Table 1: Life history effects, Krischik lab, Feb 2020 Papers on sublethal effects of neonic on native bee behavior								
species	**Pesticide/exposure (abbreviations at end)**	**Effect on weight**	**Effect on brood/ development**	**Effect on emergence**	**Effect on survivor/ mortality**		**other**	**Author(s)**
Osmia lignaria	IMD, soil				100 ppb lived 5 days less 0S, 7.5 ppb 15 ppb no effect		Tested males and females	Anderson & Harmon-Threatt 2019
Megachile rotundata	IMD, soil	15ppb 11-12% less than control		E 1-3 days slower, E 100 ppb 2 days faster	15 ppb lived 3 day longer, 100 ppb 4 day longer compared to control		Tested males and females	Anderson & Harmon-Threatt 2019
Bombus impatiens	IMD, 10-100 ppb in 50% sugar soln	Colony weight 23-50% lower in 10-100 ppb. Bee weight unaffected	Less total brood in 20-100 ppb		20-100 ppb had higher queen mortality			Scholer and Krischik 2015
Bombus impatiens	CLO, 10-100 ppb in 50% sugar soln	Colony weight 69-81% lower in 20-100 ppb	Less total brood in 50-100 ppb		20-100 ppb had higher queen mortality			Scholer and Krischik 2015
Bombus terrestris	IMD, 6 ppb in pollen and .7 ppb in sugar soln	No effect on colony size or			No effect on lifespan			Feltham & Park *et al.* 2014

		worker body size						
Bombus terrestris	TMX, chronic, 2.4 ppb in 40% sucrose soln				No effect on survivorship			Stanley & Russell *et al.* 2016
Bombus terrestris	TMX, 2.4 ppb in 50% inverted sugar syrup for 2 wks		26% fewer queens initiated colonies after hibernation					Baron & Jansen *et al*. 2017
Bombus terrestris	TMX, chronic, 10 ppb in 40% sucrose soln	No effect on worker body size					Flight arena, real flowers	Stanley & Raine *et al.* 2016
Bombus impatiens	IMD, chronic, 6 ppb in nectar		Treated colonies had reduced rates of nursing. Treated colonies less likely to insulate brood with wax (p=.0005)					Crall & Switzer *et al*. 2018
Bombus terrestris	CLO, chronic, 1 ppb in 60% sugar soln		No effect on fecundity		Exposure decreased survival of bees when harnessed for PER assay (p=.04)			Piiroinen & Botías *et al*. 2016
Bombus terrestris	AZD, chronic, 0.064-32 mg/L in sugar water, exposed for 11 weeks	Negative effect on body mass of male progeny	Drone production significantly lower at .64 mg/L; no drone production in 3.2 and 32 mg/L		Survival curve at 3.2 mg/L significantly lower than control (p<.001)		Exposure caused deformities of adult appendages	Barbosa & De Meyer *et al*. 2014
Bombus terrestris	SFX, 5 ppb in 1.8M sucrose soln, *ad libitum* for 2 weeks	No effect on dry mass of males	Treated colonies produced fewer males in total, as well as fewer		Queen longevity and colony survival not affected			Siviter & Brown *et al*. 2018

			reproductive offspring					
Osmia bicornis	ACM, IMD, & MYC, in various concentrations based on field relevancy, in pollen and sugar syrup	No effect on body size			No effect on survival or longevity			Azpiazu & Bosch *et al*. 2019
Bombus terrestris	ACY, 1 and 2 ppm in water (bees were dipped in)				2 ppm treated bees died much more quickly than control.			Muljar & Karise *et al*. 2012
Osmia bicornis	CLO, 1, 3, 10 ppb in pollen provisions	No effect on larval mass of brood or adult body mass. No effect on weight lost over winter	No effect on larval mass of brood or developmental time	No effect on emergence time	No effect on mortality			Nicholls & Fowler *et al*. 2017
Bombus impatiens	CLO, 6 (realistic) and 36 (high) ppb in Biogluc sugar soln	No effect on newly emerged bee weights	No effect on number of brood, workers, males, or queens produced				Funded by Bayer. Questionable stats/methods	Franklin & Winston *et al*. 2004
Bombus terrestris	CLO & BCY, 10g & 2g / kg seed respectively, in oilseed rape seed coats		No effect on number of worker bees. Hives at test site produced more queen brood cells ($p=.035$). No effect on the sum of queen brood cells and young queens				Funded by Bayer. Questionable stats/methods	Sterk & Peters *et al*. 2016

Bombus terrestris	IMD, various concentrations 0.08 – 125 ug/L in sugar syrup for 13 days		No effect of dosage on number of days before first oviposition. Fecundity declined with increasing dosage					Laycock & Lenthall *et al*. 2012
Bombus impatiens	IMD, granular on turf, 0.4483 kg/ha IMD, spray on turf, 0.336 kg/ha CBR, spray on turf, 6.1 kg/ha CPS, spray on turf, 1.12 kg/ha CYF, spray on turf, .077 kg/ha	Nonirrigated IMD spray plot colonies had lower total worker biomass and lower colony weight. Irrigated IMD spray had no effect. Nonirrigated CBR, CPS, and CYF plots had reduced total worker biomass and colony weight	Nonirrigated IMD spray plot colonies had fewer brood chambers & honey pots. Irrigated IMD spray had no effect. Nonirrigated CBR, CPS, and CYF plots showed reduced brood chambers & honey pots. Nonirrigated CBR and CPS plots had reduced live brood		Nonirrigated IMD spray plot colonies had fewer workers. Irrigated IMD spray had no effect. Nonirrigated CBR, CPS, and CYF plots had fewer workers		Funded by US Golf Assoc.	Gels & Held *et al*. 2002
Bombus occidentalis	IMD, chronic, 7 ng/g in pollen		No effect on number of workers, queens, or males, or on amount of brood				Funded by Bayer & Monsanto	Morandin & Winston 2003
Bombus occidentalis	IMD, chronic, 7 ng/g & 30 ng/g in pollen		No effect on number of workers, queens,				Funded by Bayer & Monsanto	Morandin & Winston 2003

			or males, or on amount of brood					
Bombus terrestris, B. lucorum, B. pratorum, B. pascuorum	TMX, 1 ppb and 4 ppb in syrup		Queens' terminal oocyte length was reduced in high dose by between 4.6% and 13.8% in different species. No treatment effects on waxing behavior		Treatment did not affect survival rate or time until death			Baron & Raine *et al.* 2017
Bombus impatiens	SPI, 0.2, 0.8, and 8.0 mg/kg in pollen patties, fed *ad libitum*		8 mg/kg treatment had fewer brood and workers		8 mg/kg treatment had more dead bees each week			Morandin & Winston *et al.* 2005
species	**Pesticide/exposure**	**Effect on weight**	**Effect on brood/ development**	**Effect on emergence**	**Effect on survivor/ mortality**		**other**	**Author(s)**

Table 2: Behavioral effects								
species	**Pesticide/exposure (abbreviations at end)**	**Effect on movement**	**Effect on foraging**	**Effect on thermoreg and metabolism**	**Effect on hygienic behavior**	**Effect on learning and memory**	**other**	**Author(s)**
Bombus impatiens	IMD, 10-100 ppb in 50% sugar soln	100 ppb no effect on queen movement, 20-100 ppb workers moved much more slowly						Scholer and Krischik 2015

Bombus impatiens	CLO, 10-100 ppb in 50% sugar soln	100 ppb no effect on queen movement, 20-100 ppb workers moved much more slowly						Scholer and Krischik 2015
Bombus impatiens	IMD, acute dose in 30% sucrose		56.2 ppb less likely to visit flowers during training			56.2 ppb no effect on color-reward assoc.	Artificial flowers in an arena	Muth & Leonard 2019
Bombus impatiens	IMD, acute, 22.5 ppb in 30% sucrose					Treated bees made twice as many errors in scent learning	Artificial flowers in an arena	Muth & Francis *et al* 2019
Bombus terrestris	IMD, chronic, 6 ppb in pollen and .7 ppb in sugar soln		No effect on nectar foraging rate. Pollen forage rate 31% less in treated bees					Feltham & Park *et al.* 2014
Bombus terrestris	TMX, chronic, 2.4 ppb in 40% sucrose soln		Treated bees foraged for 23% on avg ($p=.045$). Less treated bees returned to colony carrying pollen ($p=.03$).					Stanley & Russell *et al.* 2016
Bombus terrestris	IMD, acute, 1 ppb in 35% sucrose soln	No effect on speed of movement between flowers or total distance moved	Treated bees were 3.8 x slower to begin foraging ($p<.001$). Also visited fewer flowers ($p=.037$)			No effect on learning discriminate between different flowers	Artificial flowers in an arena	Lämsä & Kuusela *et al*. 2018
Bombus terrestris	TMX, chronic, 10 ppb in 40% sucrose soln		No effect on time spent foraging or time at each flower. More exposed bees foraged for pollen ($p=.03$)			Treated bees learned foraging behavior quicker ($p=.04$) (not sure I agree with how	Flight arena, real flowers	Stanley & Raine *et al.* 2016

						they quantified this)		
Bombus impatiens	IMD, chronic, 6 ppb in nectar	Treatment increased worker movement speed during day		Treatment impaired thermoregulation of brood (p=.005) and regulation of air temp (p=.009)			Treated colonies were sig. less active	Crall & Switzer *et al*. 2018
Bombus impatiens	IMD, acute, .1 or 1 ng/bee		1.0 ng/bee reduced foraging				Treated bees strayed further from center of nest	Crall & Switzer *et al*. 2018
Bombus terrestris	CLO, chronic, 1 ppb in 60% sugar soln					Exposure did not affect learning performance in PER assay		Piiroinen & Botías *et al*. 2016
Bombus terrestris	IMD, .06-98.4 ppb in sugar syrup			5ppb increased warming rate by ¼. Post-torpor temp reduced by 2ºC. Rewarming ability increases with low dose and decreases with higher dose				Potts & Clarke *et al*. 2017
Bombus terrestris	TMX, .06-98.4 ppb in sugar syrup			5ppb decreased warming rate by ¼. Post-torpor temp reduced by 2ºC. Rewarming ability decreases with higher dose				Potts & Clarke *et al*. 2017

Bombus terrestris	IMD, 10 ppb in sucrose soln		Treated foragers collected less pollen in later weeks (p=.001)					Gill & Raine *et al*. 2014
Bombus terrestris	LCY, 37.5 ppm sprayed on filter paper in feeding chamber (trod upon)		Fewer foraging bouts in later weeks (p=.01)					Gill & Raine *et al*. 2014
Bombus terrestris	IMD & LCY, as described in 2 above rows		Fewer foraging bouts in later weeks (p=.001). Foragers collected less pollen in later weeks (p=.03)					Gill & Raine *et al*. 2014
Melipona quadrifasciata	ACM, .015-150 ng/bee, and ACY, .030-300 ng/bee, in 50% sucrose soln (commercial mix Fastac Duo), acute				Antennation and trophallaxis frequencies were affected by pesticide (p= .022 & .005)			Boff & Friedel *et al*. 2018
Bombus terrestris	TMX, .091, .377, or 2.5 ng/bee, acute, in sucrose soln					.377 and 2.5 treated bees returned more often and earlier to flowers they'd depleted	2.5ng/bee used as a non-field-realistic positive control	Samuelson & Chen-Wishart *et al*. 2016
Bombus impatiens	IMD, .0515-5.15 ng/bee in sugar soln, acute		.0515 ng/bee did not affect sonication frequency or length but was more likely to sonicate flowers after treatment. .515 & 5.15 were less likely to					Switzer & Combes 2016

			sonicate flowers after treatment					
Bombus terrestris	TMX, acute, 10 and 2.4 ppb in 40% sucrose soln, 10ul per bee					Learning level lower at 10 ppb. Learning ability of trainable bees not affected. No effect on memory		Stanley & Smith *et al*. 2015
Bombus terrestris	TMX, chronic, 10 and 2.4 ppb in 40% sucrose soln, *ad libitum*					No effect on trainability or learning level. Trained control bees learned tasks 27% faster than 2.4ppb and 38% faster than 10ppb. Both treatments affected memory		Stanley & Smith *et al*. 2015
Bombus terrestris	AZD, chronic, 0.064-32 mg/L in sugar water, exposed for 11 weeks						3.2mg/L treatment decreased sugar water consumption by 71%.	Barbosa & De Meyer *et al*. 2014
Bombus terrestris	TMX, 2.4 and 10 ppb in 40% sucrose for 12-15 days		10 ppb colonies showed lower visitation rates to apple flowers (p=.05). Fewer 10 ppb bees returned with pollen (p=.008). 10 ppb bees spent more time foraging (p=.03) and					Stanley & Garratt *et al*. 2015

			visited more flowers of one breed of apple (p=.002) than control					
Bombus terrestris	SFX, 5 ppb in 1.8M sucrose soln, *ad libitum* for 2 weeks		No significant differences in number of bees returning to colonies from foraging, number of bees returning with pollen, or size of pollen loads					Siviter & Brown *et al*. 2018
Osmia bicornis	ACM, IMD, & MYC, in various concentrations based on field relevancy, in pollen and sugar syrup			Thoracic temperature was lower in bees treated with all 3 pesticides			IMD-treated bees consumed 80% less syrup per day (p<.001)	Azpiazu & Bosch *et al*. 2019
Bombus terrestris	SFX, 2.4, 100, or 250 ppb in 10uL sucrose soln		Exposure did not affect number of correct choices before flower revisitation			Exposure did not affect learning or working memory		Siviter & Scott *et al*. 2019
Apis mellifera	SFX, 2.4, 100, or 250 ppb in 10uL sucrose soln		Exposure did not affect number of correct choices before flower revisitation			Exposure did not affect learning or working memory		Siviter & Scott *et al*. 2019
Bombus terrestris	CLO, 5 ppb in 40% sucrose soln in the field for 5 wks		Exposure lowered avg foraging activity; avg pollen load did not differ. Treated colonies exhibited less fluctuation in proportion of foragers returning with pollen					Arce & David *et al*. 2017

Bombus terrestris	ACY, 1 and 2 ppm in water (bees were dipped in)			2 ppm but not 1 ppm bees showed decreased bursts of CO_2 releases, metabolic rates decreased. No effect on water loss rates				Muljar & Karise *et al*. 2012
Bombus terrestris	IMD, acute, 10 ppb in 50% sucrose soln in a cotton ball	Treated workers flew significantly less far ($p<.001$) and for less time than control workers. 65% of control workers flew for full hour while no treated workers did. Treated workers attained a higher mean velocity ($p=.005$) but not max velocity						Kenna & Cooley *et al*. 2019
Osmia bicornis	CLO, 1, 3, 10 ppb in pollen provisions			No sig difference between treatments on metabolic rate or engagement in continuous gas exchange				Nicholls & Fowler *et al*. 2017
Bombus impatiens	CLO, 6 (realistic) and 36 (high) ppb in		No effect on mean flower access time, no effect on pollen consumption			No effect on learning rate of foragers	Funded by Bayer. Question able	Franklin & Winston *et al*. 2004

	Biogluc sugar soln						stats/methods	
Bombus terrestris	CLO & BCY, 10g & 2g / kg seed respectively, in oilseed rape seed coats	"No abnormalities in behavior, such as apathy or a lack of flight activity" observed		No observed effect on hive thermoregulation			Funded by Bayer. Questionable stats/methods	Sterk & Peters *et al*. 2016
Osmia cornuta	CLO, 0.76 ng/bee (0.076 ppm) in diluted honey	No effect on walking speed, although treated bees walked less straight				Treated bees couldn't retrieve memories of learned navigational cues		Jin & Klein *et al.* 2015
Bombus terrestris	IMD, 125 ug/L or 98 ug/kg in feeder syrup	Treated bees exhibited reduced daily locomotory activity ($p=.002$), and once the IMD was removed from their diet they were more active than control bees	Treated bees exhibited reduced mean daily rates of feeding ($p<.001$)					Cresswell & Robert *et al*. 2012
Bombus terrestris	IMD, various concentrations 0.08 – 125 ug/L in sugar syrup for 13 days		Significant negative effect of treatment on daily feeding rates which increased with concentration					Laycock & Lenthall *et al*. 2012
Bombus impatiens	IMD, granular on turf, 0.4483 kg/ha IMD, spray on turf, 0.336 kg/ha		Granular IMD had no effect on foraging with posttreatment irrigation. Nonirrigated spray				Funded by US Golf Assoc.	Gels & Held *et al*. 2002

	CBR, spray on turf, 6.1 kg/ha CPS, spray on turf, 1.12 kg/ha CYF, spray on turf, .077 kg/ha		IMD plots showed reduced foraging activity, irrigated IMD spray had no effect. Nonirrigated CBR, CPS, and CYF plots showed reduced foraging activity					
Bombus occidentalis	IMD, chronic, 7 ng/g in pollen		No effect on pollen consumption				Funded by Bayer & Monsanto	Morandin & Winston 2003
Bombus occidentalis	IMD, chronic, 7 ng/g & 30 ng/g in pollen		No effect on number of flowers accessed per foraging trip. 30 ppb bees took 42% longer to access flowers				Funded by Bayer & Monsanto	Morandin & Winston 2003
Bombus terrestris, B. lucorum, B. pratorum, B. pascuorum	TMX, 1 ppb and 4 ppb in syrup		High dose negatively affected feeding of *B. pascuorum* and *B. pratorum*					Baron & Raine *et al.* 2017
Bombus impatiens	SPI, 0.2 and 0.8 mg/kg in pollen patties, fed *ad libitum*		0.8 mg/kg treatment spent longer at flowers and had longer foraging rates					Morandin & Winston *et al.* 2005
Apis mellifera	TMX, acute, 1.34 ng/bee in 10 uL 2.0 M glucose soln	Treated bees flew 78% longer (p=.002) and 72% farther (p=.002) after consuming TMX. No effect on mean or						Tosi & Burgio *et al*. 2017

		maximum velocity						
Apis mellifera	TMX, chronic, at 0, 32.5, or 45.0 ppb in 1.8 M sucrose soln	Treated bees flew for less distance ($p<.0001$), less duration ($p<.0001$), reduced mean velocity ($p=.002$), and reduced maximum velocity ($p=.002$)						Tosi & Burgio *et al*. 2017
Apis mellifera	TMX, acute, 1.34 ng/bee in 10 uL 1.8 M sucrose test soln	Treated bees had increased velocity on their first path towards light ($p=.001$) but not increased distance ($p=.36$). 30 min after treatment, treated bees showed increased velocity ($p=.0091$) and increased time spent moving ($p=.024$). TMX also increased number of falls ($p=.013$)						Tosi & Nieh 2017

Apis mellifera	TMX, chronic, 45 ppb in 1.8 M sucrose soln	Exposure resulted in a shorter first path towards light (p=.016). Exposure increased proportion of bees that couldn't climb to the top (p=.021). No effect on time spent moving, distance covered, or overall velocity						Tosi & Nieh 2017
species	**Pesticide/exposure (abbreviations at end)**	**Effect on movement and flight**	**Effect on foraging and feeding**	**Effect on thermoreg and metabolism**	**Effect on hygienic behavior**	**Effect on learning and memory**	**other**	**Author(s)**

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Pesticide abbreviations:

ACM = acetamiprid (neonicotinoid)

ACY = α-cypermethrin (pyrethroid)

AZD = azadirachtin (secondary metabolite derived from neem)

BCY = β-cyfluthrin (pyrethroid)

CBR = carbaryl (carbamate)

CLO = clothianidin (neonicotinoid)

CPS = chlorpyrifos (organophosphate)

CYF = cyfluthrin (unspecified, pyrethroid)

IMD = imidacloprid (neonicotinoid)

LCY = λ-cyhalothrin (pyrethroid)

MYC = myclobutanil (triazole fungicide)

SFX = sulfoxaflor (sulfoxamine)

SPI = spinosad (from bacteria)

TMX = thiamethoxam (neonicotinoid)