glides, or hops to ground, picking prey up on landing or while standing on ground	Breeds March-August in North-East Europe, mid April in South and Central Europe. The 4-6 eggs are incubated for 13-14 days, by female only. There is a potential for rearing three broods.
Red-backed Shrike *Lanius collurio*	Mainly insects, chiefly beetles, also other invertebrates, small mammals, birds, and reptiles. Most prey located from exposed, though usually low, perch using sit and wait strategy	Eggs are laid between the end of May and late July; only one clutch consisting of 3-6 eggs (incubation 12-16 days usually by the female bird) is produced each year[89]

* Sources (unless indicated otherwise): Avibirds European bird guide online, www.avibirds.com or ARKive, www.arkive.com

[87] del Hoyo, J., Elliott, A. and Sargatal, J. (2004) *Handbook of the Birds of the World. Volume 9: Cotingas to Pipits and Wagtails.* Lynx Edicions, Barcelona

[88] Cummins S & O'Halloran J (2002) Assessment of the diet of nestling Stonechats *Saxicoloa torquata* using compositional analysis. Bird Study 49, 139-145

[89] RSPB (November 2001) http://www.rspb.org.uk

The decline of invertebrate-dependent bird species at the Dutch coast

Thirty-one breeding bird species are monitored in the Wadden Sea by the Joint Monitoring Group for Breeding Birds (JMBB), and trends are now available for the period 1991-2006[90]. Negative trends in the Dutch Wadden Sea since 1991 were observed for

- Pied Avocet *Recurvirostra avosetta*;
- Kentish Plover *Charadrius alexandrinus*;
- Eurasian Curlew *Numenius arquata*;
- Common Redshank *Tringa totanus*;
- Common Eider *Somateria molissima*;
- Hen Harrier *Circus cyaneus*;
- Short-eared Owl *Asio flammeus*;
- Oystercatcher *Haematopus ostralegus*;
- Black-tailed Godwit *Limosa limosa*;
- Northern Lapwing *Vanellus vanellus*;
- Herring Gull *Larus argentatus*.

In addition, the Northern Wheatear *Oenanthe oenanthe* breeding population declined dramatically by 87% since 1990 to only 230-270 pairs in 2008, and the once common Red-backed Shrike *Lanius collurio* was only occasionally seen breeding along the Dutch coast after 1998[91].

The population of Pied Avocet has very recently declined by 40% from 8850 pairs in 2000 to 5100-5300 pairs in 2008[92,93], which is mainly attributable to a decline along the coast of the northern provinces of Friesland and Groningen. The ragworm *Nereis diversicolor* was found to be the most important food item for Avocets in the Wadden Sea[94]. Other small prey like *Corophium* and insects complete the diet of Avocets. Locally, Avocets feed in brackish channels on small crustaceans (*Paleomonetus and Neomysis*) (see literature review in Leopold et al., 2004, reference 94)

The population of the Kentish Plover has declined from 700-900 pairs in 1973-1977 to 180-210 pairs in 2008[95], three-quarters of which are now breeding in the Delta area. Reproductive success of the Kentish Plover in the Delta area in 2000-2005 was on average only 0.39 chicks per pair per year, which is far too low to sustain the population[96].

[90] JMBB 2010. Trends in breeding birds in the Wadden Sea 1991-2006.www.waddensea-secretariat.org, Wilhelmshaven, Germany
[91] Van Oosten H, Beusink P & Waasdorp S (2008) Grauwe Klauwieren in de vastelandsduinen in 2008. Stichting Bargerveen.
[92] SOVON: Broedvogels in Nederland in 2008, Monitoringrapport 2010/01. SOVON Vogelonderzoek Nederland, Beek-Ubbergen, The Netherlands
[93] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Kluut [A132]
[94] Leopold MF et al (2004) Alterra –rapport 954, SOVON-onderzoeksrapport 2004/07, Alterra, Wageningen
[95] Ministerie Landbouw, Natuur en Voedselkwaliteit (Dutch Ministry of Agriculture, Nature and Food Quality). Vogelrichtlijnsoorten. Strandplevier [A138]
[96] Meininger PL et al. (2006) Broedsucces van kustbroedvogels in het Deltagebied in 2005. Rapport RIKZ/2006.006. Rijksinstituut voor Kust en Zee, Middelburg

The most recently recorded (2007-2008) decline of the Kentish Plover population in the Delta area (estimated at 144 pairs in 2008) can be attributed to a large extent to changes in the breeding populations in the Grevelingen lake area, which showed a decline from 91 pairs in 2007 to 59 pairs in 2008. In its most important breeding area (Slikken van Flakkee) there was a decline from 62 pairs in 2007 to 32 pairs in 2008. This coincides with recent decline of the Red-listed bumblebee *Bombus muscorum* in this area (several dozens were sighted in 2005, but only 1 in 2009) and possibly other wild bee species as well[97]. In addition, there is evidence of major insecticide (imidacloprid and carbendazim) contamination of surface water in 2007 on the island of Goeree-Overflakkee, i.e. in the vicinity of the Slikken van Flakkee (Table 9), at levels that are bound to be toxic to insects. Cramp & Simmons (1983) state that polychaete worms, molluscs and crustaceans are important prey in coastal and inland saltwater areas[98]. In Schleswig-Holstein stomachs of six birds contained insects and their larvae, crustaceans (*Carcinus maenas*), *Nereis*, gastropods (*Hydrobia, Littorina*) and a bivalve.[99,100]

Up to the 1980s, the insectivorous Northern Wheatear was a common breeder along the entire Dutch coast (dunes) and the heath lands of the southern provinces of North-Brabant and Limburg (Figure 2), but, in 2005, its most important breeding areas were largely confined to the Wadden isles (Ameland, Texel), Noordduinen/Botgat (in the province of North-Holland) and the Aekingerzand (in the province of Drenthe)[101].

Table 9. Insecticide contamination of surface water on the island of Goeree-Overflakkee

Location	Date of sampling	Compound	Concentration in water sample in ng/L	Factor above maximum acceptable limit	Geographical Coordinates (x, y)
Oude Tonge	24-05-2007	Imidacloprid	870	13	(73740, 411390)
Middelharnis	17-07-2007	Imidacloprid	1500	22	(68183, 421759)
	17-07-2007	Carbendazim	4700	9	(68183, 421759)
Achthuizen	24-05-2007	Imidacloprid	580	9	(80769, 408678)

Maximum acceptable limits: imidacloprid 67 ng/L, carbendazim 500 ng/L, propoxur 10 ng/L. Source: Information provided by Dutch Water Boards

[97] Roos M en Reemer M (2009) De Moshommel Bombus muscorum in Zuid-Holland, EIS Nederland, Leiden.
[98] Cramp S & Simmons KEL (1983) Handbook of the birds of Europe, the Middle East and North Africa, vol. 3: Waders-Gulls. Oxford University, Oxford
[99] Lange G (1968) Beitr. Vogelkunde 13: 225-334
[100] Höfmann H and Hoerschelmann H (1969) Corax 3: 7-22
[101] Van Turnhout C, Van Oosten H, Majoor F (2008) Overzicht populatie gegevens Tapuit 2007 en 2008, SOVON/Stichting Bargerveen.

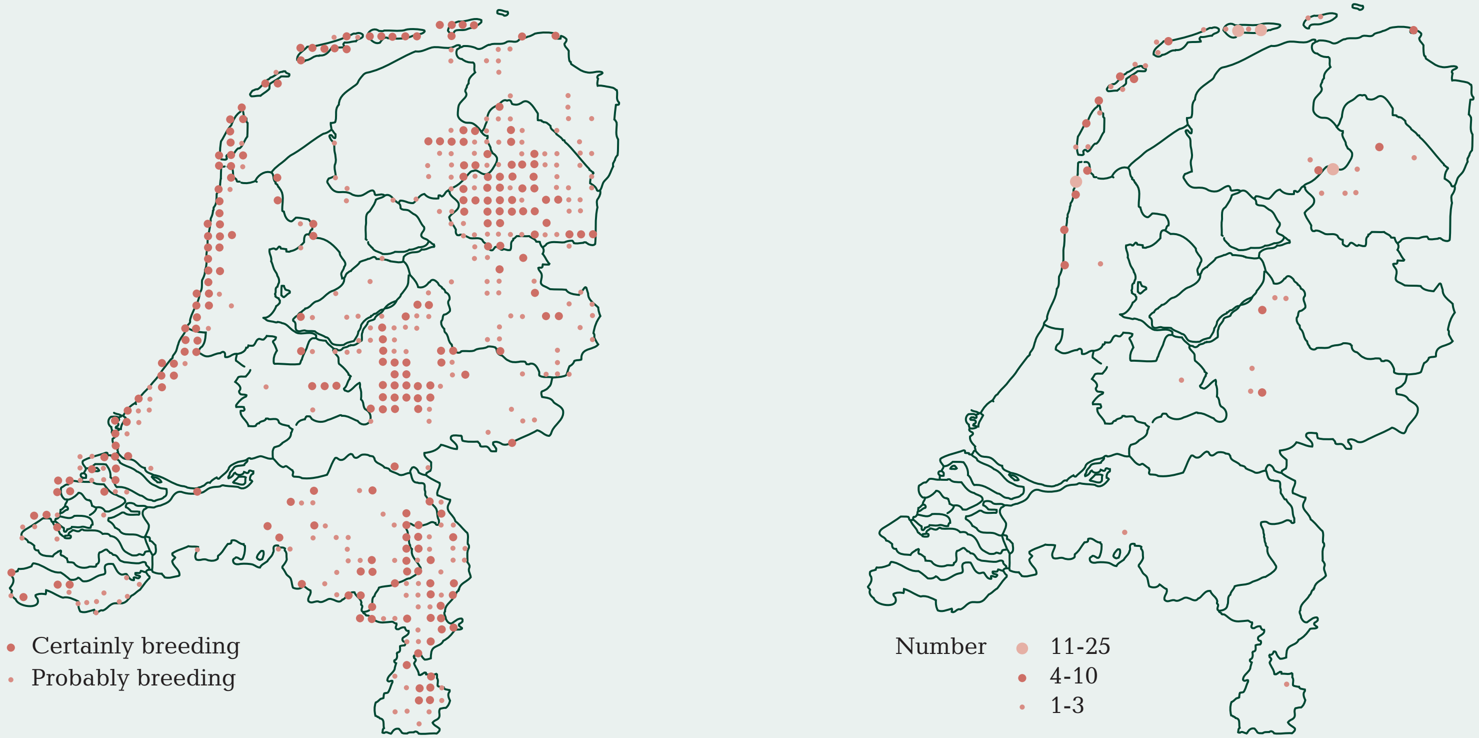


Figure 2.

Distribution of the Northern Wheatear (breeding pairs) in the Netherlands in 1973-1977 (left) and in 2005 (right).

Source: Van Turnhout C, Van Oosten H, Majoor F (2008) Overzicht populatie gegevens Tapuit 2007 en 2008, SOVON/Stichting Bargerveen

The insectivorous Red-backed Shrike shows a very similar pattern of decline which, however, started much earlier than that of the Northern Wheatear. The last breeding pairs of the Red-backed Shrike along the Dutch coast were seen on the Wadden isle of Ameland in 1997 and 1998. A shortage of larger prey (> 5mm) was shown to be cause of failing reproductive success of the last (1997-1998) Red-backed Shrikes on Ameland. In particular, there was a shortage of beetles (*Scarabeidae*), which constituted nearly 50% of prey in 1989 but hardly 4% of prey in 1997-1998. The Ameland population of the Northern Wheatear is in steep decline since 1998[102].

The decline in coastal areas of meadow birds such as Black-tailed Godwit, Northern Lapwing, Eurasian Oystercatcher, Eurasian Curlew, and Common Redshank is in line with negative trends observed on the Dutch mainland, as described earlier. The number of Oystercatchers in the Dutch Wadden Sea has declined by 40% from 1984 to 2004 (both the breeding and the larger wintering population). The number of breeding pairs on the Dutch Wadden isle of Schiermonnikoog declined 4.6% annually. Reproductive output was virtually zero in the last 7 years of the 1984-2004 observation period, and associated with a dramatic decline in summer of two prey species for raising the young, i.e. ragworm *Nereis diversicolor* and Baltic tellin *Macoma baltica*[103]. The main Dutch breeding habitat for the Eurasian Curlew is heather and dune habitats on the Wadden Sea isles of Terschelling, Ameland, Texel and Vlieland. Based on extensive literature review, Leopold et al. (2004), reference 94, concludes that the diet of Curlews is very diverse, consisting mainly out of bivalves and large worms (*Nereis* and *Arenicola*, added with 20% other prey such as *Carcinus maenas* and shrimps. Curlews are not strictly bound to intertidal flats and are often seen on inland meadows where they forage on earthworms (*Lumbricus terrestris*), and other typical inland prey (*Diptera-larvae*).
The Redshank's diet is diverse, comprising of several species of worms (*Nereis*, *Nephtys*, *Lanice*, *Scoloplos*, *Harmothoe*), *Crustacea* (small craps as well as shrimps and *Corophium*) and *Hydrobia* (see literature review in Leopold et al., 2004, reference 94). Inland meadows can provide an alternative and additional food source[104]. Prey determined from remains in faeces and pellets on coastal grazing marsh showed that adult Lapwing and chicks and adult Redshank fed on a wide range of soil, surface-active and aquatic invertebrates. The proportion of aquatic invertebrates in the diet of both species increased as the breeding season progressed, while that of soil invertebrates decreased[105].
The decline of Common Tern *Sterna hirundo* and Herring Gull in the Wadden Sea has been attributed to mercury pollution of the German Wadden Sea[106,107,108]. The rivers Elbe and Weser have been identified as being major sources of industrial pollutants, including mercury, reaching the North Sea. Among the species breeding there, Terns have the highest egg-mercury levels and approached those at which breeding success may be impaired[109].

102 Postma J (2009) De tapuiten van Ameland TWIRRE natuur in Fryslan 17: 132-137
103 Van de Pol M (2006). Ph.D. thesis, University of Groningen. http://irs.ub.rug.nl/ppn/296208205
104 Van de Kam J et al. (1999) Ecologische atlas van de Nederlandse wadvogels. Schuyt en Co, Haarlem
105 Ausden M et al (2003) Bird Study 50: 285-293
106 Becker PH et al (1993) Ecotoxicology 2: 33-40
107 Thompson DH et al. (1993) Journal of Applied Ecology 30: 316-320
108 Becker PH et al (1994) Archives of Environmental Contamination and Toxicology 27: 162-157
109 Becker PH et al (1993) Environmental Pollution 79(3): 207-213

The Wadden Sea region is of pronounced international importance for conservation of breeding Hen Harrier and Short-eared Owl. At mainland sites in the Wadden Sea states the species have more or less disappeared as breeding birds. Only three territories of Hen Harrier were found on Ameland in 2001, where, as late as 1990, 26 bp bred. The number of Dutch Hen Harrier breeding pairs in 2007 was half that of 2004. Food shortage (small mammals, esp. voles) appears to be an important cause[110,111].

A pair of Short-eared Owls nested on Griend, an islet in the Dutch Wadden Sea, was studied in 1992, 1994, 1995 and 1996. In the four years one, one, four and zero chicks fledged. Growth of the chicks showed differences corresponding with hatching order. Oldest chicks grew faster than their younger siblings. In 1996, chicks grew notably slower than in 1995. Pellets and plucking remains found in the immediate vicinity of the chicks revealed that Dunlins and Wood Mice made up 69 and 28%, respectively, of prey items in 1995. Other avian prey included Redshank, Turnstone, Common- and Arctic Tern. In 1996, however, Wood Mice made up 76% of prey items, while Dunlins accounted for only 8%. Timing of the start of the breeding season seems important for the Short-eared Owl on Griend. It was suggested that the islands' Wood Mice population alone does not allow for optimal growth and survival of owl chicks. When owls started breeding relatively early (1995: late March), Dunlins, present in large flocks, constituted an additional prey during the chick rearing period. This resulted in fast chick growth and good breeding success. In 1992 and 1996, Dunlins disappeared to migrate to their breeding areas one week after owl eggs had hatched; consequently, chick survival was low. Wood Mice were inadvertently introduced to the islet in 1988[112].

Common Eiders are specialised feeders on large benthic invertebrates, mainly blue mussels *Mytilus edulis* and common cockles *Cerastoderma edule*[113]. Recently, cut trough shells *Spisula subtruncata* in the adjacent North Sea coastal zone have been used as an alternative prey in some years[114]. Food shortage in winter and spring 1999/2000 was suggested to be the principal cause for the low reproductive output of Common Eiders in 2000, when an estimated 21,000 Common Eiders died in the Dutch Wadden Sea. Adult females probably failed to accumulate sufficient energy stores needed for their prolonged fast during laying and incubation[115].

[110] JMBB. The breeding bird season in the Wadden Sea in 2001. Wadden Sea Newsletter 2002-1
[111] Klaassen O et al (2009). Blauwe Kiekendieven op de Waddeneilanden in 2008. SOVON-onderzoeksrapport 2009/04. SOVON, Beek-Ubbergen
[112] Stienen EWM & Brenninkmeijer A (1997). Food and growth of Short-eared Owl *Aseo flammeus* chicks. Limosa 70: 5-10
[113] Swennen C (1976) Ardea 64: 311-371
[114] Leopold MF et al (2001) Wadden Sea Newsletter 23: 25-31
[115] Oosterhuis R & van Dijk K (2002) Atlantic Seabirds 4(1): 29-38

The decline of invertebrate-dependent woodland birds in Britain, France and Germany

Since the 1990s there has been an alarming decline of invertebrate-dependent birds in the woodlands of Britain, France and Germany (Table 10). The British Breeding Bird Survey (BBS)[116] has revealed a steep decline (since 1994) of the Willow Tit *Parus montanus* (down 77 per cent), Spotted Flycatcher *Muscicapa striata* (down 59 per cent), Wood Warbler *Phylloscopus sibilatrix* (down 67 per cent) and Pied Flycatcher *Ficedula hypoleuca* (down 54 per cent)[117]. Similarly dramatic population changes for these bird species were observed in France[118] and Germany[119] (Table 10).

In France, there has been a steep decline since the 1990s of the Wood Nuthatch *Sitta europaea* (down 48%), Willow Warbler *Phylloscopus trochilus* (down 54%), Marsh Tit *Parus palustris* (down 53%), Grey-faced Woodpecker *Picus canus* (down 62%), Wryneck *Jynx torquilla* (down 44%) and Common Crossbill *Loxia curvirostra* (down 54%) as well (Table 10). Similarly dramatic decline took place in the woodlands of Germany since the 1990s (with the exception of the Wood Nuthatch). The German Golden-Oriole *Oriolus oriolus* is in decline since the 1990s as well (Table 10).

The dramatic woodland bird decline in the UK, France and Germany appears to be associated with decline of the Eurasian Sparrowhawk *Accipiter nisus*, which nearly exclusively takes birds (Table 10). The Northern Goshawk *Accipiter gentilis* is in steep decline in Germany as well (Table 10).

116 Risely K et al. (2008) The Breeding Bird Survey 2007. BTO Research Report 508, British Trust for Ornithology, Thetford
117 RSPB, 17 July 2008
118 Jiguet F (2009) Suivi Temporel des Oiseaux Communs. Bilan pour la France en 2008
119 Flade M & Schwarz J (2004). Ergebnisse des DDA-Monitoringsprogramm, Teil II: Bestandsentwicklung von Waldvögeln in Deutschland. Vogelwelt 125:177-213

Table 10. Population changes of invertebrate-dependent woodland birds in the UK, France and Germany since the 1990s

Species	UK 1994-2007 in %	France 1989-2008 in %	Germany 1989-2003 in % p.a.*		Feeding habits§
			West	East	
Wood Warbler *Phylloscopus sibilatrix*	- 67	- 65	- 8.2	- 3.4	Mainly insects and other invertebrates, with some fruit and seeds in autumn
Willow Tit *Parus montanus*	- 77	- 59	- 1.5	- 3.3	Invertebrates and seeds: mainly invertebrates in breeding season, with seeds, from autumn onwards, dominating in winter
Pied Flycatcher *Ficedula hypoleuca*	- 54	- 33#	- 2.5	-4.7	Arthropods, flying and non-flying, especially *Hymenoptera*, *Diptera*, and beetles. During breeding season, larval *Lepidoptera*
Spotted Flycatcher *Muscicapa striata*	- 59	- 57	- 0.7	- 3.0	Feed on flying insects which they catch by pursuit, especially flies, aphids, beetles, ants, bees and wasps.
Willow Warbler *Phylloscopus trochilus*	+ 1	- 54	- 3.7	- 1.7	Insects and spiders, in autumn also berries. Food obtained mostly by picking from leaves, twigs, and branches, also flycatching
Wood Nuthatch *Sitta europaea*	+ 71	- 48	+ 0.2	+ 0.4	Invertebrates and (in autumn and winter) seeds. Most food obtained on trees, feeds also on ground, especially spring and autumn
Marsh Tit *Parus palustris*	- 6	- 53	- 0.6	- 2.3	Mostly insects and spiders in spring and summer, also seeds, berries, and nuts at other times of year
Grey-faced Woodpecker *Picus canus*	No data	- 62	- 6.5	- 9.2	Ants and other insects, insect pupae, larvae and spiders, and flies
Wryneck *Jynx torquilla*	No data	- 44	- 4.3	- 5.1	Principally, and sometimes exclusively, ants, but also other insects
Golden-Oriole *Oriolus oriolus*	No data	+ 32	- 2.1	- 4.3	Insects and berries. Feeds mainly in tops of trees, picking items from foliage
Tree Pipit *Anthus trivialis*	- 11	- 23	- 3.5	- 4.5	Chiefly insects with some plant material in autumn and winter. Food taken mostly from ground, occasionally after short aerial pursuit.
Common Crossbill *Loxia curvirostra*	- 37	- 54	- 6.5	- 8.8	Like many other seed-eating birds, the chicks are fed on insects initially, as these are highly nutritious
Northern Goshawk *Accipiter gentilis*	No data	+ 37	- 7.7	- 4.8	A wide variety of vertebrates and, occasionally, insects taken on the ground, in vegetation, or in the air. Preys may include birds.
Eurasian Sparrowhawk *Accipiter nisus*	- 12	- 77	- 1.1	- 4.6	Takes birds of varying sizes. Birds may account for well over 90% and may be as high as 98% of their diet

* p.a. per annum; # 2001-2008; § Avibirds European bird guide online, www.avibirds.com or ARKive, www.arkive.com. Sources for bird population changes: UK: Risely K et al. (2008) The Breeding Bird Survey 2007. BTO Research Report 508, British Trust for Ornithology, Thetford; France: Jiguet F (2009) Suivi Temporel des Oiseaux Communs. Bilan pour la France en 2008; Germany: Flade M & Schwarz J (2004). Ergebnisse des DDA-Monitoringsprogramm, Teil II: Bestandsentwicklung von Waldvögeln in Deutschland. Vogelwelt 125:177-213. Note that the German data are expressed as an annual percentage.

The decline of invertebrate-dependent farmland birds in Britain, the Low Countries, Germany, Switzerland, and France

Benton et al.[120] found temporal correlative links between numbers of farmland birds, numbers of invertebrates, and agricultural practice near Stirling in Scotland, and suggested that, although entirely correlative, their results were consistent with the view that agricultural change has influenced birds through changes in food quality or quantity. This was recently substantiated by a Europe-wide study that demonstrated negative effects of agricultural intensification on wild plant, carabid and bird species diversity[121]. The use of pesticides had consistent negative effects on biodiversity. Pesticides may affect food availability for birds through three main mechanisms[122]:

1) insecticides may deplete or eliminate arthropod food supplies, which are exploited by adults and their dependent young during the breeding season and, in so doing, reduce breeding productivity;
2) herbicides may reduce the abundance of, or eliminate, non-crop plants that are hosts for arthropods taken as food by farmland birds during the breeding season, and thereby reduce breeding productivity. A large number of wild plants are pollinated predominantly or exclusively by bumble bees and there is mounting evidence that many bumble bee species have declined in recent decades[123]. Reduced pollination services can be particularly detrimental when plants are already scarce[124];
3) herbicides may also deplete or eliminate weed species, which provide either green matter or seeds for herbivorous and granivorous species, respectively, thereby reducing survival of those birds that rely on those food supplies.

On a farm scale, comparison of organic and conventional farms often indicates increased biodiversity in the former, e.g. birds[125,126,127] arthropods[128,129,130] soil organisms[131,132] and weeds[133,134]. Invertebrates are a major component of chick food for many farmland bird species, such as Chaffinch *Fringilla coelebs*, Cirl Bunting *Emberiza cirlus*, Corn Bunting *Miliaria calandra*, Goldfinch *Carduelis carduelis*, Greenfinch *Carduelis chloris*, Grey Partridge *Perdix perdix*, House Sparrow *Passer domesticus*, Red-legged Partridge *Alectoris rufa*, Reed Bunting *Emberiza schoeniclus*, Rook *Corvus frugilegus*, Skylark *Alauda arvensis*, Stone Curlew *Burhinus oedicnemus*, Tree Sparrow *Passer montanus*, Yellowhammer *Emberiza citrinella* and Yellow Wagtail *Motacilla flava*[135].

[120] Benton TG et al. (2002) Journal of Applied Ecology 39: 673-687
[121] Geiger F et al (2010) Basic and Applied Ecology
[122] Boatman ND et al (2004), Ibis 146, 131-143
[123] Goulson D (2003) Bumblebees: Behaviour and Ecology, Oxford University Press, Oxford, UK
[124] Biesmeijer JC et al. (2006) Science Vol. 313. no. 5785, pp. 351 - 354
[125] Wilson JD et al. (1997) Journal of Applied Ecology 34: 1462-1478
[126] Christensen KD et al. (1996) Dansk Orntogisk Forenings Tidsskrift 90: 21-28
[127] Freemark KE & Kirk DA (2001) Biol. Conserv. 101: 337-350
[128] Moreby SJ et al. (1994) Ann. Appl. Biol. 125: 13-27
[129] Feber RE et al (1997) Agric. Ecosyst. Environ. 64: 133-139
[130] Feber RE et al. (1998) J. Arachnol. 26: 190-202
[131] Yeates GW et al. (1997) Journal of Applied Ecology 34: 453-470
[132] Hansen B et al (2001) Agric. Ecosyst. Environ. 83: 11-26
[133] Hald AB et al. (1999) Ann. Appl. Biol. 134: 307-314
[134] Rydberg NT & Milberg P (2000) Biol. Agric. Hortic. 18: 175-185
[135] DEFRA EPG 1/5/188

Farmland birds in Germany are declining since the 1960s in East and West, but the decline was disproportionately greater in West Germany than in East Germany[136], as illustrated by German distribution charts of Northern Wheatear *Oenanthe oenanthe* and Whinchat *Saxicola rubetra* (right) during the breeding season of 1985 (Figure 3). Ground-nesting farmland birds such as Northern Lapwing, Skylark, Whinchat and Meadow Pipit continued to decline in Germany in the 1990s and the breeding population of the Black-tailed Godwit has shrunk to less than half its former level. Particularly alarming is the steep decline of ground-nesting birds in the eastern state of Saxony (Table 11) since 1993-1996[137].

Table 11. The decline of ground-nesting farmland bird populations (breeding pairs) in Saxony since the mid 1990s

Species	1993-1996	2004-2007	Comment
Grey Partridge *Perdix perdix*	1,500-3,000	300-400	The effects of pesticides on arthropods important in chick diet were identified as a major causal factor in the decline of the Grey Partridge (Potts, 1986)
Northern Lapwing *Vanellus vanellus*	900-1,600	500-800	Chicks require ground-dwelling prey such as ground beetles (*Carabidae*) and earthworms (*Lumbricidae*) on the surface (Table 4)
Whinchat *Saxicola rubetra*	2,500-5,000	1,500-2,500	The decline of the Whinchat was shown to be related a decrease in the availability of nestling food affecting parents' foraging efficiency and reproductive success (Britschgi et al, 2006)
Northern Wheatear *Oenanthe oenanthe*	600-1,000	350-600	Diet based chiefly on insects, also spiders, molluscs, and other small invertebrates, supplemented by berries. Normally locates prey visually, chiefly on ground or in low vegetation (Table 8)
Meadow Pipit *Anthus pratensis*	2,500-5,000	1,500-2,500	Diet based on invertebrates, with some plant seeds in autumn and winter. Feeds almost exclusively on ground, walking at steady rate picking invertebrates from leaves and plant stems
Crested Lark *Galerida cristata*	500-800	250-400	Diet is mainly based on plant material and fewer invertebrates in winter. Most food taken from on or below ground surface. Digs with blows of bill to left and right. Will take insects by aerial-pursuit and stripping wings off before eating body.

Sources (unless indicated otherwise): Anonymous (2008). Ist das Artensterben in der Agrarlandschaft noch aufzuhalten? Dokumentation der Fachtagung „Biodiversität“ der Fraktion Bündnis 90/Die Grünen im Sächsischen Landtag am 17. November 2008; Britschgi A et al (2006) Biological Conservation 130: 193-2005; Potts GR (1986). The Partridge: Pesticides, Predation and Conservation. London: Collins

[136] Anonymous (2008) Birds and Biodiversity in Germany – 2010 Target. Dachverband Deutscher Avifaunisten, www. dda-web.de
[137] Anonymous (2008). Ist das Artensterben in der Agrarlandschaft noch aufzuhalten? Dokumentation der Fachtagung „Biodiversität“ der Fraktion Bündnis 90/Die Grünen im Sächsischen Landtag am 17. November 2008.

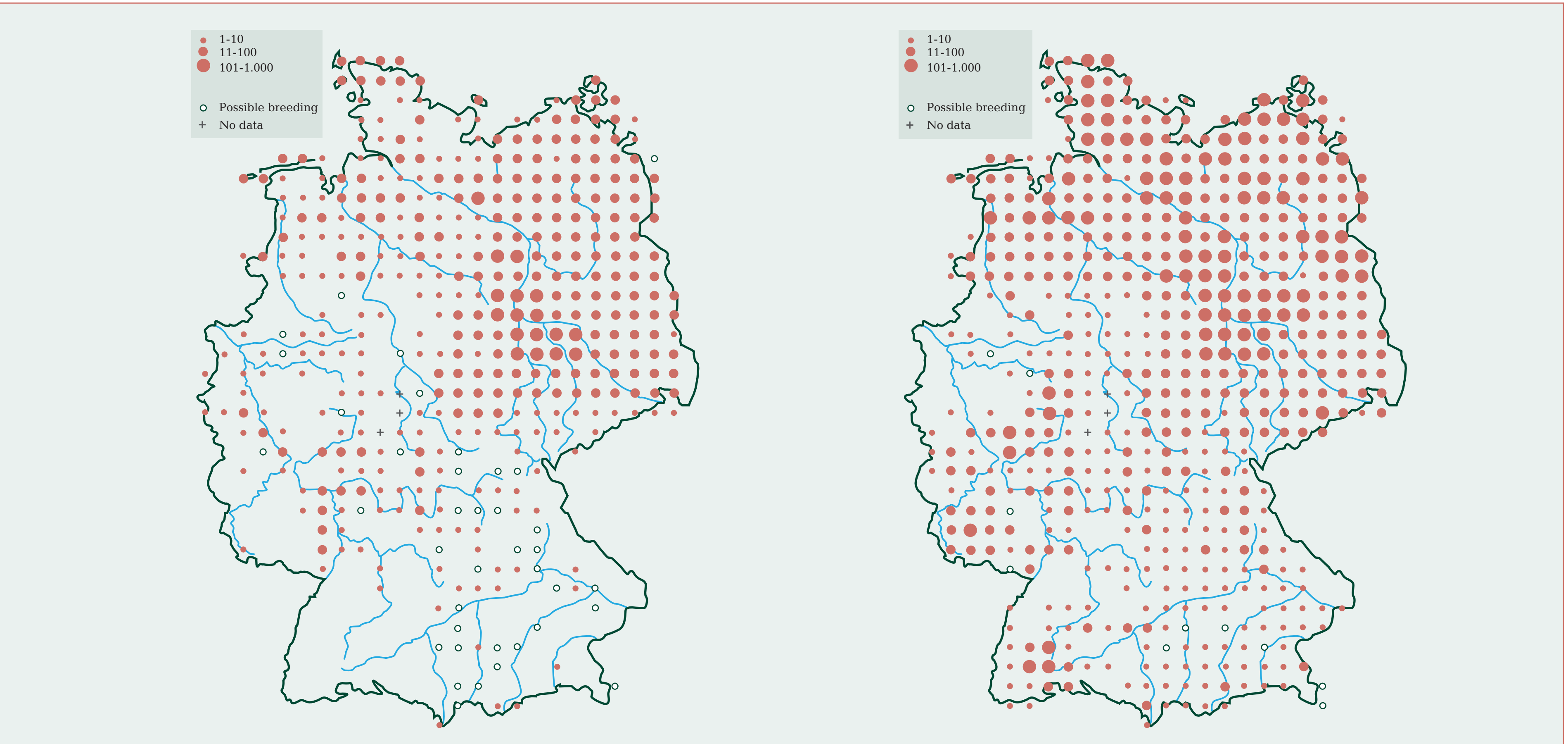


Figure 3.
Distribution of the Northern Wheatear *Oenanthe oenanthe* (left) and Whinchat *Saxicola rubetra* (right) during the breeding season in Germany in 1985.

Source: Rheinwald, G. (1993): Atlas der Verbreitung und Häufigkeit der Brutvögel Deutschlands – Kartierung um 1985. Schriftenr. Dachverband Dt. Avifaunisten 12

Northern Wheatear, Whinchat, and Crested Lark *Galerida cristata* are close to extinction in Flanders[138]. In the grasslands of Luxemburg there has been a massive 70-90% decline of the Whinchat, Meadow Pipit *Anthus pratensis* and Yellow Wagtail from 1996 to 2007[139]. Corn Buntings *Miliaria calandra* were abundant throughout arable agricultural landscapes in Europe, but have catastrophically declined since the mid 1970s with changes in farming practice[140]. Following continued steep decline in the 1990s, the Corn Bunting is now considered extinct in the Netherlands[141,142] (Figure 4) and in the Republic of Ireland[143]. The Corn Bunting has almost completely disappeared from West-German farmland and declined by a staggering 83% over the past twenty years, according to a recent study of thirty sites in Aberdeenshire and Angus[144]. Data from a study site on the South Downs in Sussex showed that Corn Buntings collected invertebrates for their chicks in areas that received relatively few **insecticide** and **herbicide** applications. These areas contained more invertebrates of the types commonly fed to chicks than more heavily sprayed areas. When the abundance of chick-food invertebrates was low close to a nest, breeding success was low. In these conditions chicks were underweight, parents foraged further from the nest and nest failure rate was high. When chick-food invertebrates near the nest were more abundant, breeding success was higher[145]. Breeding and wintering abundance of Corn Buntings in an agricultural landscape of Alentejo (southern Portugal) was assessed in relation to agricultural intensification and other environmental variables during 1994-1997. Bird abundance was lowest in intensively managed farmland in both seasons[146]. Indirect effects of **insecticides** on behavior and nestling conditions of Yellowhammers *Emberiza citrinella* have also been observed[147]. Insecticide use was associated with reduced abundance of invertebrate food at the field scale resulting, early in the season (when nestlings were fed exclusively on invertebrates) in a negative correlation with Yellowhammer foraging intensity. There was also a negative relationship between insecticide use and nestling body condition. A recent study identified two factors that may limit breeding productivity of the Reed Bunting *Emberiza schoeniclus*, which is in significant decline in England since the 1990s: ground vegetation providing concealment from nest predators and availability of invertebrate prey for chicks[148]. The effects of pesticides on arthropods important in chick diet were identified as a major causal factor in the decline of the Grey Partridge *Perdix perdix*[149]. Foraging sites with low vegetation height and density, but with high arthropod biomass, are selected by Meadow Pipits breeding on intensively grazed moorland[150]. Meadow Pipits select particular prey types to provision nestlings, in particular, *Lepidoptera* larvae, adult *Tipulidae* and *Arachnida*.

138 Devos K & Anselin A (1999) Natuurrapport 1999. Toestand van de natuur in Vlaanderen: cijfers voor het beleid. Instituut voor Natuurbehoud
139 Gilles Biver, L-1899 Kockelscheuer, Wiesenvogel-Kartierung 2007
140 Fox T & Heldbjerg H. (2008) Agriculture, ecosystems & environment , vol. 126, pp. 261-269
141 Kurstjens G et al. (2003). Limosa 76: 89-102
142 Dijk, A.J. van et al. (2009). Broedvogels in Nederland in 2007. SOVON-monitoringrapport 2009/01. SOVON Vogelonderzoek Nederland, Beek-Ubbergen
143 Taylor AJ and O'Halloran (2002) Biology and Environment: Proceedings of the Royal Irish Academy, vol 102B, no 3, pp 165-175
144 RSPB, 18 July 2009
145 Brickle N (1999) Pesticides News 43: 17
146 Stoate C et al (2000). Agriculture, Ecosystems and Environment 77: 219-226
147 Morris AJ et al. (2005), Agriculture, Ecosystems and Environment 106, 1-16
148 Brickle NW and Peach WJ (2004) Ibis 146: 69-77
149 Potts GR (1986). The Partridge: Pesticides, Predation and Conservation. London: Collins
150 Douglas DJT et al (2008) Bird Study 55: 290-296

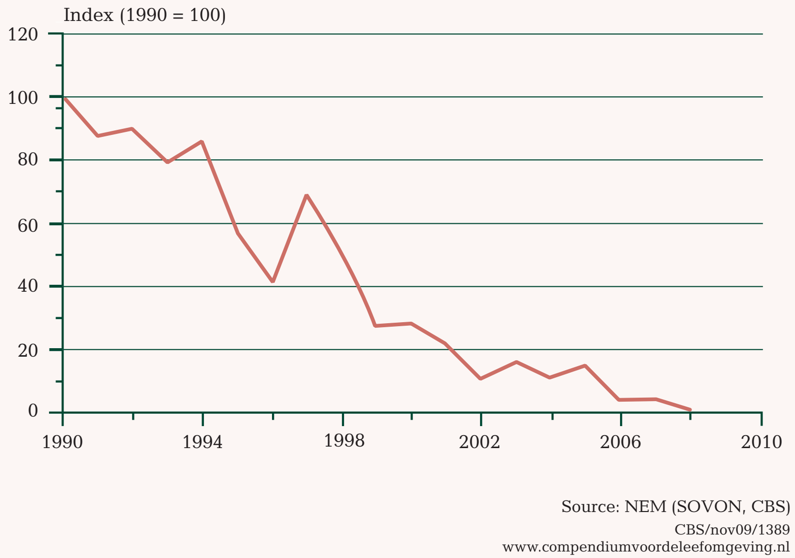


Figure 4.
The decline to extinction of the Corn Bunting *Miliaria calandra* since 1990 in the Netherlands.

Source: Netwerk Ecologische Monitoring (NEM) [CBS (Dutch Central Statistics Office), SOVON Vogelonderzoek Nederland]

In Switzerland, the Whinchat *Saxicola rubetra* is a threatened meadow breeder. The Swiss population (breeding pairs) declined by 31.1% from 1990 to 2004[151]. Apart from a few remnant populations, it has disappeared from the lowland plateau ("Mittelland") and is now restricted to low-intensity grassland in the montane and subalpine regions. Whinchat populations are declining in most regions in Switzerland and the adjacent countries (French parts of the Jura and Alsace, Southern Germany, Liechtenstein and Austria)[152]. The decline of the Whinchat in Switzerland was shown to be related to the recent intensification of farming practices, which has led to a decrease in the availability of grassland invertebrates, and of important Whinchat nestling food in particular, affecting parents´ foraging efficiency and reproductive success[153]. When food supply and nestling diet in intensively vs. traditionally managed grassland were compared, abundance and diversity of arthropods were much lower in intensive areas, where small-sized invertebrates, which do not enter nestling diet, were also predominant. Parents breeding in intensive habitats fed less biomass to nestlings than adults from traditional habitats. Nestling diet was less diverse and dominated by less profitable prey items in intensive than in traditional habitats. Feeding rate did not differ between the two habitats, but foraging distances from nest tended to be greater in intensive farmland. There were no significant differences in clutch sizes and hatching success with respect to management intensity, but fledging success was higher in traditional habitats.

On lowland wet grassland sites in England and Wales there were significant declines of 38% for Northern Lapwing *Vanellus vanellus*, 61% for Snipe *Gallinago gallinago*, 40% for Curlew

Numenius arquata and 29% for Redshank *Tringa totanus* between 1982 and 2002[154]. There has been a massive 95% decline in the UK Tree Sparrow *Passer montanus* population between 1974 and 1999. The nestling diet of Tree Sparrows is largely composed of invertebrates. It is possible that due to agricultural intensification in the late 20th century and increased use and effectiveness of insecticides there has been a decline in invertebrate prey, rendering large areas of farmland as suboptimal breeding habitat for Tree Sparrows[155].

There has been a large population decline of the Song Thrush *Turdus philomelos* in Britain during the last three decades, which has reduced breeding densities on farmland by nearly 70% between 1968 and 1999[156]. Survival of birds in their first year of life after fledging was shown to have a great impact on population changes. Changes in survival in the first winter are sufficient to have caused the Song Thrush population decline. Earthworms and other soil-dwelling invertebrates form a large component of the diet of Song Thrushes, particularly between December and May. Earthworms move deeper into the soil and/or become inactive during periods of cold weather and hence become less available as prey for Song Thrushes. Reduced availability of invertebrate food could explain reduced survival in the winter.

[151] Zbinden N et al (2005) Der Ornithologische Beobachter 102: 271-282
[152] Horch, P et al. (2008) Ornithol. Beob. 105: 267–298
[153] Britschgi A et al (2006) Biological Conservation 130: 193-2005
[154] Wilson et al. (2005) Bird Study 52: 55-69
[155] Field RH and Anderson GQA (2004) Ibis 146, 60-68
[156] Robinson RA et al. (2004) Journal of Animal Ecology 73: 670-682

The decline of invertebrate-dependent birds in settlements in Britain, France, Germany and Switzerland

A major decline of the insectivorous Northern House Martin *Delichon urbica* and Barn Swallow *Hirundo rustica*, bird species that are characteristic for settlements, has been observed in France, Switzerland[157] and Germany[158,159] since the 1990s (Table 12). The insectivorous Common Swift *Apus apus* and the omnivorous Starling *Sturnus vulgaris* are in major decline in the UK since 1994 (Table 12). The House Sparrow *Passer domesticus* was in decline in Germany, France and the UK in the 1990s (Table 12). The four most common building nesters in Germany – House Sparrow, Common Swift, Northern House Martin and Barn Swallow – show largely parallel population declines since the 1990s. The Swiss population of the insectivorous Common Redstart *Phoenicurus phoenicurus* is in steep decline since 1990 (Table 12).

Past reductions in the availability of pasture may have reduced the numbers of aerial invertebrates, and may have contributed to Barn Swallow population declines, and possibly those of other aerial insectivores[160]. Aerial invertebrate abundance over pasture fields in lowland mixed farmland in southern Britain was more than double that over silage, and more than three and a half times greater than that over cereal fields. Pasture fields also hosted approximately twice as many foraging Barn Swallows as both silage and cereal fields. Swifts spend their life almost entirely on the wing and even feed, sleep and mate in flight. They feed exclusively on insects and only come to land when nesting. An abundant supply of insects is critical for their survival. Parent Swifts collect lots of insects to take back to their chicks – up to 1,000 at once which make a big bulge in their throat. When they have chicks to feed, Swifts can gather as many as 100,000 insects a day[161].

Long-term changes in total aerial insect biomass have been estimated for a wide area of Southern Britain from 1973 to 2002[162], and there was a significant decline in total biomass at Hereford. The Hereford samples were dominated by large *Diptera*, particularly *Dilophus febrilis*, which showed a significant decline in abundance. The use of insecticides to control leatherjackets (*Tipulidae* larvae) may have had an effect on the similar and closely related *D. febrilis*[163]. *Diptera* have been identified as important in the diet of adults and chicks across a range of bird species[164,165,166].

157 Zbinden N et al (2005) Der Ornithologische Beobachter 102: 271-282
158 Bundesamt für Naturschutz, Birds and Biodiversity in Germany, Target 2010
159 Schwarz J & Flade M (2000) Bestandsveränderungen von Vogelarten der Siedlungen seit 1989. Vogelwelt 121: 87-106
160 Evans KL et al. (2007) Agriculture, Ecosystems & Environment 122, 267-273
161 RSPB (2009) Summer visitor making a swift exit
162 Shortall CR et al. (2009). Insect Conservation and Diversity 2, 251-260
163 McCracken DI & Tallowin JR (2004) Ibis 146 (suppl. 2): 108-114
164 Holland JM et al. (2006) Annals of Applied Biology 148: 49-71
165 Moreby SJ (2004) Insect and Bird Interactions (ed. by van Emden HF & Rothschild M), pp. 21-35, Intercept, Andover, UK
166 Buchanan GM et al. (2006) Ibis 148: 615-628

There is additional evidence for a general decline of insects in Britain over the last 30-35 years. In a 35 yr study of British moths[167], two-thirds of 337 species studied showed decline and 21% (71) of the species declined >30% 10 yr^{-1}. In a UK-wide Big Bug Count held throughout June 2004, nearly 40,000 conservation-minded drivers counted the bugs splattered on their vehicle number plates[168]. Using a cardboard counting-grid dubbed the "splatometer", they recorded an average of only one squashed insect every five miles, whereas in the summers of 30-odd years ago, car bonnets and windscreens would quickly become encrusted with tiny bodies.

Starling *Sturnus vulgaris* populations have declined throughout Europe over the last two decades[169,170]. The Starling is commonest in urban and farmland habitats, though density in the latter is much lower. Soil and ground-dwelling invertebrates, particularly leatherjackets (tipulid larvae) and earthworms, are the main prey of Starlings. The use of insecticides on grassland is targeted partly at tipulids, which may have reduced foraging opportunities for Starlings.

Britain's House Sparrow population has actually declined by 68 percent since 1977[171]. Recent large declines in House Sparrow populations in many European towns and cities have generated much speculation as to possible environmental causes. Reproductive failure linked to inadequate invertebrate availability provides a plausible demographic mechanism accounting for declines in urban-suburban House Sparrow populations[172]. A study focusing on factors affecting nesting success and annual productivity of nesting House Sparrows along an urban-suburban-rural gradient centred on the city of Leicester showed that the abundance of invertebrate prey within home ranges of House Sparrows breeding within suburban and rural habitats limits the quantity and quality of chicks raised to fledging. The combined effects of relatively high rates of chick starvation and low body masses at fledging (and consequently low post-fledging survival) observed in suburban localities are large enough to result in rapid population declines[173].

[167] Conrad KF et al. (2006) Biological Conservation 132, 279-291
[168] The Independent, 2 September 2004
[169] Robinson RA et al. (2002) BTO Research Report No. 290
[170] Robinson RA et al. (2006) Acta Zoologica Sinica 52: 550-553
[171] Birder's Magazine, 20 November 2008
[172] Peach WJ et al. (2008) Animal Conservation 11: 493-503
[173] Vincent KE (2005). Investigating the causes of the decline of the urban House Sparrow *Passer domesticus* population in Britain. De Montfort University, Ph.D. Thesis

Table 12. **The decline of invertebrate-dependent birds in settlements in Britain, France, Germany and Switzerland**

Species	UK 1994-2007 change in %	France 1989-2008 change in %	Germany 1989-1998 change p.a. in %		Switzerland 1989-1998 change in %	Feeding habits and habitat§
Common Redstart *Phoenicurus phoenicurus*	+ 23	+ 31	+ 4.5		- 58	Diet based largely on insects and spiders. Adapted to woodland edges, streamside and roadside trees, orchards, and gardens in human settlements.
House Sparrow *Passer domesticus*	- 10	- 14	- 13.1		No data	Weed and grass seeds, grains, and insects. These non-migratory birds are often closely associated with human populations and are found in highest abundance in agricultural, suburban, and urban areas
Common Swift *Apus apus*	- 41	- 20	- 6.2 east	+ 3.2 west	No data	Insectivorous, feeding solely on aerial insects and spiders. Prefers areas with trees, or buildings with open spaces
House Martin *Delichon urbica*	+ 9	- 42	- 2.7 east	- 3.6 west	- 50	Almost wholly flying insects, especially flies and aphids. General use of buildings, bridges, and other artefacts
Barn Swallow *Hirundo rustica*	+ 25	- 8	- 1.5 east	0.0 west	- 34	Mostly flying insects, especially flies. Barn Swallows need open areas to forage and suitable sites for nesting, now almost always buildings, bridges, or other man-made structures
Starling *Sturnus vulgaris*	- 26	- 6	- 0.41		+ 7	Starlings eat a diverse, omnivorous diet of invertebrates, berries and other fruit, grains, and seeds. They usually forage in open areas, especially lawns, agricultural fields, or other developed areas, but require nearby nesting cavities.

§Avibirds European bird guide online, www.avibirds.com or ARKive, www.arkive.com. Sources for bird population changes: UK: Risely K et al. (2008) The Breeding Bird Survey 2007. BTO Research Report 508, British Trust for Ornithology, Thetford; France: Jiguet F (2009) Suivi Temporel des Oiseaux Communs. Bilan pour la France en 2008; Germany: Schwarz J & Flade M (2000) Ergebnisse des DDA-Monitoringsprogramm. Teil I: Bestandsveränderungen von Vogelarten der Siedlungen seit 1989. Vogelwelt 121: 87-106. Note that the German data are expressed as an annual percentage; Switzerland: Zbinden N et al (2005) Bestandsentwicklung von regelmässig brütenden Vogelarten der Schweiz 1990-2004. Der Ornithologische Beobachter 102: 271-282

The decline of invertebrate-dependent birds in alpine regions of France, Germany and Switzerland

The German breeding population of the Western Capercaillie *Tetra urogallus* decreased by 20-50% between 1996 and 2005[174]. The total number of Capercaillie *Tetra urogallus* males in Switzerland in spring 2001 was estimated to be between 450 and 500, less than one-half of the 1968/1971 census carried out with the same method (1100 males)[175]. Since 1970, the distribution range of the Western Capercaillie in Switzerland has shrunk, too. Although the food of adults is predominantly, if not exclusively, plants, young Capercaillie chicks take substantial amounts of animal material, mainly insects and spiders. The breeding populations of Wallcreeper *Tichodroma muraria*, Rock Trush *Monticola saxatilis* and Ring Ouzel *Turdus torquatus* are in decline in Switzerland since the 1990s (Table 13). The breeding populations of Alpine Accentor *Prunella collaris* and Bonellis Warbler *Phylloscopus bonelli* are declining in France since the 1990s (Table 13).

Table 13. The decline of invertebrate-dependent birds in alpine regions of France and Switzerland

Species	France 1989-2008 change in %	Switzerland 1990-2004 change in %	Feeding habits and habitat§
Wallcreeper *Tichodroma muraria*	No data	- 56	Small insects and spiders. Breeds in mountains regions of lower middle latitudes
Rock Trush *Monticola saxatilis*	+ 62#	- 33	Mainly large insects, especially beetles, *Lepidoptera* larvae, and *Orthoptera*. Breeds in open, rocky habitats, usually in mountainous areas
Ring Ouzel *Turdus torquatus*	+ 33#	- 29	In spring and early summer, adult and larval insects and earthworms, at other times, mainly fruit. Breeds in upper and middle latitudes, largely oceanic upland in former and continental montane in latter.
Alpine Accentor *Prunella collaris*	- 60#	No data	Diet based on insects, plus significant proportion of plant seeds. Breeds exclusively in mountain ranges of middle latitudes, from 1800 m up to snow line, in some places up to 4000 m.
Bonellis Warbler *Phylloscopus bonelli*	- 42	No data	Mainly insects and a few other invertebrates. Most foraging done in tree crown, frequently on outermost branches and twigs. Breeds in mixed woodland, especially on mountain slopes and gorges.

2001-2008 §Avibirds European bird guide online, www.avibirds.com or ARKive, www.arkive.com. Sources for bird population changes: France: Jiguet F (2009) Suivi Temporel des Oiseaux Communs. Bilan pour la France en 2008; Switzerland: Zbinden N et al (2005) Bestandsentwicklung von regelmässig brütenden Vogelarten der Schweiz 1990-2004. Der Ornithologische Beobachter 102: 271-282

[174] Bundesamt für Naturschutz, Birds and Biodiversity in Germany, Target 2010
[175] Mollet P et al (2003) Der Ornithologische Beobachter 100: 67-86

Conclusions

Neonicotinoid insecticides, first introduced in 1991, differ from conventional spray products in that they can be used as seed dressings or as soil treatments. When used as a seed dressing, the insecticide will migrate from the stem to the leaf tips, and eventually into flowers and pollen. Any insect that feeds on the crop dies, but bees or butterflies that collect pollen or nectar from the crop are also poisoned. Neonicotinoid insecticides act by causing virtually irreversible blockage of postsynaptic nicotinergic 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 in the long run.

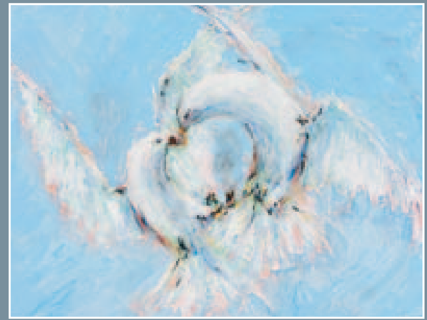
But there is even more trouble ahead. Neonicotinoid insecticides, such as imidacloprid, clothianidin and thiamethoxam, are persistent and mobile in soil, soluble in water and stable to breakdown by water at neutral pH, and - as a result of these properties - the compounds may leach from soils. Since 2004 major contamination of Dutch surface water with imidacloprid has been detected by the Water Boards, particularly in the western part of the country. Consequently, high concentrations of imidacloprid have been diffusing through the environment in the Netherlands for many years now, killing or debilitating non-target insects and possibly other arthropods, and by doing so progressively reducing invertebrate prey for birds. Invertebrate-dependent bird species in the Netherlands have been declining on a massive scale in recent times. Monitoring data reveal steep decline since 2000 in the number of invertebrate-dependent Dutch meadow birds (Skylark, Yellow Wagtail, Oystercatcher, Black-tailed Godwit, Northern Lapwing, Common Redshank, Meadow Pipit), particularly in the western part of the country. Evidence collected in the Wormer- and Jisperveld reserve in the western province of North-Holland indicates that the decline of the Black-tailed Godwit is caused by a lack of larger insects on which the chicks depend for their survival. The breeding populations of several invertebrate-dependent bird species observed on Dutch heath land (Northern Wheatear, Whinchat, Black Grouse, Tawny Pipit, Wryneck and Red-backed Shrike) have declined dramatically in recent decades, and there is evidence from the Dwingelderveld heath reserve that the decline of Northern Wheatear and Whinchat is related to food shortage (ground beetles). Likewise, the negative trends in the Dutch Wadden Sea observed since 1991 for the breeding populations of many invertebrate-dependent bird species (Pied Avocet, Kentish Plover, Eurasian Curlew, Common Redshank, Common Eider, Oystercatcher, Black-tailed Godwit, Northern Lapwing, Northern Wheatear, and Red-backed Shrike) appear to have been caused by food shortage. The breeding populations of invertebrate-dependent Dutch marsh birds (such as the Great Reed Warbler, Bearded Tit and Spotted Crake) are also steeply declining since 1990. In stark contrast, the populations of fish-eating marsh bird species (such as Great Bittern, Purple Heron, Eurasian Spoonbill and Black-crowned Night Heron) were stable or have grown in size since 1990.

Elsewhere in western Europe the situation is not much different. Ground-nesting invertebrate-dependent farmland birds such as Northern Lapwing, Skylark, Whinchat and Meadow Pipit continued to decline in Germany in the 1990s. On lowland wet grassland sites in England and Wales there were significant declines for Northern Lapwing, Snipe, Curlew and Redshank between 1982 and 2002. In Switzerland, the Whinchat has disappeared from the lowland plateau ("Mittelland") and is now restricted to low-intensity grassland in the montane and subalpine regions. The Whinchat is close to extinction in the Low Countries. Corn Buntings, once abundant throughout arable agricultural landscapes in Europe, have catastrophically declined and are now considered extinct in the Netherlands and in the Republic of Ireland. The Reed Bunting, Song Thrush and Tree Sparrow are in massive decline in the UK. Since the 1990s there has been an alarming decline of invertebrate-dependent birds in the woodlands of Britain, France and Germany (Willow Tit, Spotted Flycatcher, Wood Warbler, Pied Flycatcher, Wood Nuthatch, Willow Warbler, Marsh Tit, Grey-faced Woodpecker, Wryneck, Common Crossbill, and Golden-Oriole), which even leads to a decline of the Eurasian Sparrowhawk. Invertebrate-dependent bird species that are characteristic for settlements (Northern House Martin, Barn Swallow, Common Swift, Starling, House Sparrow and Common Redstart) are also in major decline in several European countries since the 1990s. In alpine regions, the breeding population of the Western Capercaillie is declining. The breeding populations of Wallcreeper, Rock Trush and Ring Ouzel in Switzerland and of Alpine Accentor and Bonellis Warbler in France are also steeply declining since the 1990s. 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 it is actually taking place before our eyes, and that it must be stopped.

Artwork

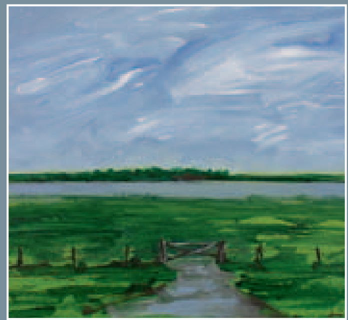
Ami-Bernard Zillweger was born in 1942 in Fribourg, in the French-speaking part of Switzerland. In 1971, after many years of cultural travel, he settled in Zutphen. The use of colour and light puts Zillweger's work in the French painter tradition, albeit with his own distinctive marks. He uses many techniques for numerous subjects such as landscapes, portraits, circus, theatre scenes and still lives: large and small drawings, acrylic resin paintings, lithographs, water-colour, even wooden objects. The colours in his landscape paintings convert sensation into a harmony of complimentary contrasts, based entirely on his own intuition.

Landscape I

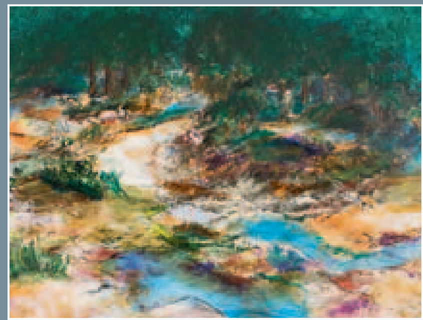


Battling Gulls

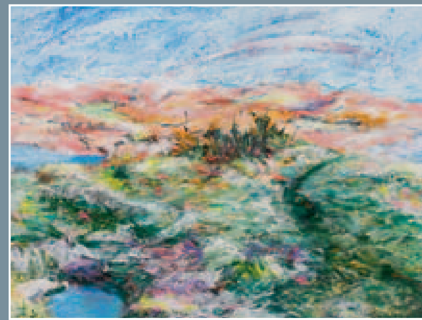
River Town



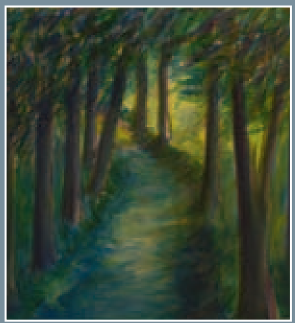
Green Land at the River



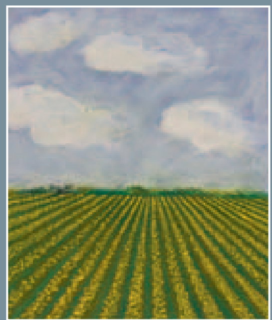
Wet Spot in Woodland



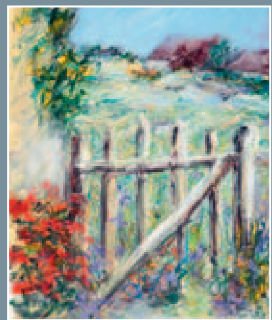
Landscape II



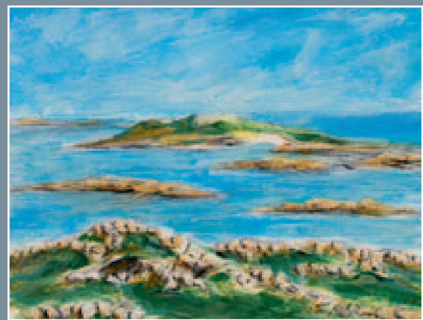
The Light in Val Bregaglia



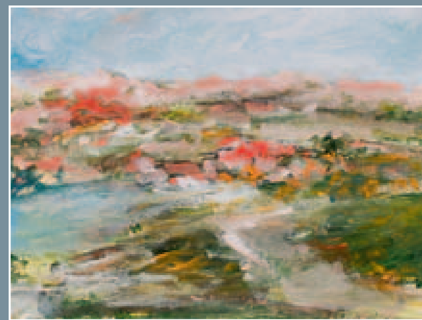
Arable Land Behind the Dyke



Back Garden with Fence



Connemara, Ireland



High Bank

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