United States Environmental Protection Agency

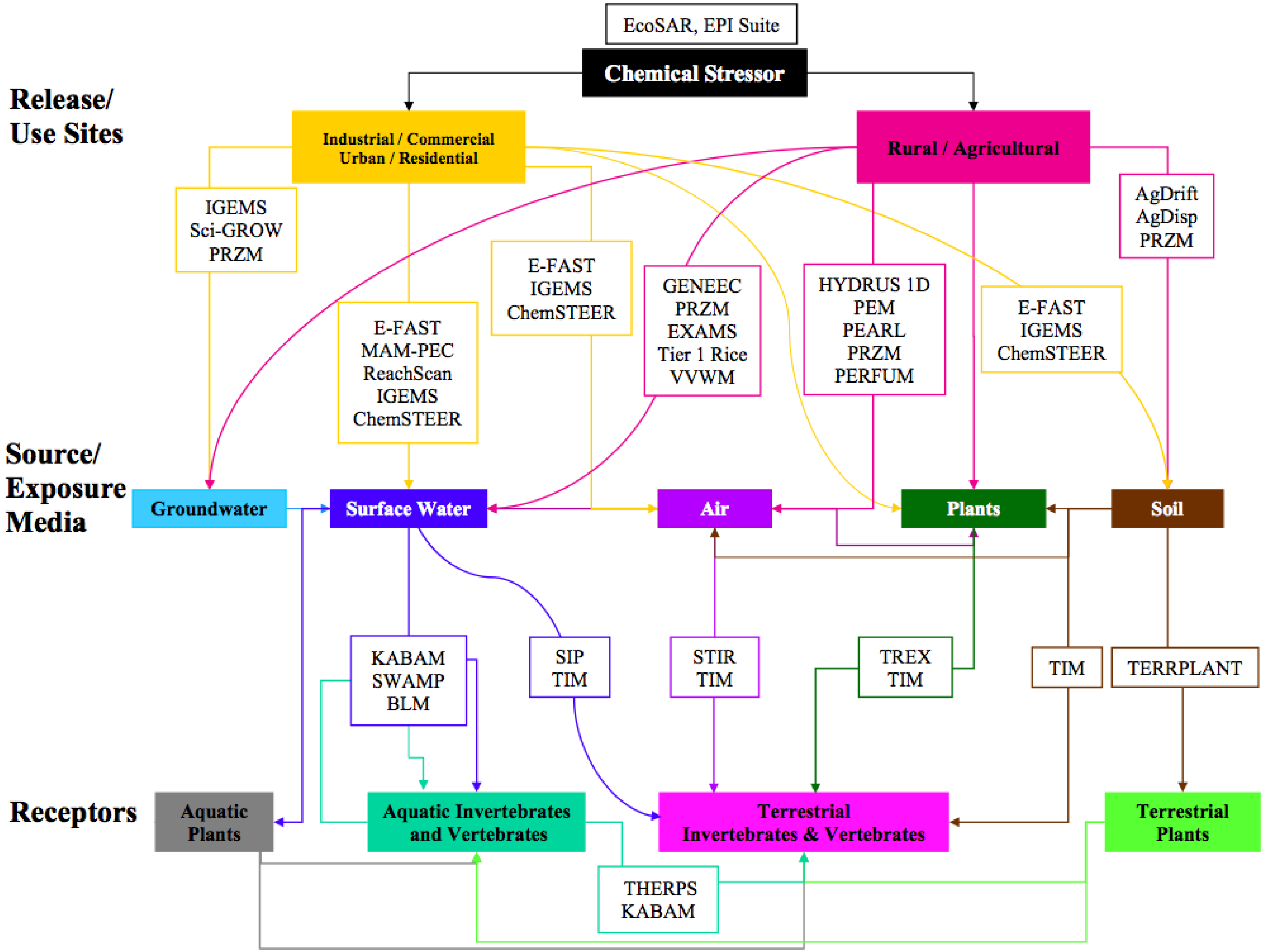
Estimating terrestrial dermal amphibian pesticide exposures for regulatory use

Terrestrial Vertebrates Risk Assessment to Pesticides
SETAC Latin America Symposium

Tom Purucker (purucker.tom@epa.gov)

Ecological Risk Estimation for Registration and Effects Assessment

- Tiered ecological risk for pesticides (effects determination, registration)
- Must clear external review
- Complex problem- many combinations of:
    - species,
    - chemicals,
    - physical settings,
    - data sources,
    - application rates/methods;
    - often a spatial component.
- Many lines of evidence and models are evaluated for a pesticide registration.


EcoSAR, EPI Suite
Chemical Stressor
Release/ Use Sites
Industrial / Commercial Urban / Residential
Rural / Agricultural
IGEMS Sci-GROW PRZM
E-FAST MAM-PEC ReachScan IGEMS ChemSTEER
E-FAST IGEMS ChemSTEER
GENEEC PRZM EXAMS Tier 1 Rice VVWM
HYDRUS 1D PEM PEARL PRZM PERFUM
E-FAST IGEMS ChemSTEER
AgDrift AgDisp PRZM
Source/ Exposure Media
Groundwater
Surface Water
Air
Plants
Soil
KABAM SWAMP BLM
SIP TIM
STIR TIM
TREX TIM
TIM
TERRPLANT
Receptors
Aquatic Plants
Aquatic Invertebrates and Vertebrates
Terrestrial Invertebrates & Vertebrates
Terrestrial Plants
THERPS KABAM

https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/technical-overview-ecological-risk-assessment-1

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Technical Overview of Ecological Risk Assessment - Analysis Phase: Exposure Characterization

About Exposure Characterization

Table of Contents for Technical Overview of

Dietary Exposure for Reptiles and Amphibians through Food Items

For terrestrial reptiles and amphibians, EPA uses a modified version of T-REX called T-HERPS (Terrestrial Herpetofaunal Exposure Residue Program Simulation) to estimate dietary exposure. The allometric equations in T-REX have been adjusted to account for the lower metabolic rate and food intake of herptiles compared to birds. Information concerning T-HERPS can be found on the Models for Pesticide Risk Assessment website.

- source(s) of the pesticide and what is exposed (e.g., plants, animals, media),
- fate and t
- how ofter concern t

Templates
- Ecotoxicity Categories
- Analysis - Exposure Characterization

Dermal Exposure to Birds, Mammals, Reptiles, and Amphibians

Currently, EPA is developing a model (Dermal Uptake Screening Tool (DUST)) to estimate exposure to birds, mammals, reptiles, and amphibians through the dermal route. DUST compares a ratio of exposure to toxicity and then compares this ratio to a limit of concern to determine if dermal exposure warrants further exploration. After the model is finalized, it will be used as a qualitative tool to screen out pesticides that are not of concern when considering exposure through the dermal route.

efsa
European Food Safety Authority

https://www.efsa.europa.eu/en/consultations/call/170410

Calendar english (en)

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Grants

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Public consultation on the Draft Scientific Opinion on the state of the science of pesticide risk assessment for amphibians and reptiles

Deadline: 24 May 2017

Document (7.18 MB)

Privacy statement (78.67 KB)

EFSA has launched an open consultation on the draft Scientific Opinion on the state of the science on pesticide risk assessment for amphibians and reptiles. This document proposes the scientific basis for developing a future risk assessment scheme. The coverage of the risk to amphibians and reptiles by current risk assessments for other

to the line and page numbers.

Subject area

Pesticides

The PPR Panel was tasked to provide a scientific opinion on the state of the science on pesticide risk assessment for amphibians and reptiles. Concerns had been raised that the current risk assessment of pesticides may not sufficiently cover the risk to amphibians and reptiles. The opinion should provide the scientific basis for potentially developing a guidance document for pesticide risk assessment for amphibians and reptiles.

The Panel concludes that exposure of amphibians and reptiles to pesticides does occur, and that this exposure may lead to decline of populations and harm individuals, which would be of high concern. Therefore, a specific environmental risk assessment (ERA) scheme is needed for for these groups.

Amphibian Dermis and Exposure

Gas & water exchange

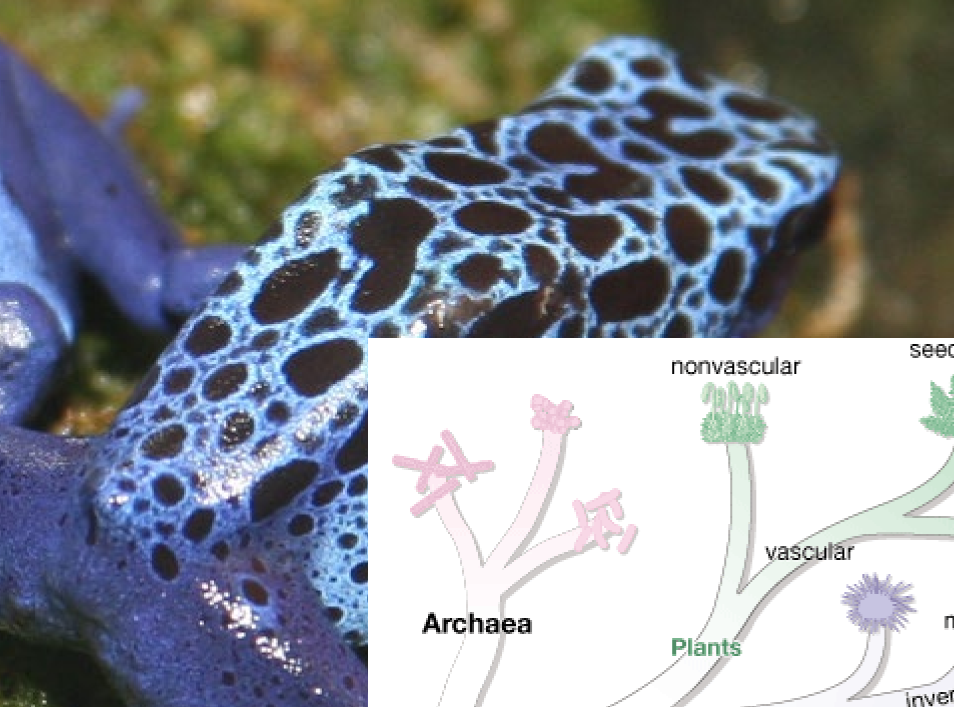
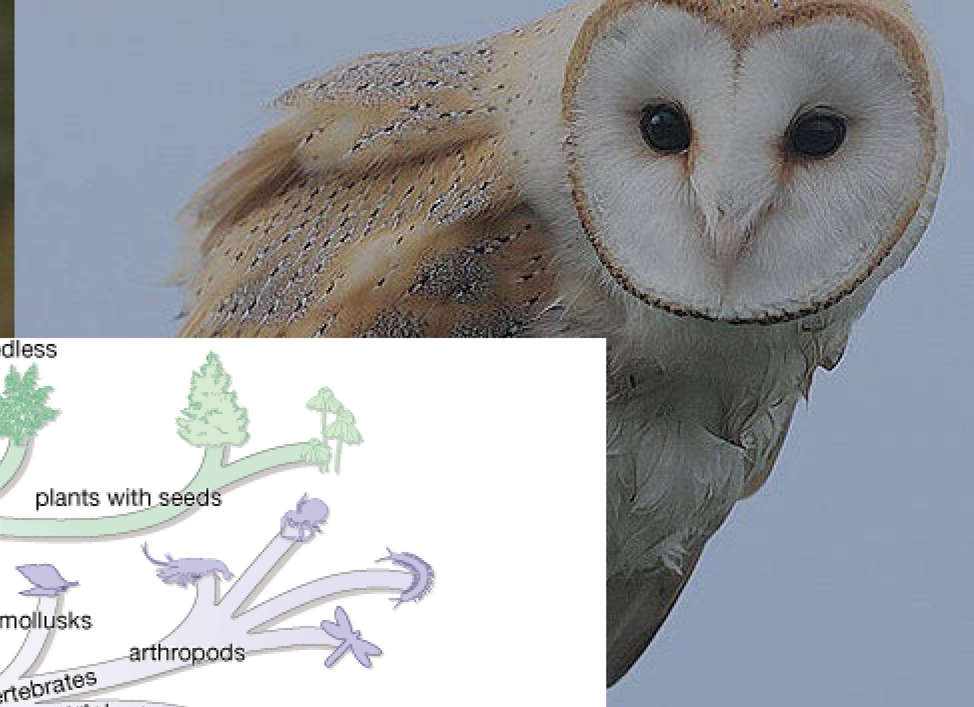
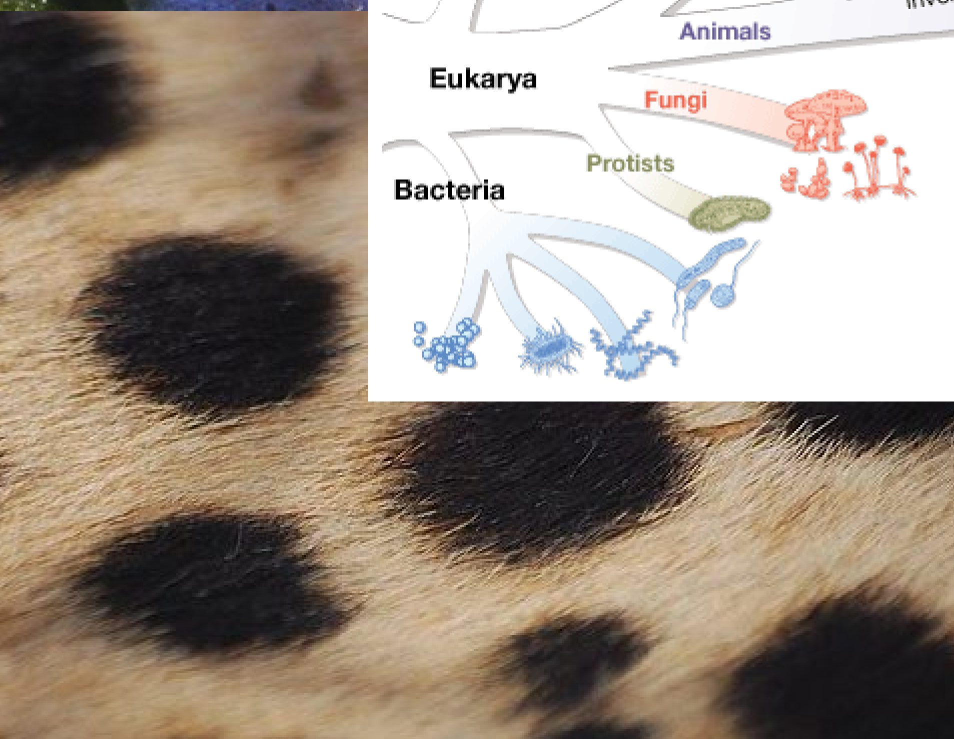
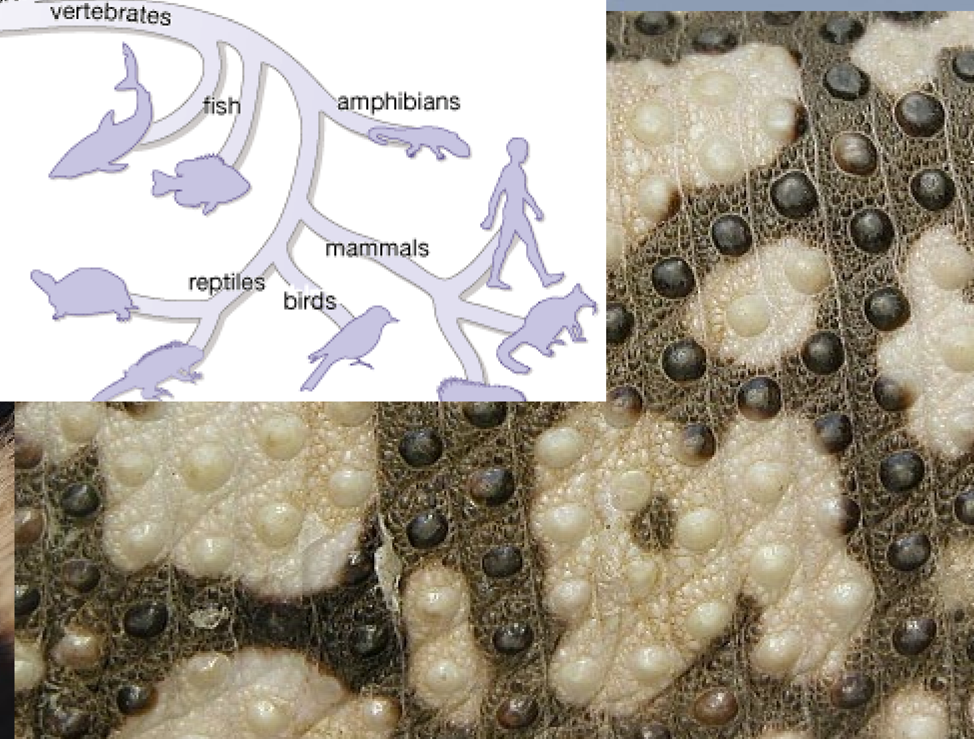
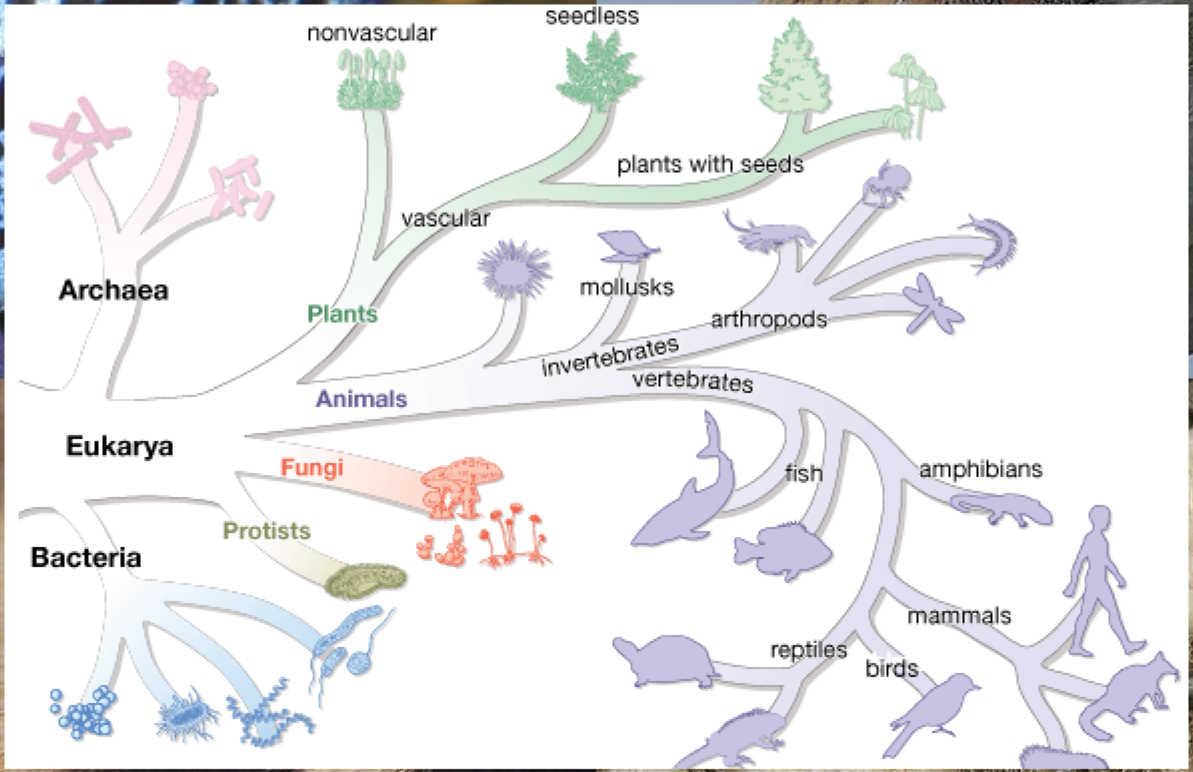
Comparatively thinner stratum corneum

Water transport via aquaporins

Lack outer hydrophobic barrier

Highly vascularized seat patch

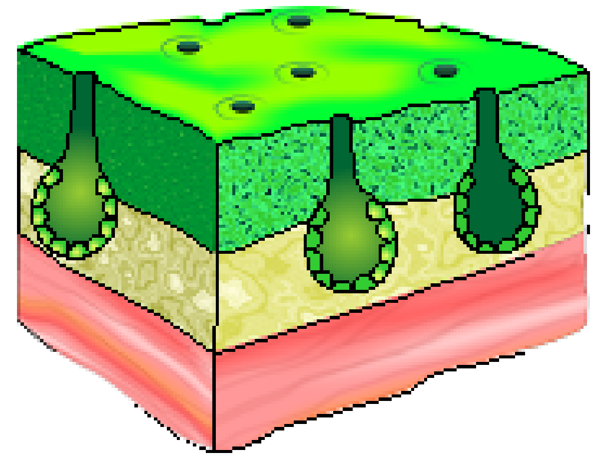
Less keratinized

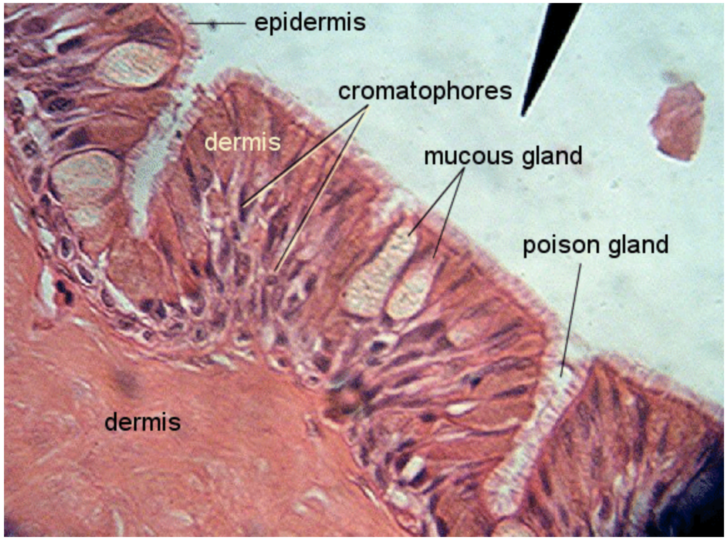






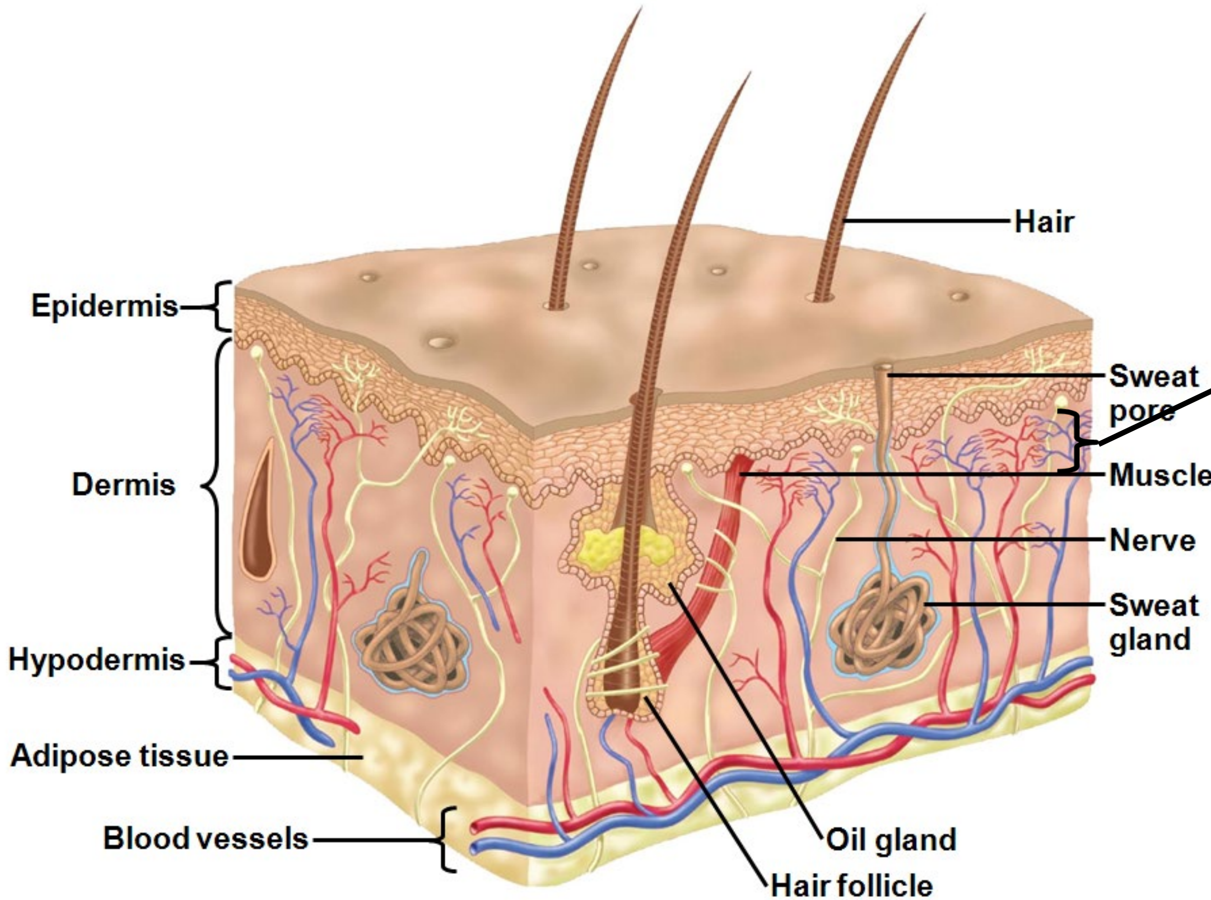
nonvascular
seedless
plants with seeds
vascular
Archaea
Plants
mollusks
arthropods
invertebrates
vertebrates
Animals
Eukarya
Fungi
fish
amphibians
Protists
Bacteria
mammals
reptiles
birds

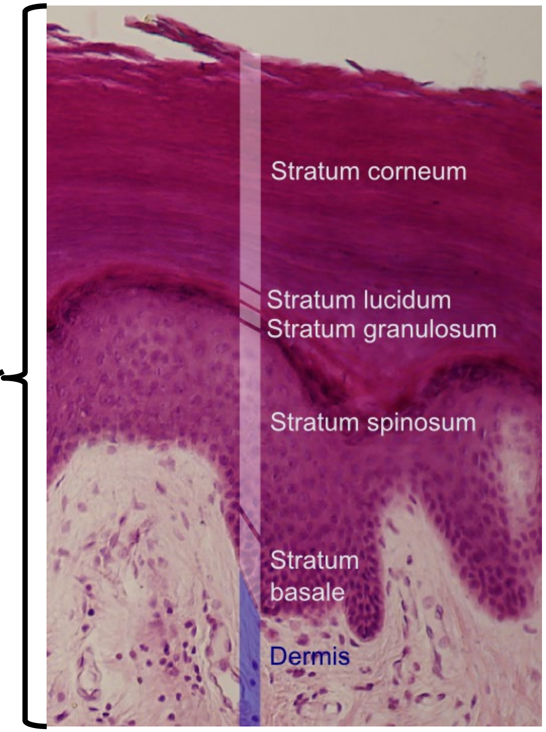
Amphibian dermis structural differences

- Relatively thinner
- Thin stratum corneum
- No external hydrophobic barrier
- Less keratinized
- High rates of gas and water exchange
- Seat patch as preferential pathway
- Physiological properties change over life history









Hydrophilic (low K_{ow}) and lipophilic (high K_{ow}) molecules have separate pathways for dermal exposure in humans
For humans, lipophilic molecules get the most attention with a focus on non-ionic (neutral, lipophilic) chemicals for dermal.

The seat patch

Amphibian seat patch is a preferential path for osmotic water uptake. Water potential dependent.

Amphibian seat patch is crenulated - effective surface area for uptake is much larger than the actual size of the patch.

Movement exposes seat patch to pesticides sprayed on bare soil and leaf surfaces.

Behavioral Assumptions are Important

Bundesarchiv, Bild 183-21377-0001
Foto: Gerbeth | 21. September 1953

Burrowing behavior

Irrigated farm systems are preferential habitats, terrestrial amphibians prefer soils with high moisture content.

Amphibians (often) burrow, overnight or overwinter, to rehydrate - 100% contact with soil can be a significant portion of exposure.

Also while burrowing for long periods of time they ingest shedded skin, adding a dermal component to the ingestion scenario.

Agriculture Habitat

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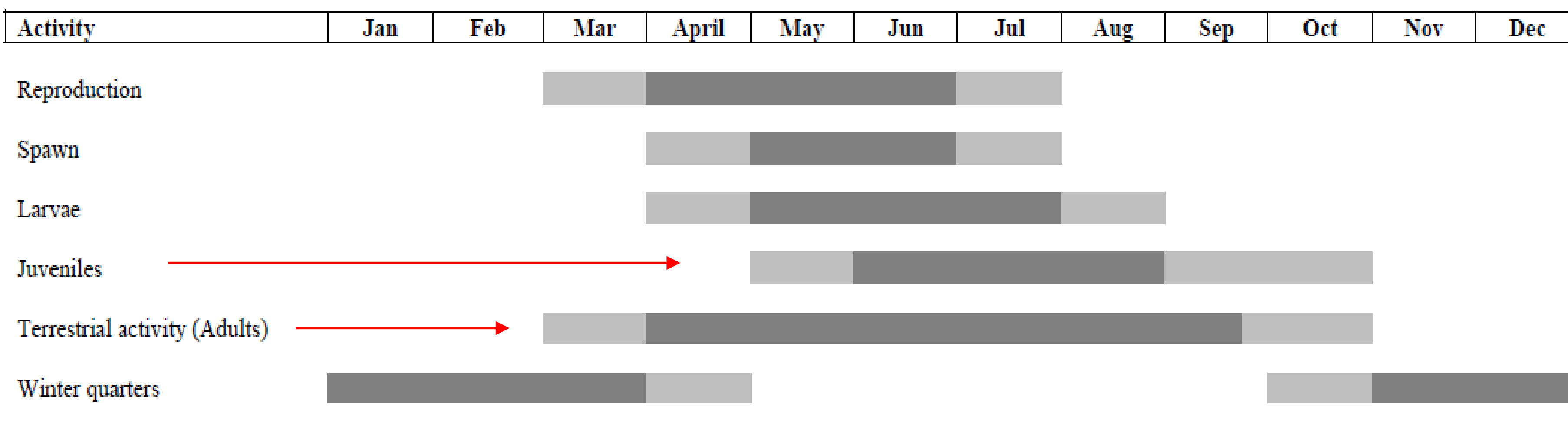
Adult dispersal to and metamorph dispersal from breeding ponds can coincide with pesticide applications

Seasonal activity of *Hyla arborea* in Germany based on information in Pfeffer et al. (2011). Darker area represents the main period of activity.



Fryday & Thompson 2012

Amphibian Movement Behavior

- Seasonal, Night/Day
- Additive exposures over time
- Specific behaviors can increase or decrease exposures

What does this mean for dermal pesticide exposure?

The more terrestrial an amphibian’s life cycle is, the more likely it is to use the skin to regulate its water content in order to maintain hydration.

Also, terrestrial amphibians are more likely to use soil water or puddles as rehydration sources – with higher pesticide concentrations.

Behavior can amplify exposures beyond ‘conservative’ screening assumptions, or decrease exposures.

Amphibian dermal contact can be a key exposure pathway compared to non-amphibian receptors.

Dermal contact approaches for eco risk

Higher trophic level ecological risk assessment endpoints are usually mammals and/or birds (surrogates)

Dermal exposure is generally assumed to be negligible for birds and mammals (Suter 2006)

Hope (1995) recommended 2 dermal models:

1) organism is exposed to all contamination in soil it is in contact with while at rest

2)

$$D_{der} = \frac{C\,A\,F_d\,F_b\,B_d}{W}$$

These one-size-fits-all models can seem conservative, but they may underestimate

Estimating dermal dose with Kp

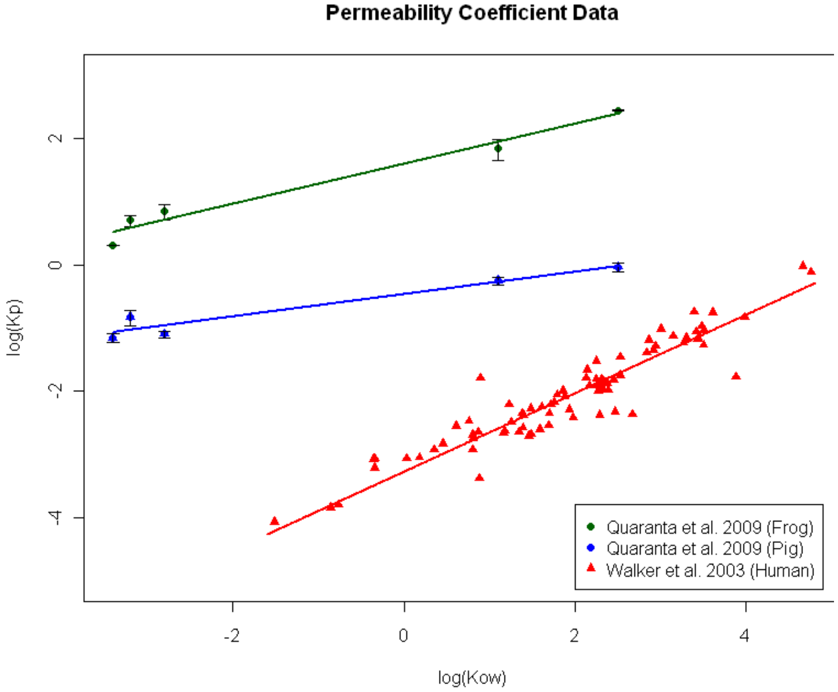
$$D_{der} = \frac{C K_p A T B_d F_b}{W}$$

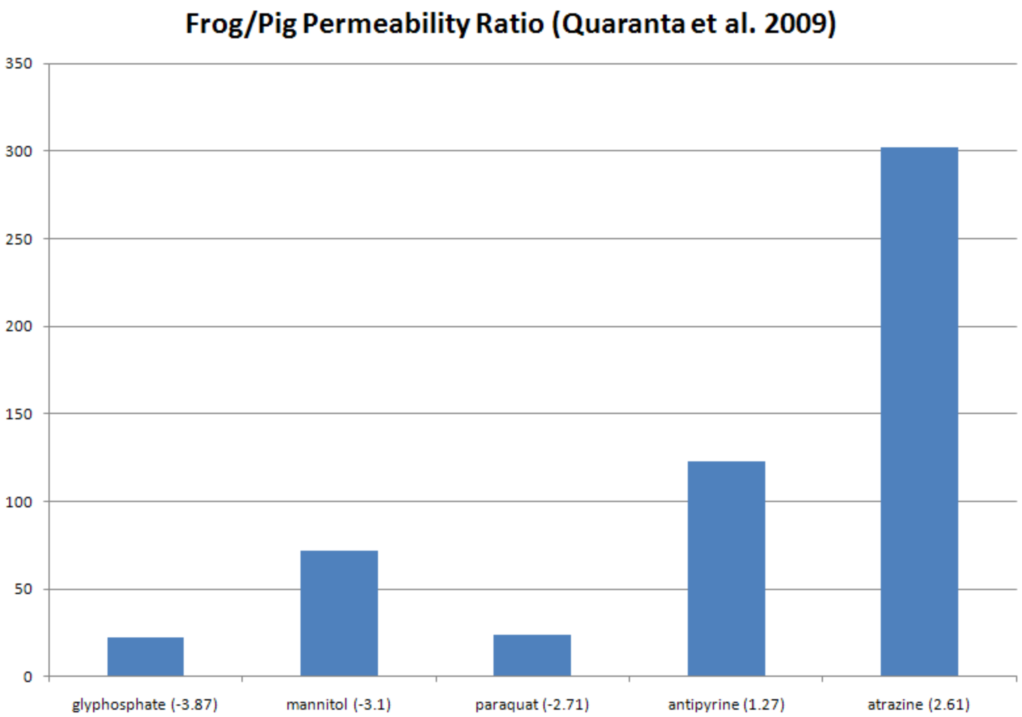
Physical differences in skin causes differences in empirical permeability rates – cm/hour

Number of studies available for mammals, few for non-mammals.

Permeability coefficient is primarily a function of hydrophobicity - log(K_{ow}) - and molecular volume or perhaps could be empirical

Measured dermal permeability coefficients





Initial modeling study--Relative pathway exposures

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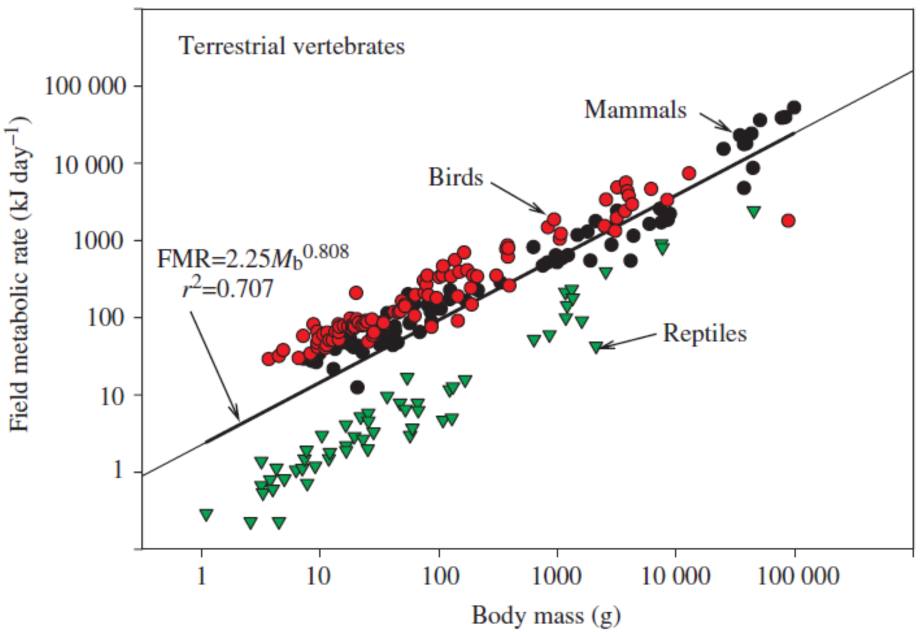
$$D_{Diet}(mg/kg\ BW/d) = FMR(kcal/d)/(BW(g)(C_{insects}(mg/kg))/(1.7\ kcal/g)$$

$$D_{der} = \frac{C K_p A T B_d F_b}{W}$$

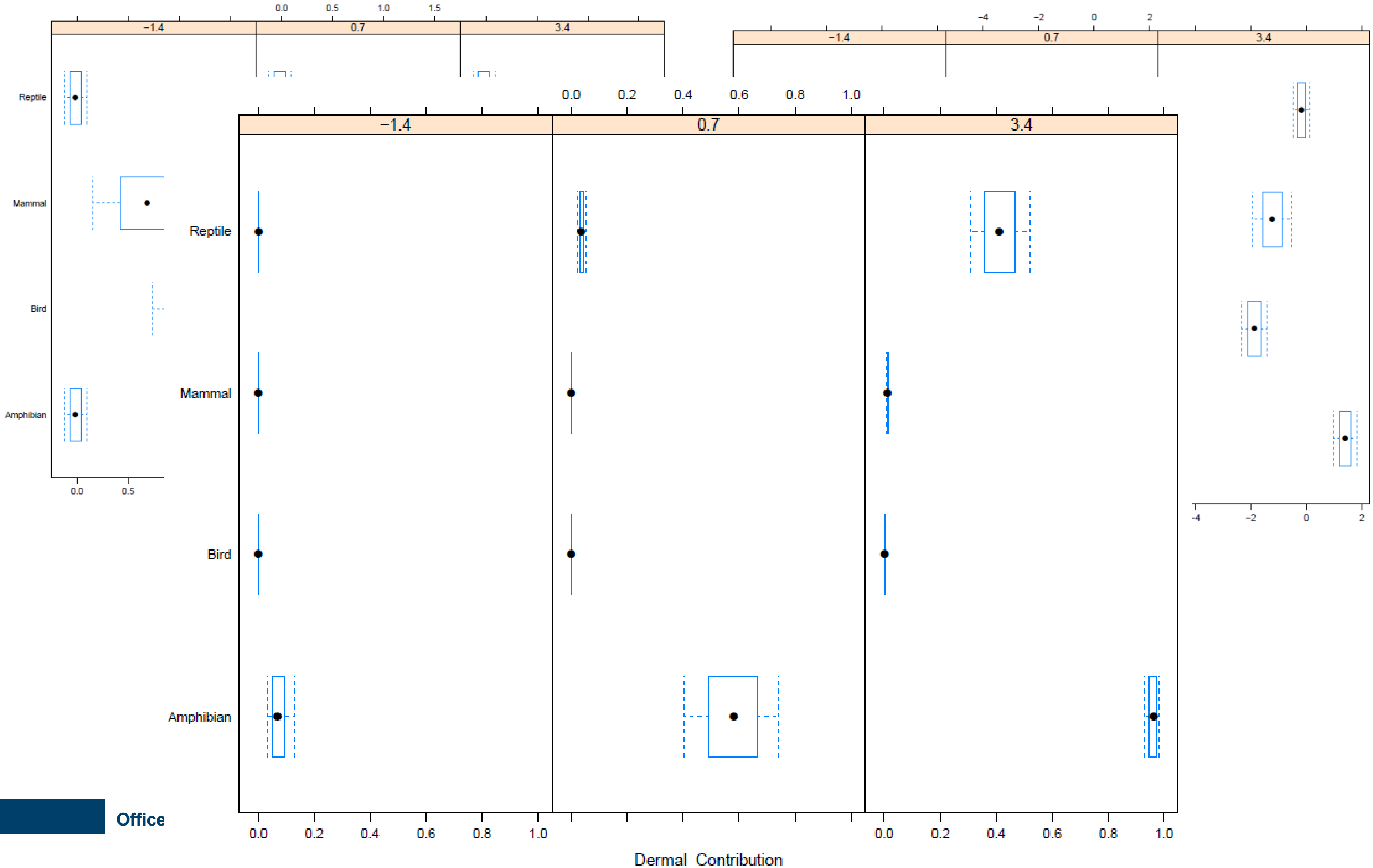
- Calculate exposure for diet (Weir et al. 2010) and dermal for amphibians, birds, mammals, reptiles.
- Solve for range of appropriate body weights for insectivores in each class (instead of representative receptor).
- Range of K_{ow}.
- Compare total dose between classes and relative contribution of dermal.
- No tox comparisons, just looking at exposure.

Field Metabolic Rates (Nagy 2005)



Weir et al. 2010. Ecological risk of anthropogenic pollutants to reptiles: Evaluating assumptions of sensitivity and exposure. Environmental Pollution, 158:3596-3606.

MC of Dietary, Dermal and Relative Dose Estimates



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Initial Modeling Exercise Conclusions

Calculated dietary and dermal doses, parameterized for Amphibians, Birds, Mammals, Reptiles

Amphibians/Reptiles may get significant percentage of dose from dermal, Birds/Mammals not so much.

Significant uncertainties and data limitations for assessing dermal exposure: needs – data!, dermal properties, aquaporin impacts, seat patches, soil water, chemical property effects, etc.

We decided to conduct some amphibian exposure studies.

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Rearing Amphibians

S. Leopard Frog

Fowler's Toad

Gray Treefrog

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Exposure Methods

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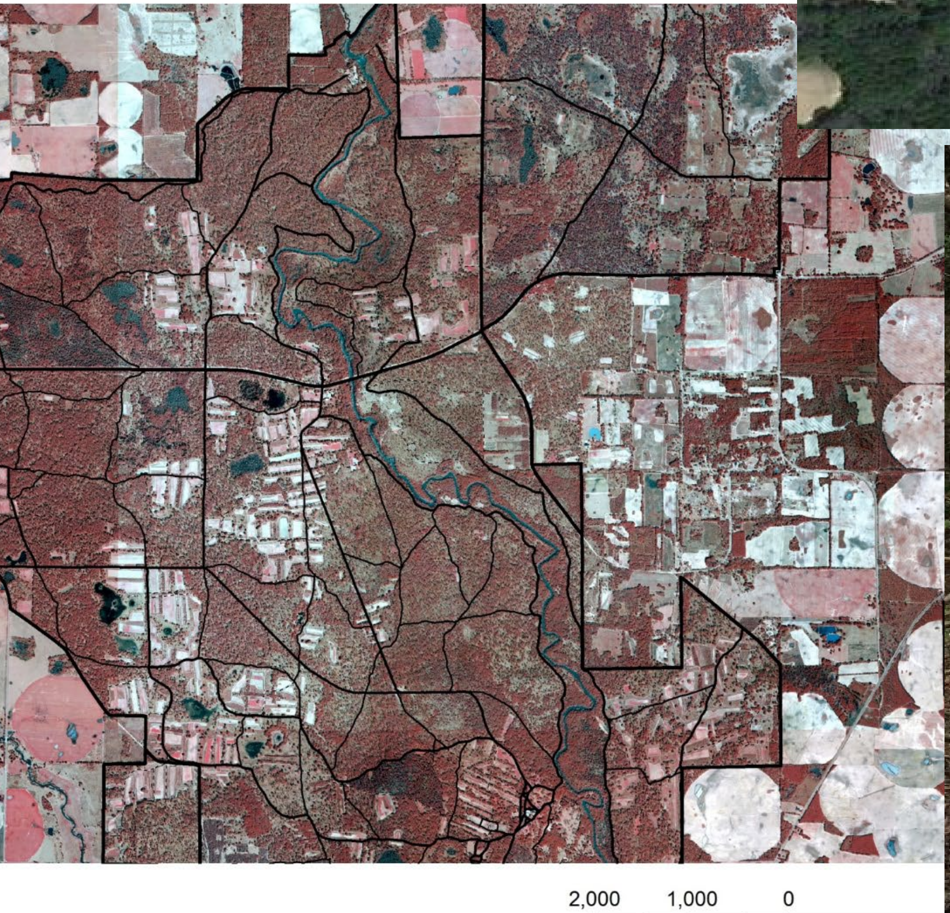
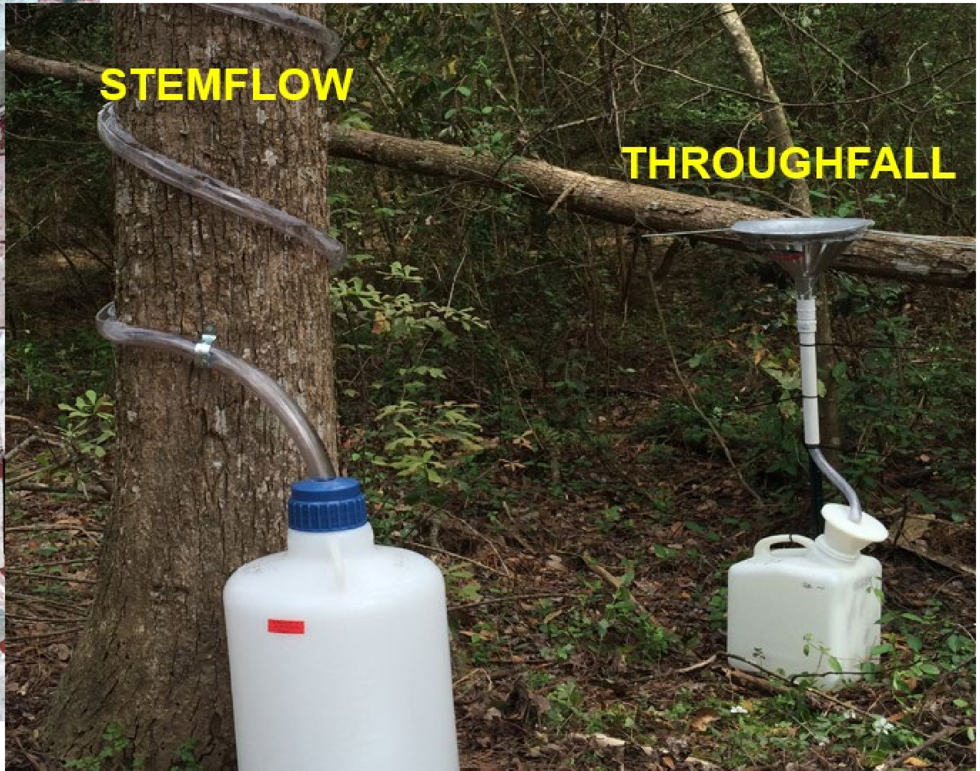
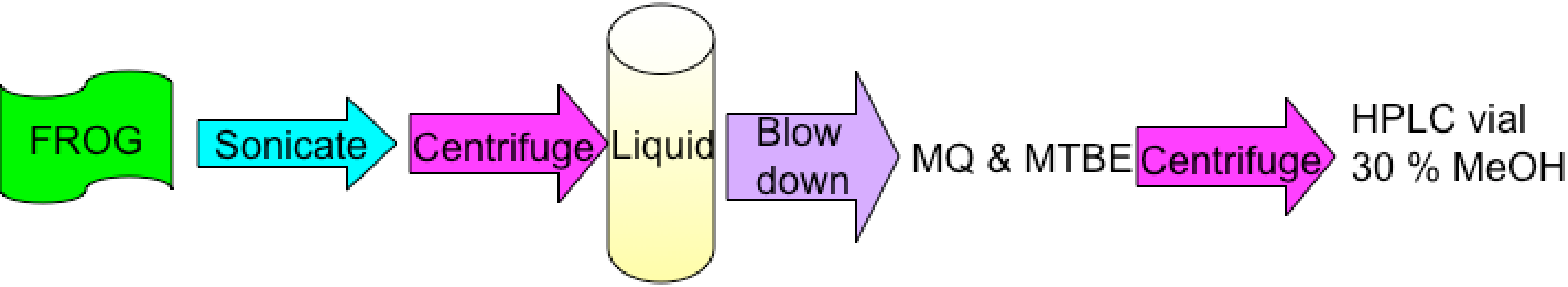
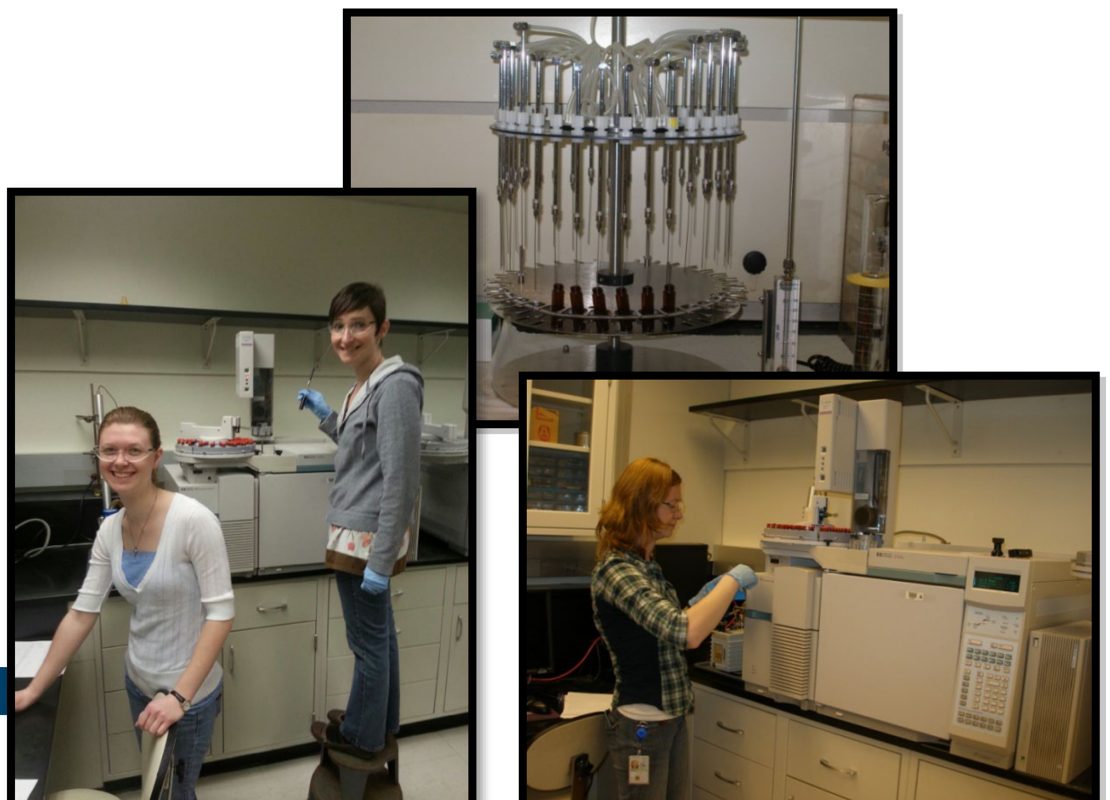
Field sites



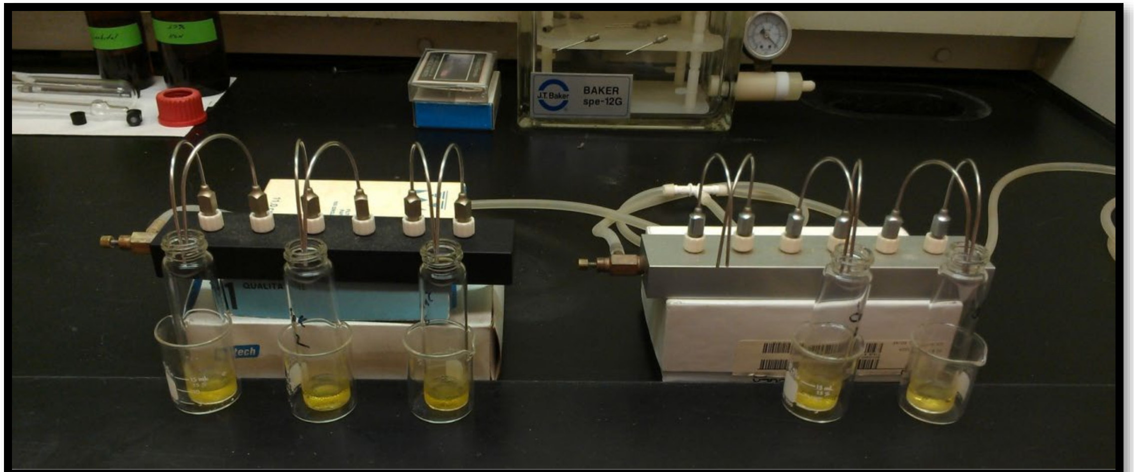


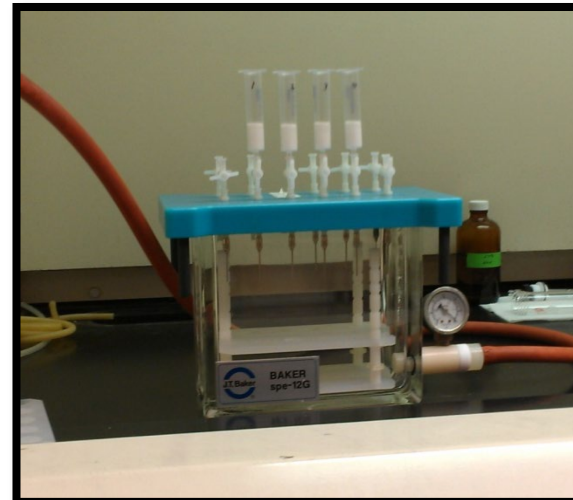
Sample Extraction





Protocol Development





Whole body frog tissue, livers, soil, water extraction methods

Methanol and MTBE solvents

GC/MS & LC/MS analysis of pesticide body burdens, metabolomics

Study	N	BCF	Species	Pesticides	Treatments
Henson-Ramsey et al. 2008	9	0.015 – 0.133	*Ambystoma tigrinum*	Malathion	Soil application
Van Meter et al. 2014	106	0.005-0.614	*Lithobates sphenocephala, Anaxyrus fowleri, Hyla versicolor, Acris crepitans, Gastrophyne carolinensis, Hyla gratiosa, Hyla cinera*	Imidacloprid, triadimefon, fipronil, pendimethalin	Soil application
Van Meter et al. 2015	90	0.013 – 1.16	*Hyla gratiosa, Hyla cinerea*	Imidacloprid, atrazine, triadimefon, fipronil, pendimethalin	Direct spray versus soil application
Van Meter et al. 2016	96	0.01-0.61	*Anaxyrus americanus*	Imidacloprid, atrazine, triadimefon, fipronil, pendimethalin	Exposures on soil with contrasting organic matter content
Glinski et al. 2018a	300	0.00014-2.76	*Lithobates sphenocephala, Anaxyrus fowleri*	Atrazine, triadimefon, metolachlor, chlorothalonil, imidacloprid	Soil exposures after varying dehydration times
Glinski et al. 2018b	60	NA	*Anaxyrus fowleri*	Atrazine, triadimefon, fipronil	Soil application
Van Meter et al. 2018	137	NA	*Lithobates clamitans*	Atrazine, metolachlor, 2,4-D, malathion, propiconazole	Soil applications including pesticide mixtures
Glinski et al. 2018c	192	0.0004-4.84	*Lithobates sphenocephala*	Bifenthrin, metolachlor, triadimefon	Soil applications including pesticide mixtures
Van Meter et al 2019	96	NA	*Lithobates sphenocephala*	Atrazine, alachlor	Exposures on soil, including mixtures
Glinski et al. 2021	24	0.18-4.63	*Lithobates sphenocephala*	Bifenthrin, chlorpyrifos, trifloxystrobin	Exposures on soil versus surface water
Van Meter et al 2022	48	0.19-2.47	*Lithobates sphenocephala*	Atrazine, alachlor	Exposures on soil, including mixtures

Selected Research Questions

- Is hydrophobicity (using Kow as a proxy) a useful predictor like it is on other terrestrial vertebrates?
  - Answer: not so much. Van Meter et al. 2014, Environmental Pollution.
- Is there a significant difference between direct (aerial) and indirect (soil) exposures for dermal uptake?
  - Answer: Yes, significant difference. Van Meter et al. 2015. Environmental Contamination and Toxicology.
- Does soil organic carbon content impact amphibian uptake?
  - Answer: Yes, high OC content significantly negatively impacts uptake. Van Meter et al. 2016
- Can we quantify hepatic microsomal metabolic rates of pesticides with known degradates?
  - Yes, for commonly applied pesticides in south Georgia. Glinski et al. 2018a.
- Can we identify changes in metabolic profiles for exposed amphibians versus controls?
  - Yes, Snyder et al 2017, Aquatic Toxicology. Van Meter et al 2018, Glinki et al 2018b
- Can we quantify forested exposure concentrations experienced by treefrogs?
  - Yes, pesticide concentrations characterized in stemflow and canopy throughfall in south Georgia. Glinski et al. 2018c.
- Does the hydration status of an exposed amphibian affect dermal uptake?
  - Answer: Yes, but in the opposite way that we expected. Glinski et al 2018c.

Amphibian Exposure Database

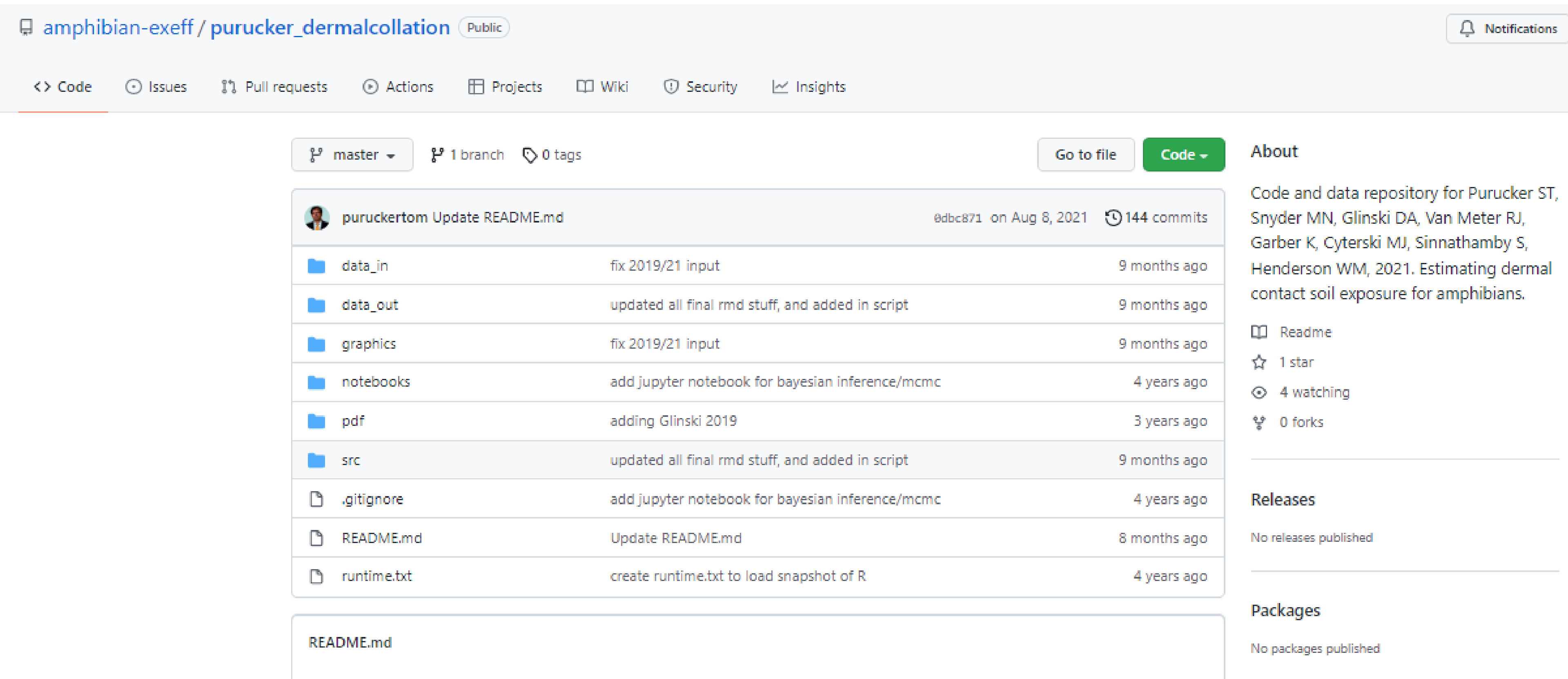
Each published study tests a hypothesis but also added another terrestrial amphibian exposure database to the literature.

- Species used: Barking treefrog (*Hyla gratiosa*), Green treefrog (*Hyla cinerea*), American toad (*Bufo americanus*), Southern leopard frog (*Lithobates sphenocephala*), Fowler's toad (*Anaxyrus fowleri*), Eastern narrowmouth toad (*Gastrophryne carolinensis*)
- Amphibians reared in Athens (field collected adults -> fertilized eggs -> metamorph stage)
- Pesticides used in the lab: Imidacloprid, Atrazine, Triadimefon, Fipronil, Pendimethalin, Metolachlor, Bifenthrin, Tebiconazole, Chlorothalonil.
- Pesticide applications at maximum labeled rates.
- Untargeted analyses of field caught amphibians and associated exposure concentrations in south Georgia

We have combined these data sets into a single data set for testing amphibian dermal exposure models

Collated dataset is now published (in press IEAM) and publicly available

https://github.com/amphibian-exeff/purucker_dermalcollation



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Metadata

```
# --------------------------------------------------
Metadata for amphib_dermal_collated.csv

"Estimating dermal contact soil exposure for amphibians"
Purucker ST, Snyder MN, Glinski DA, Van Meter RJ, Garber K, Cyterski MJ, Sinnathamby S, Henderson WM.
# --------------------------------------------------


amphib_dermal_collated.csv is the final collated data set containing all amphibian dermal exposure studies.



Column labels and description of the column for the csv file.

app_rate_g_cm2  - application rate of pesticide in g/cm^2
application     - application method
                        (overspray, soil, indirect)
body_weight_g   - body weight of exposed amphibian in grams
chemical        - pesticide used in the study
exp_duration    - duration of exposure experiment in hours
formulation     - commercial formulation or active ingredient dissolved in Methanol
                        (commercial formulation = 1, active ingredient dissolve in Methanol = 0)
sample_id       - sample identifyer used in the original study
soil_conc_ugg   - soil concentration of pesticide in ug/g
soil_type       - type of soil used in the study if available
                        (PLE = Plott series soil, OLS = Orangeburg loamy-sand soil, NA)
source          - manuscript where data originated from
species         - amphibian species name
                        (Barking treefrog, Cricket frog, Fowlers toad, Gray treefrog, Green treefrog, Leopard frog, Mole salamander, Narrowmouth toa
tissue conc ugg - amphibian tissue concentration in ug/g
```

1158 observations of tissue residues in 11 amphibian species across 14 different pesticides.

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Dataset

1		app_rate_g_cm2	application	body_weight_g	chemical	exp_duration	formulation	sample_id	soil_conc_ugg	soil_type	source	species	tissue_conc_ug
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3	2	5.58e-06	overspray	2.61111	imidacloprid	8	0	HGOI2	0.47984644	PLE	rvm2015	Barking treefrog	1.636083216
4	3	5.58e-06	overspray	1.82332	imidacloprid	8	0	HGOI3	0.47984644	PLE	rvm2015	Barking treefrog	0.926100389
5	4	5.58e-06	overspray	2.91551	imidacloprid	8	0	HGOI4	0.47984644	PLE	rvm2015	Barking treefrog	0.718277624
6	5	5.58e-06	overspray	2.49115	imidacloprid	8	0	HGOI5	0.47984644	PLE	rvm2015	Barking treefrog	1.08903614
7	6	2e-05	overspray	2.09766	pendimethalin	8	0	HGOP1	12.11934838	PLE	rvm2015	Barking treefrog	2.138795205
8	7	2e-05	overspray	2.41178	pendimethalin	8	0	HGOP2	12.11934838	PLE	rvm2015	Barking treefrog	2.01901591
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11	10	2e-05	overspray	2.23741	pendimethalin	8	0	HGOP5	12.11934838	PLE	rvm2015	Barking treefrog	1.232549848
12	11	2.3e-05	overspray	2.02028	atrazine	8	0	HGOA1	15.10490982	PLE	rvm2015	Barking treefrog	12.2881692
13	12	2.3e-05	overspray	1.69156	atrazine	8	0	HGOA2	15.10490982	PLE	rvm2015	Barking treefrog	8.916353622
14	13	2.3e-05	overspray	2.07221	atrazine	8	0	HGOA3	15.10490982	PLE	rvm2015	Barking treefrog	9.702578705
15	14	2.3e-05	overspray	2.36942	atrazine	8	0	HGOA4	15.10490982	PLE	rvm2015	Barking treefrog	17.83079959
16	15	2.3e-05	overspray	1.96104	atrazine	8	0	HGOA5	15.10490982	PLE	rvm2015	Barking treefrog	14.21727551
17	16	1.11e-06	overspray	2.73317	fipronil	8	0	HGOF1	3.492483429	PLE	rvm2015	Barking treefrog	2.400285765
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19	18	1.11e-06	overspray	2.12849	fipronil	8	0	HGOF3	3.492483429	PLE	rvm2015	Barking treefrog	1.662784049
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21	20	1.11e-06	overspray	1.52771	fipronil	8	0	HGOF5	3.492483429	PLE	rvm2015	Barking treefrog	1.915890199
22	21	2.85e-06	overspray	1.72511	triadimefon	8	0	HGOT1	8.451291713	PLE	rvm2015	Barking treefrog	0.636157453
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24	23	2.85e-06	overspray	1.55295	triadimefon	8	0	HGOT3	8.451291713	PLE	rvm2015	Barking treefrog	0.397699131
25	24	2.85e-06	overspray	2.37346	triadimefon	8	0	HGOT4	8.451291713	PLE	rvm2015	Barking treefrog	0.642604155
26	25	2.85e-06	overspray	1.57685	triadimefon	8	0	HGOT5	8.451291713	PLE	rvm2015	Barking treefrog	0.48091159
27	26	5.69e-06	soil	1.95576	imidacloprid	8	0	HGI1	2.565991685	PLE	rvm2015	Barking treefrog	0.329814712
28	27	5.69e-06	soil	2.26328	imidacloprid	8	0	HGI2	2.565991685	PLE	rvm2015	Barking treefrog	0.210770534
29	28	5.69e-06	soil	1.27439	imidacloprid	8	0	HGI3	2.565991685	PLE	rvm2015	Barking treefrog	0.50673308
30	29	5.69e-06	soil	1.89439	imidacloprid	8	0	HGI4	2.565991685	PLE	rvm2015	Barking treefrog	0.292676446
31	30	5.69e-06	soil	1.4839	imidacloprid	8	0	HGI5	2.565991685	PLE	rvm2015	Barking treefrog	0.622028925
32	31	1.98e-05	soil	2.44812	pendimethalin	8	0	HGP1	13.61565316	PLE	rvm2015	Barking treefrog	0.409017886
33	32	1.98e-05	soil	2.46997	pendimethalin	8	0	HGP2	13.61565316	PLE	rvm2015	Barking treefrog	0.257508419

Exposure data set utility

This data set can be used to test the protectiveness and accuracy of amphibian dermal exposure models

- We have tested screening models to ensure that they do not underpredict body burdens
- Can be used by us (and others) to evaluate screening and higher tiered models of dermal exposure

This is only one aspect of amphibian exposure modeling, but an important area where not much info was available

Testing existing/proposed models

- We have used this dataset to test the dermal component of TIM and a proposed EFSA modification
- Can also be used to test other surrogate models in use, proposed models at different tiers
- Comparing to available field data to estimate differences between post-exposure field and laboratory body burdens
- Lower-tier models can be evaluated to ensure that they do not underpredict body burdens, higher-tier models can be evaluated/calibrated for accuracy while ensuring protectiveness

TIM Dermal Exposure Algorithm (Direct Interception)

Dermal exposure from applied pesticide droplets is considered for each time step representing a pesticide application for aerial, airblast and ground applied sprays (See **Section 1.4.2**). The dermal exposure dose from direct interception ($D_{intercept(t)}$) is calculated by considering the pesticide application rate relationship to the surface area and BW of the bird (**Equation 6.2; Table 6.1**). The dermal interception model assumes that pesticide deposition occurs in a manner consistent with a horizontal surface in the treatment area. Surface area calculation of a bird for the interception model assumes that the upper half of the bird in the field is exposed as a result of either ground or aerial spray applications. Therefore, the total surface area of the bird is multiplied by 0.5. The total surface area of a bird is calculated using the allometric equation for relating BW to surface area (USEPA, 1993; **Equation 6.3**). The dermal adsorption fraction (DAF) is used to account for pesticide specific data that define a fraction of the pesticide mass present on the bird that is actually absorbed by the bird. These data may be submitted by the registrant (non-guideline study) or obtained from the literature. When no data are available to parameterize DAF, the default value is 1. In this equation, a factor of 11.2 is used to convert the units of the application rate, which are lb a.i./A, to the metric units needed to generate a concentration value expressed in µg a.i./g-bw.

Equation 6.2. $D_{intercept(t)} = \frac{(A_{rate} * 11.2) * (SA_{total} * 0.5) * DAF}{BW}$

Equation 6.3. $SA_{total} = 10 * BW^{0.667}$

United States Environmental Protection Agency

EFSA Modification

Dermal exposure

For the calculation of the dermal dose (Tables 60, 61 and 62), it was assumed that the animal is oversprayed in field at the full rate (worst-case assumption of no crop interception), only upper side exposed (half of its surface) and that 100% is absorbed. The application rate was assumed to be 1 kg/ha (as for oral uptake).

Amphibians

In Wildlife exposure factors handbook (USEPA), equations are provided to calculate the skin area surface (SAskin) with a power function of the animals' weight (p 3–14 or 514/572):

SAskin (cm^2) = 1.131 $Wt^{0.579}$ (g) (all frogs) (less protective when compared with two other models)
SAskin (cm^2) = 0.953 $Wt^{0.725}$ (g) bull frog
SAskin (cm^2) = 0.997 $Wt^{0.712}$ (g) green frog
SAskin (cm^2) = 8.42 $Wt^{0.694}$ (g) salamanders

The allometric equations for body surface area from the US EPA exposure handbook are identical with the ones from Hutchinson et al. (1968).

The formula for *Hyla arborea* from Hutchinson et al. (1968) was added to the species from the Wildlife exposure handbook.

$SA = 0.905 \times W^{0.823}$
SA = surface area in cm^2
W = body weight in g

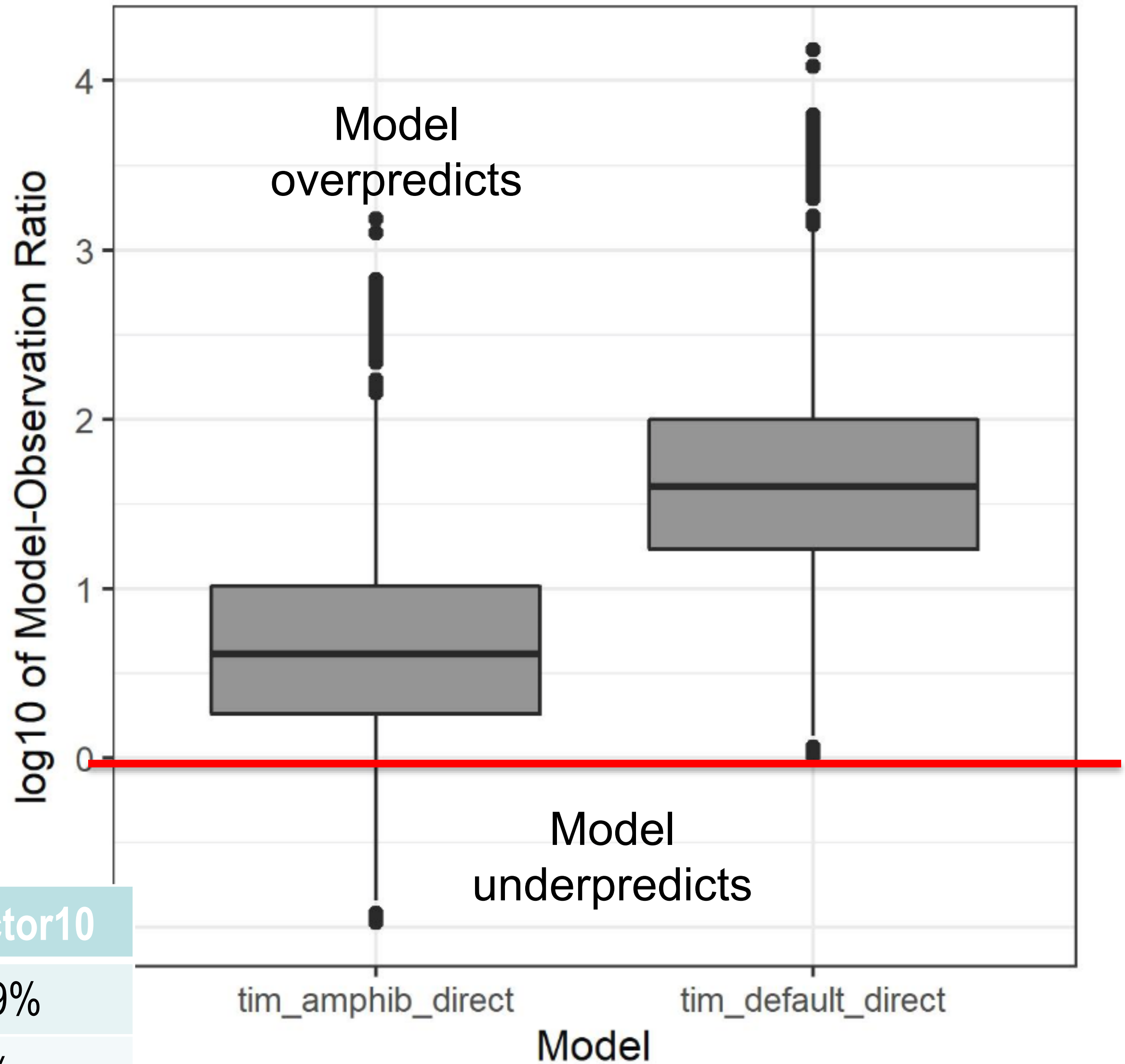
Table 60: Dermal exposure calculation from overspray for different groups of amphibians

Amphibians	Body weight (g)	Total surface (cm^2)[(a)]	Dermal absorption%	Applied rate (kg/ha)	Applied rate (mg/cm^2)	Dermal dose (mg/kg bw)
Green frog	85	23.5744	100	1	0.01	1.387
Bull frog	500	86.2673	100	1	0.01	0.863
All frogs	100	16.2728	100	1	0.01	0.814
Hyla arborea	1.4	1.1937	100	1	0.01	4.263
Hyla arborea	11	6.5120	100	1	0.01	2.96
Salamander	50	127.1737	100	1	0.01	12.717

bw: body weight.
(a): For the calculation of the dermal dose, the total surface was divided by 2 assuming that only the upper side of the animal is exposed.

Model ratios: (Model_Predictions/Observations)

Comparison of model predictions to observations



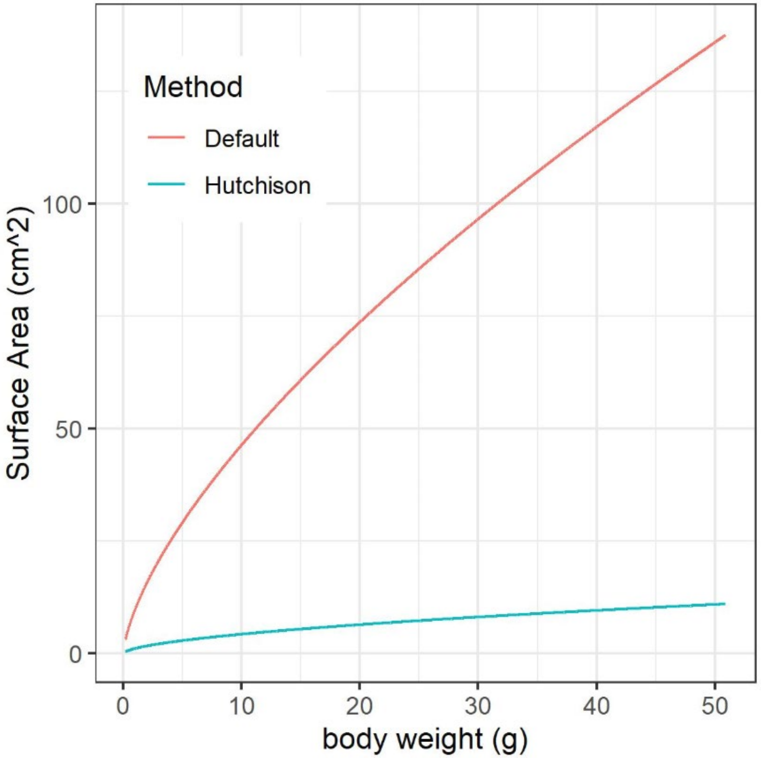
model	under	Factor10
tim_default_direct	0%	11.9%
tim_amphib_direct	11.3%	63%

Why the difference?

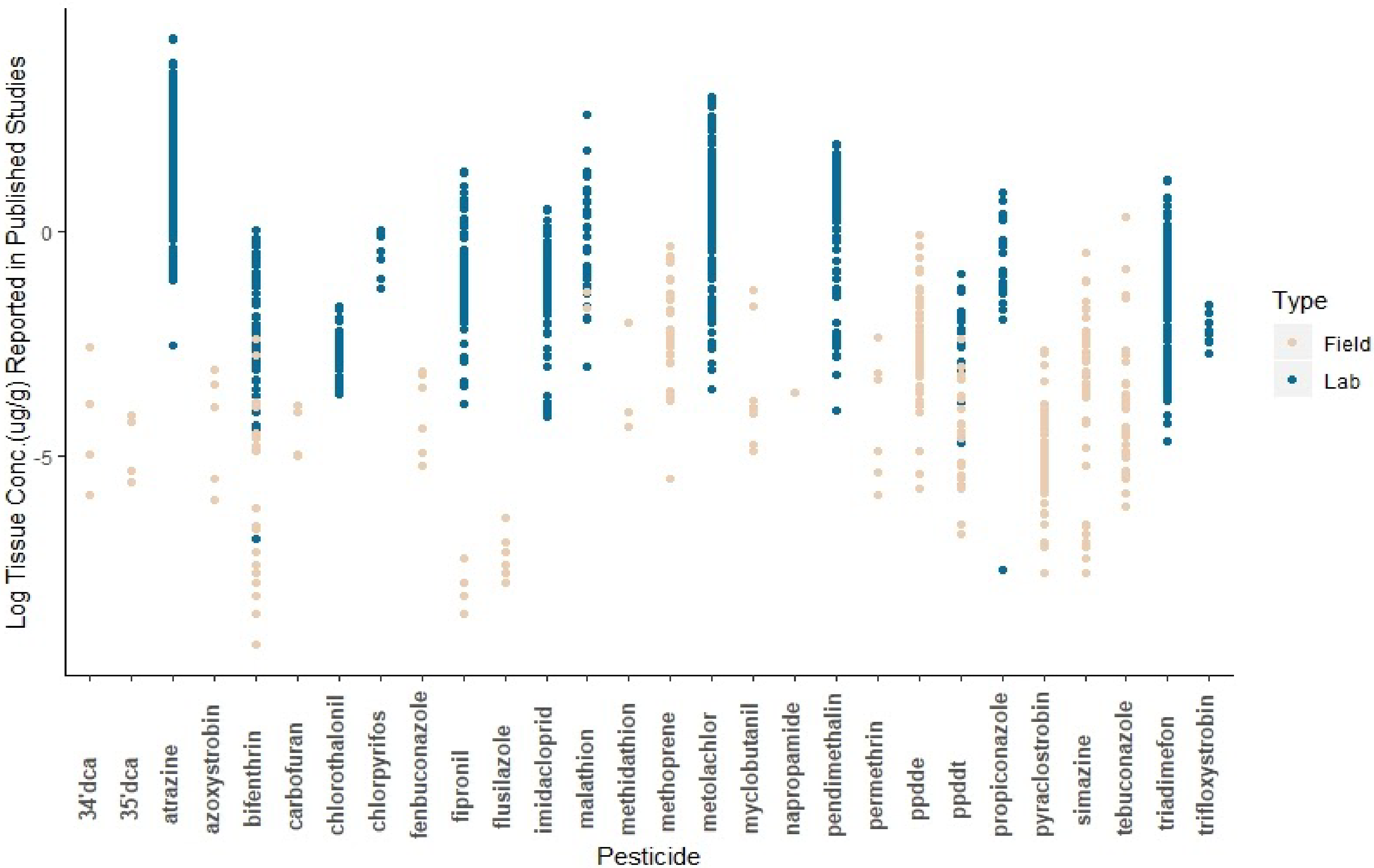
We have used this dataset to test the dermal component of TIM (based on birds) and a proposed EFSA modification (using amphibian surface area)

Can also be used to test other surrogate models in use, proposed models at different tiers

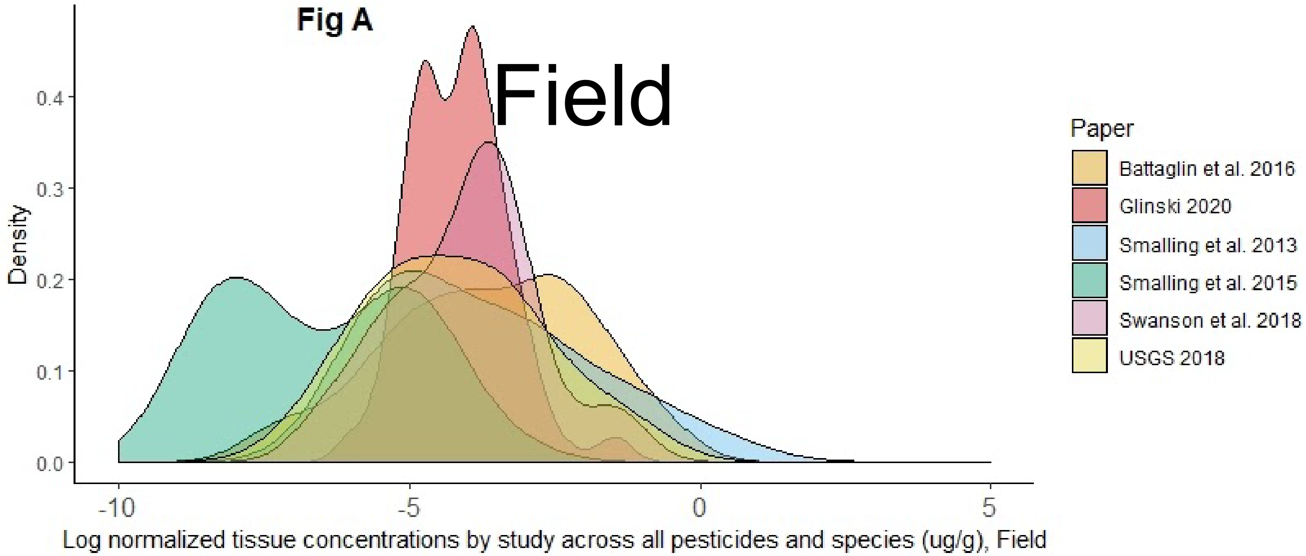
EFSA uses Hutchison modification

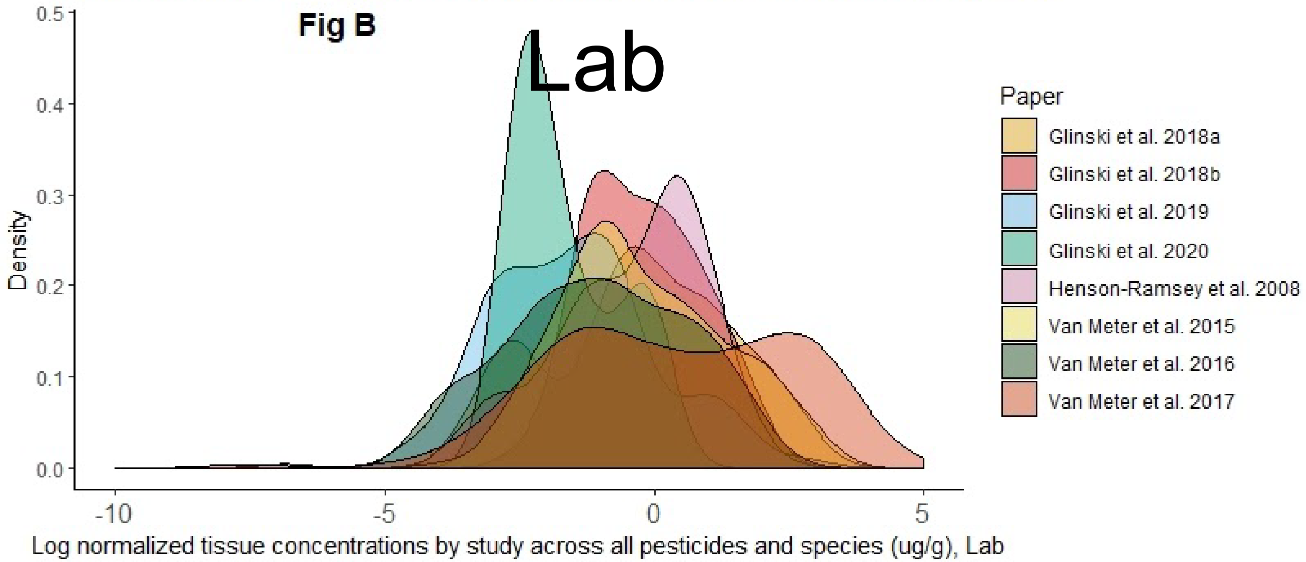


Ongoing work- field data collation



Field v Lab Data (Pesticides combined)

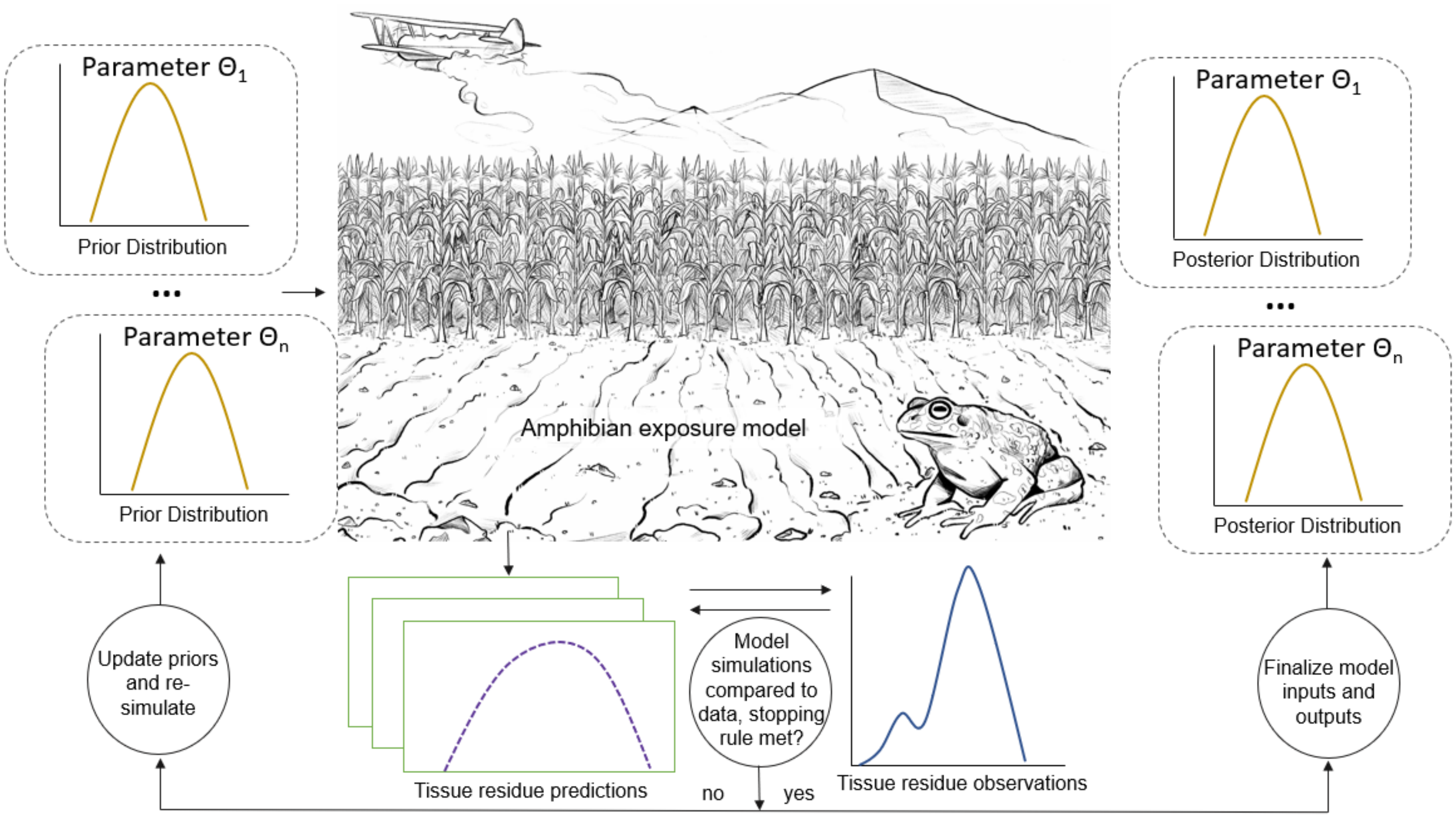




Ongoing work

We are also leveraging this dataset to parameterize and test alternative candidate models

Trying different model constructs, physical properties, exposure assumptions, etc.



Status and Next Steps

Dermal exposure for amphibians is an important route for many species and habitat combinations (T-Rex covers ingestion, TIM adds dermal)

We have published a collated data set that can be used to evaluate existing and proposed dermal exposure algorithms

The USEPA current TIM dermal approach is protective (though perhaps not for the right reasons)

The proposed EFSA modification with amphibian surface area modifications is logical but problematic (for screening)

This data set can be used to evaluate new fit-for-purpose amphibian-specific exposure algorithms at different tiers

EPA United States Environmental Protection Agency

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