Tier I method for estimating exposure of honey bees to pesticides

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Outline

- Overview of Tier I exposure assessment
- Food Consumption
  - What do honey bees eat?
  - Proposed food consumption rates for larval and adult workers
  - Discussion of conservativeness of proposed consumption rates
- Estimating Exposures for Tier I assessment
  - Foliar Spray Applications
  - Seed Treatments
  - Soil Applications

Overview of Tier I exposure assessment

Purpose of Tier I Exposure Assessment

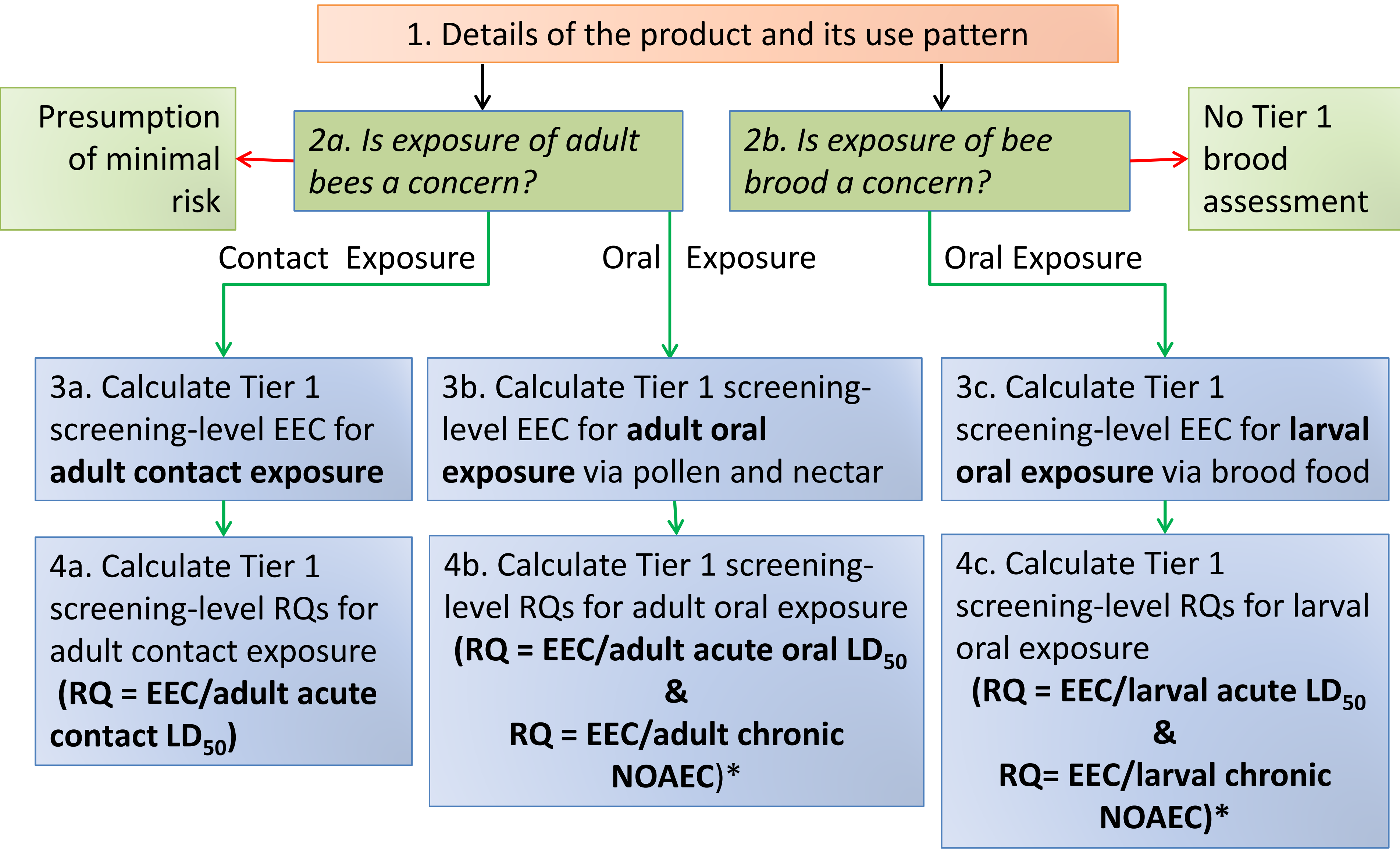
- The goal is to generate "reasonably conservative" estimates of pesticide exposures to bees

- Intended to distinguish between:
  - Pesticides that do not pose a risk to bees and
  - those that may need additional information

- Type I and II Errors
  - Tier I assessment should not conclude that there is no effect when there actually is (Type II)
  - It is more acceptable at the Tier I level to conclude that there is a potential effect when there is none (Type I)

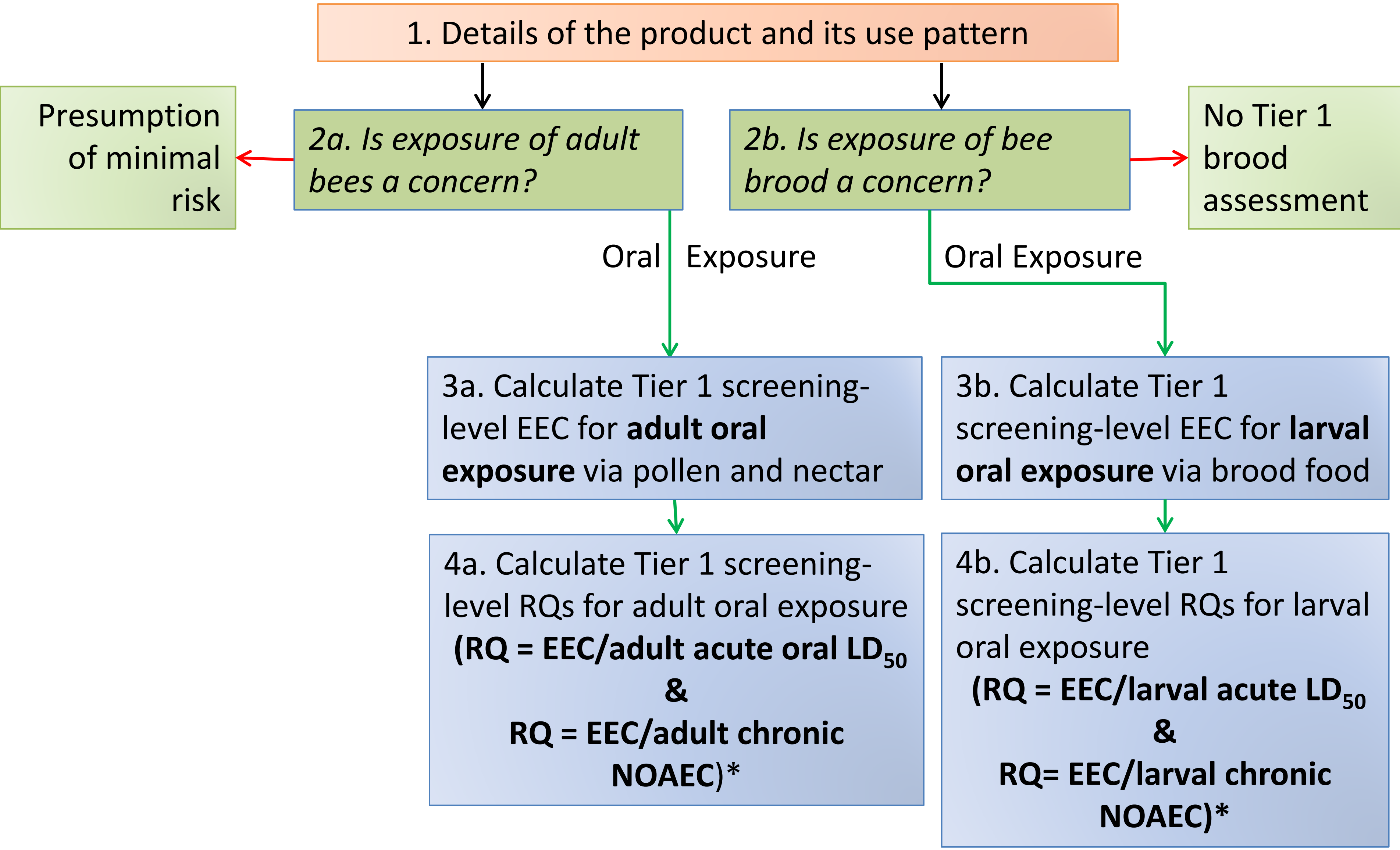
Tier I exposure assessment component of decision tree for foliar spray applications.

Yes
No



Tier I exposure assessment component of decision tree for seed and soil treatments.

Yes
No



Food consumption of honey bees

Honey bee diet

- What do honey bees eat?
  - Pollen
  - Bee bread
  - Nectar
  - Honey
  - Jelly
    - Royal Jelly
    - Brood Food
- Food consumption varies
  - By caste
  - By age

Proposed food consumption rates for Tier I exposure assessment

- Adult honey bees = 292 mg food/day
  - Based on nectar foraging worker
  - Represents consumption of nectar
  - Pollen consumption is insignificant relative to nectar
- Larvae = 120 mg food/day
  - Based on 5 day old worker larvae
  - Represents consumption of honey (converted to nectar equivalent) and pollen

Assumptions for Tier I Exposure Assessment (related to Food Consumption)

- Pesticide does not dissipate while stored in the hive
  - Pesticide concentrations in pollen and bee bread are equivalent
  - Pesticide concentrations in nectar can be used to represent concentrations in honey
- Honey consumption rate can be converted to a nectar equivalent basis
  - Using sugar consumption rates and sugar contents of honey and nectar
  - Pesticide doses will be eqivalent
- Pesticide doses received from pollen and nectar are protective of doses from jelly
  - Available data indicate that pesticides are ≥100x greater in food of nurse bees compared to royal jelly
- Pesticide concentration in foliage = conc. in nectar = conc. in pollen

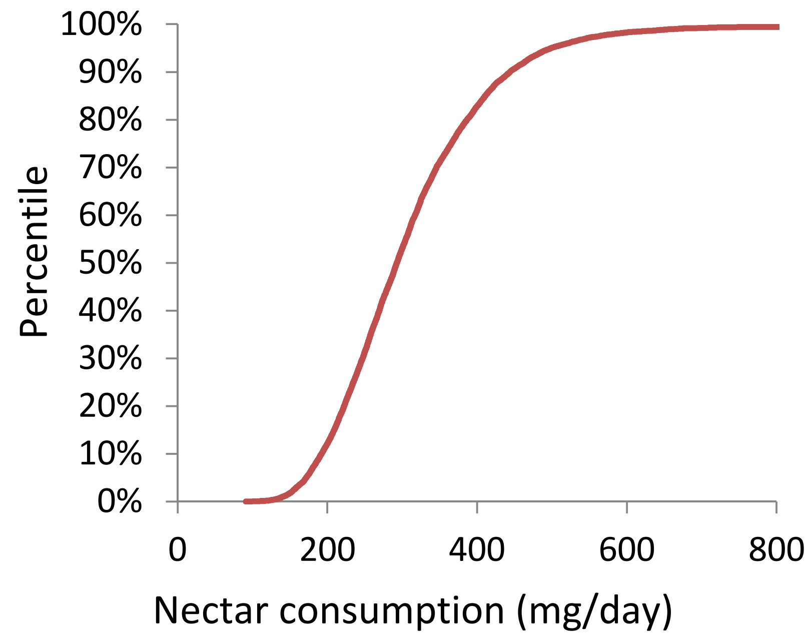
Proposed food consumption rate: Adult Worker Bees

- Food Consumption rates for adult worker bees
  - Nectar: Rortais et al. (2005)
  - Pollen: Crailsheim et al (1992)
  - Nectar forager bees have highest food consumption rates

Adult worker task	Age (d)	Consumption rate (mg/day)		
		Pollen	Nectar	Total food
Cell cleaning and capping	0-10	2.2-8.2	60	62-68
Brood and queen attending	6-17	1.7-9.5	113-167	115-177
Comb building, cleaning and food handling	11-18	1.7	60	62
Forager (pollen)	>18	0.041	35-52	35-52
Forager (nectar)	>18	0.041	107-428	107-428

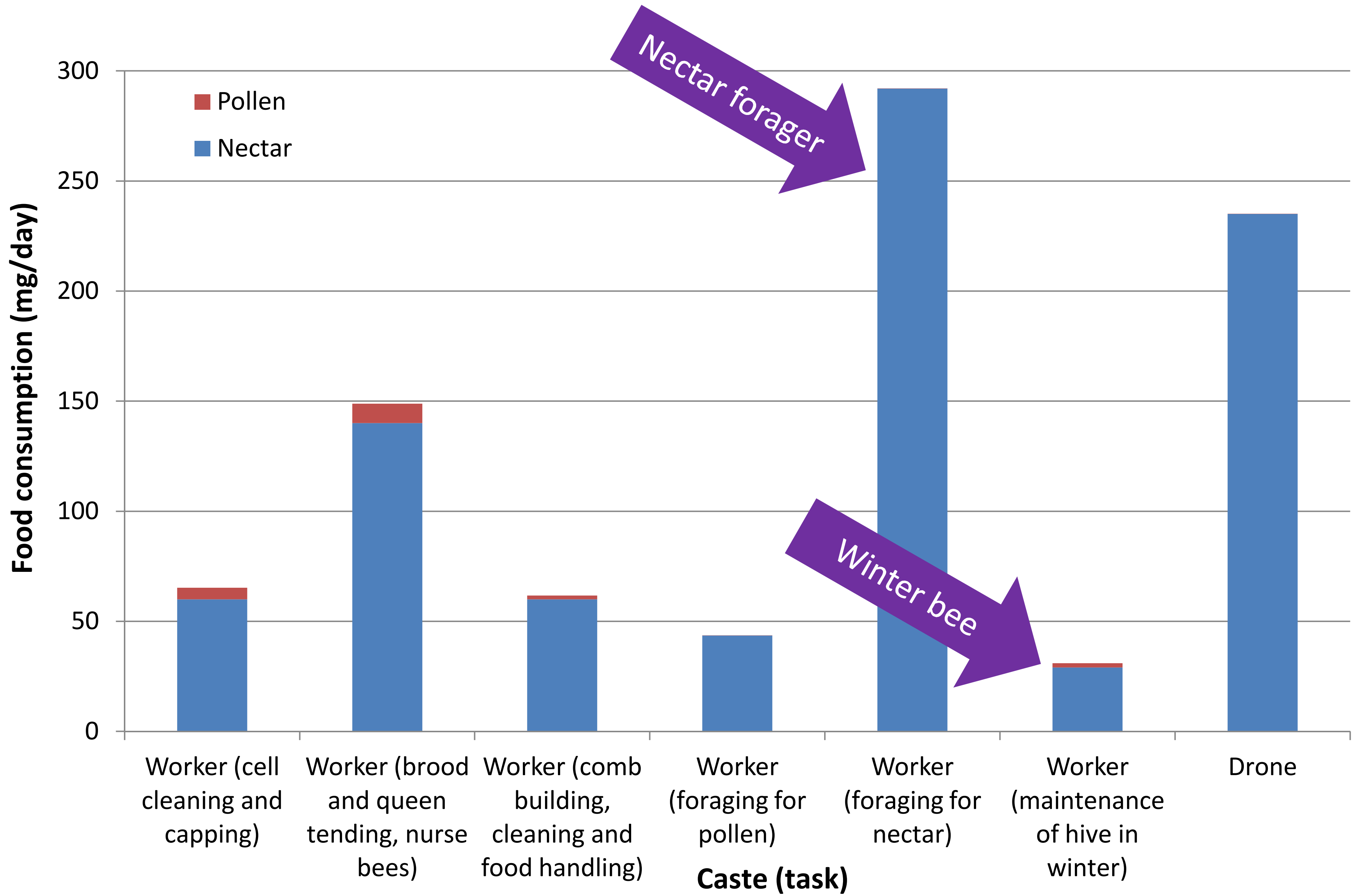
Proposed food consumption rate: Adult Worker Bees = 292 mg/day

- Proposed value is estimated using modification to Rortais et al.'s method
  - Monte Carlo Simulation of 5 variables
    - Sugar required for flying
    - Number of foraging trips made in a day
    - Duration of foraging trip
    - Fraction of time spent flying during trip
    - Amount of sugar present in nectar

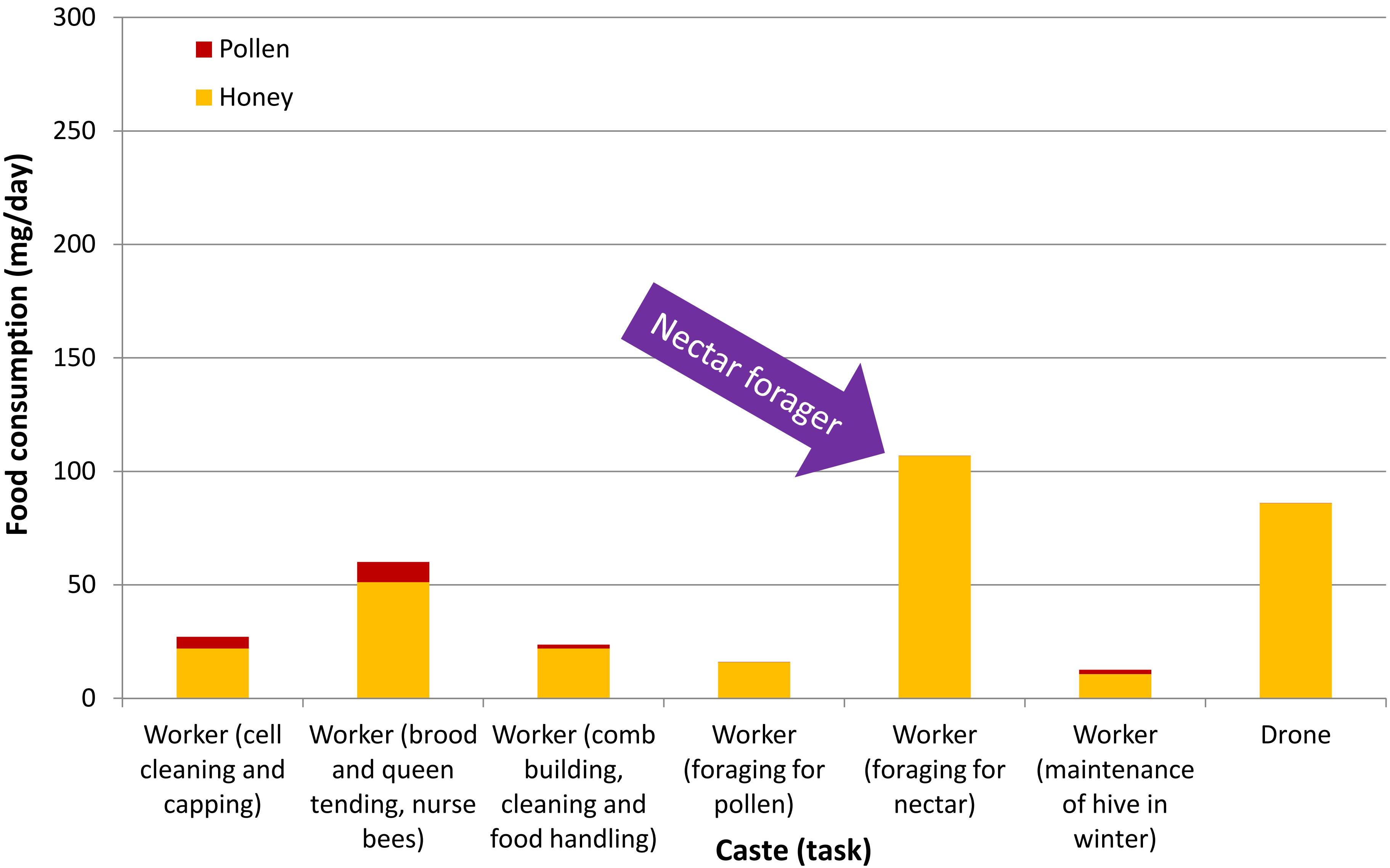


  - Analysis also included sugar requirements while resting
  - Proposed value is median of 10,000 simulated bees

Nectar and pollen consumption rates of adult worker bees by task and drones.



Honey and pollen consumption rates of adult worker bees by task and drones.



Comparison of proposed food consumption rates (mg/day) to non-*Apis* bees: Adults

Species	Nectar	Pollen	Total food
Honey bee worker *(Apis mellifera)*	292	0.04	292
Bumblebee *(Bombus spp.)*	183-372	27-30	210-402
European mason bee *(Osmia cornuta)*	45-193	na	45-193
Alfalfa leaf-cutting bee (*Megachile rotundata*)	110-165	na	110-165

Proposed food consumption rate: Larval Worker Bees

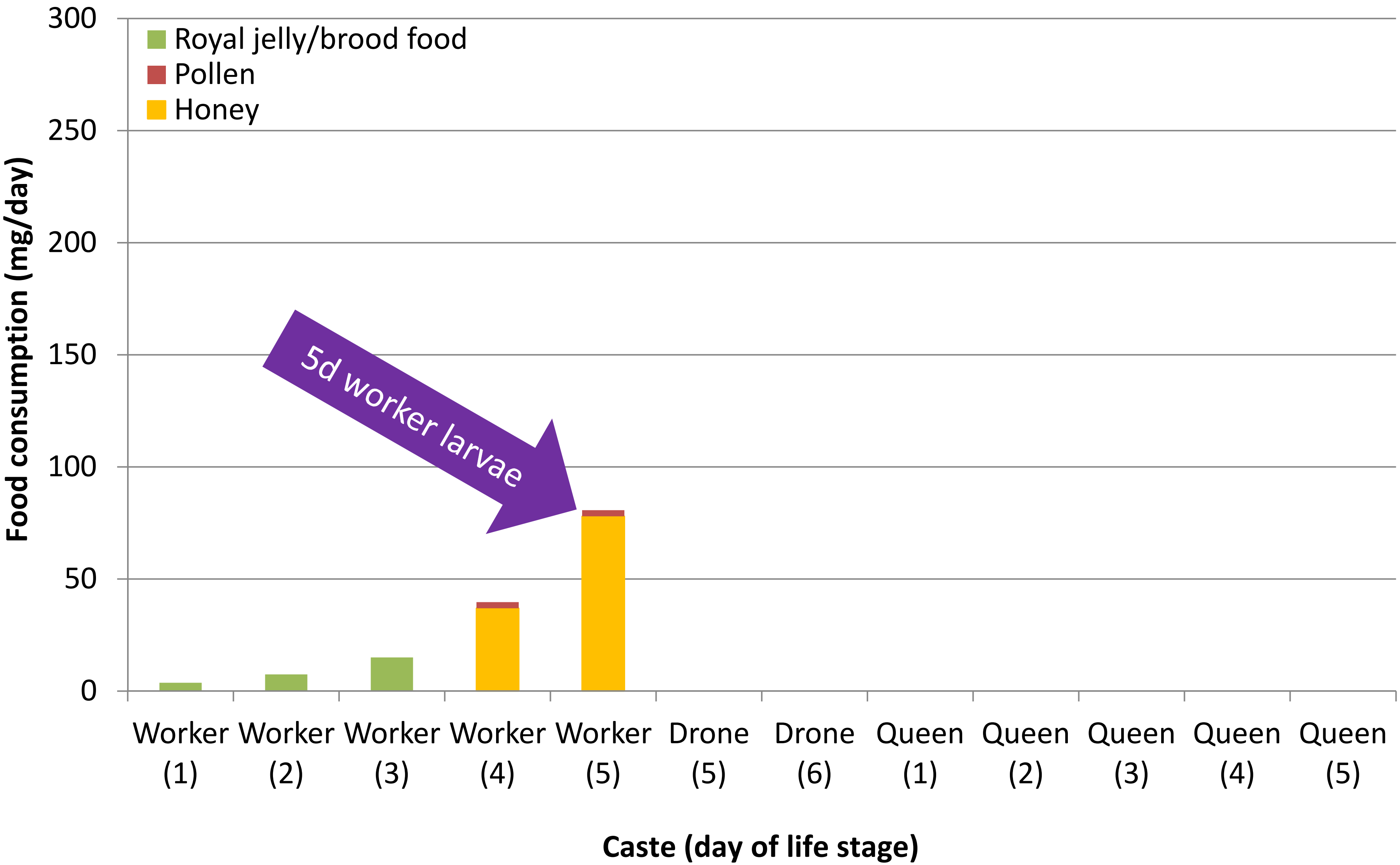
- It is assumed that larvae grow exponentially and that their daily food consumption rate doubles every day
  - Consume 120 mg total food during days 4 and 5
    - 5.4 mg pollen
    - 115 mg honey (diluted to 45% sugar; Rortais et al. 2005)

Day of life stage	Daily food consumption rate (mg/day)			
	Brood food / royal jelly	Honey	Pollen	Total food
1	3.8	none	none	3.8
2	7.5	none	none	7.5
3	15	none	none	15
4	none	37	2.7	40
5	none	77	2.7	80

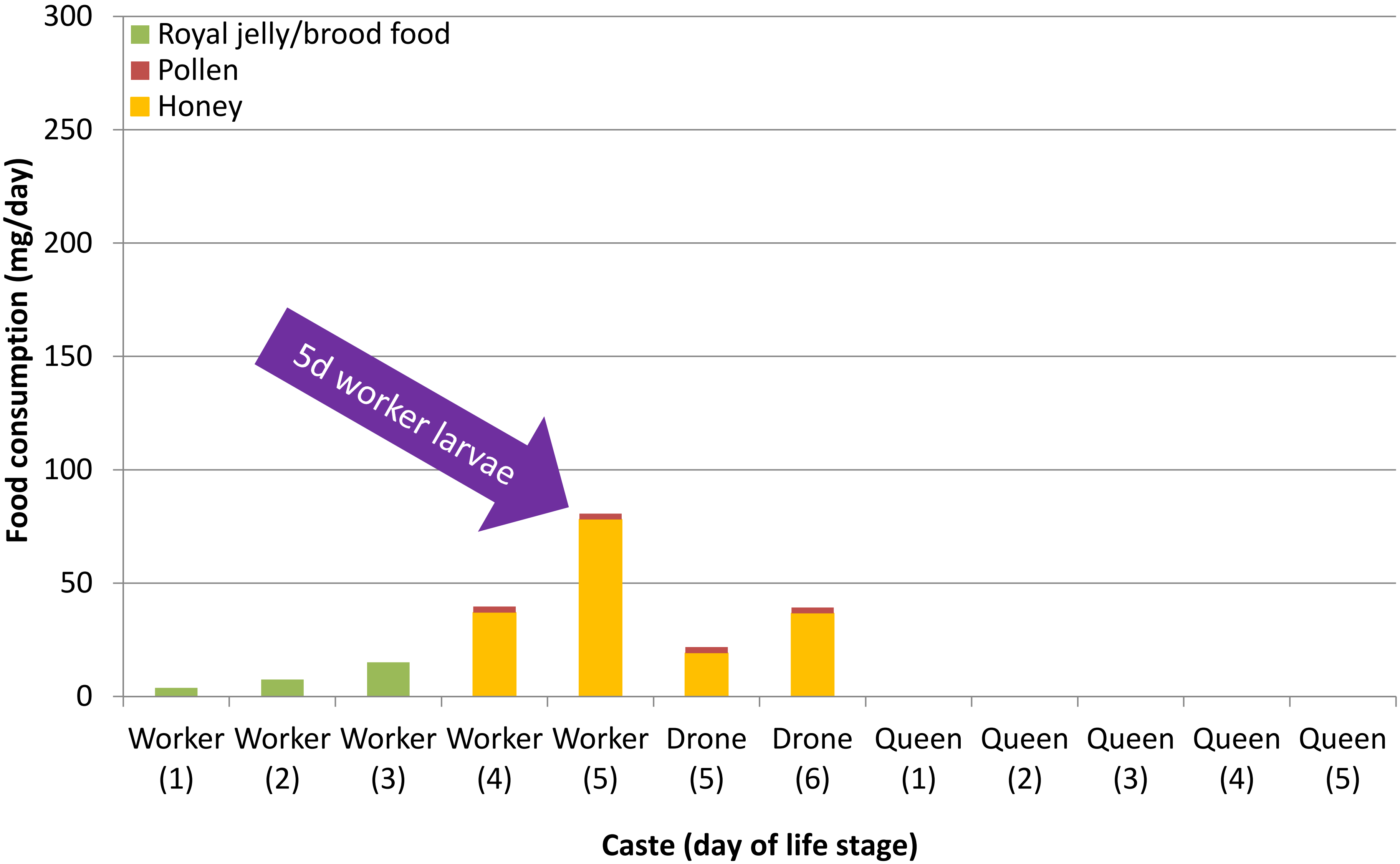
Proposed food consumption rate: Larval Worker Bees

- Proposed value of 120 mg/day is based on 5th day of life stage
  - Highest food consumption value compared to other days of larval life stage
  - Consumption of 2.7 mg pollen
  - Honey consumption rate is converted to nectar equivalent rate (117 mg/day)

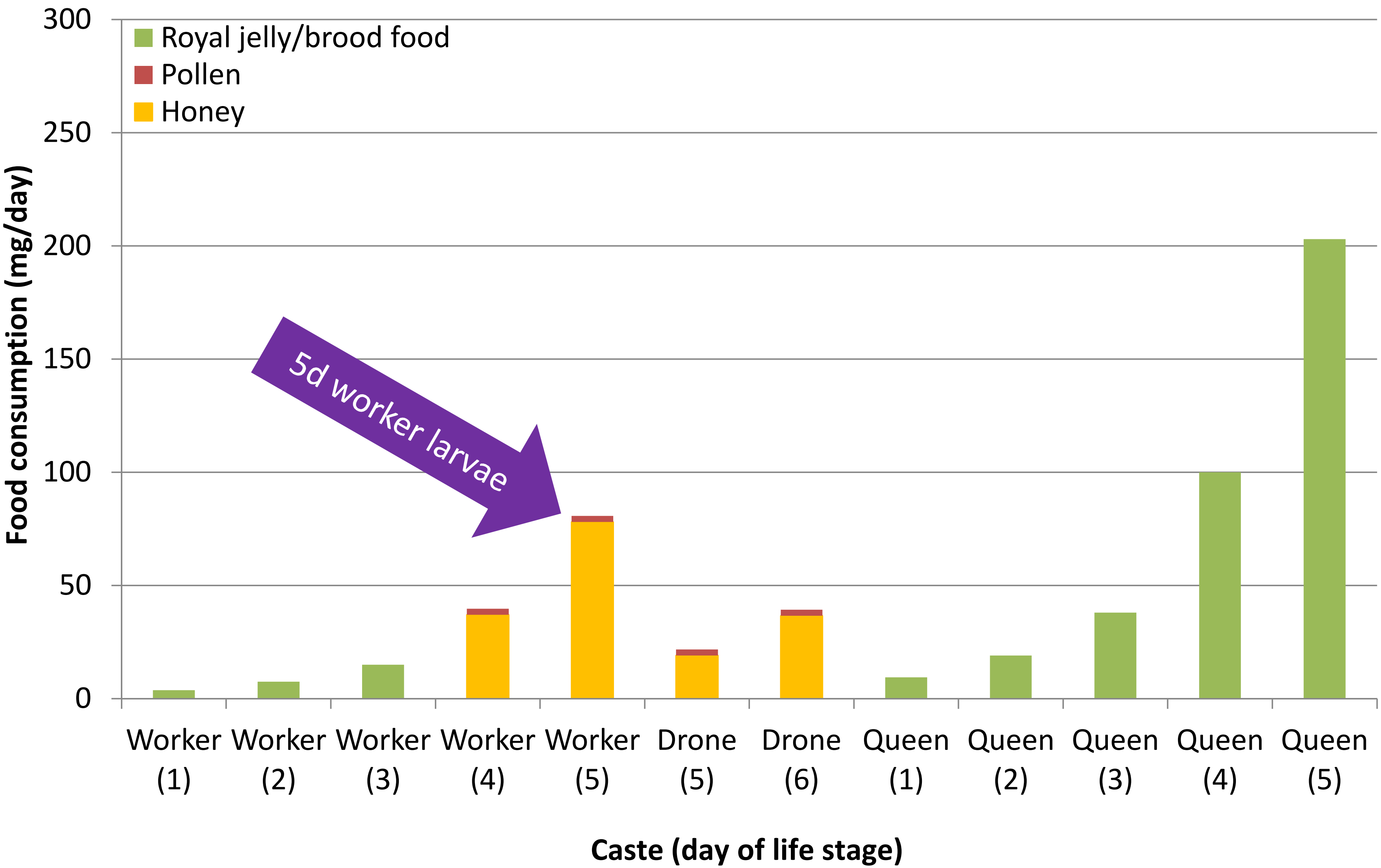
Honey, pollen and brood food or royal jelly consumption rates of larvae of different castes and ages.



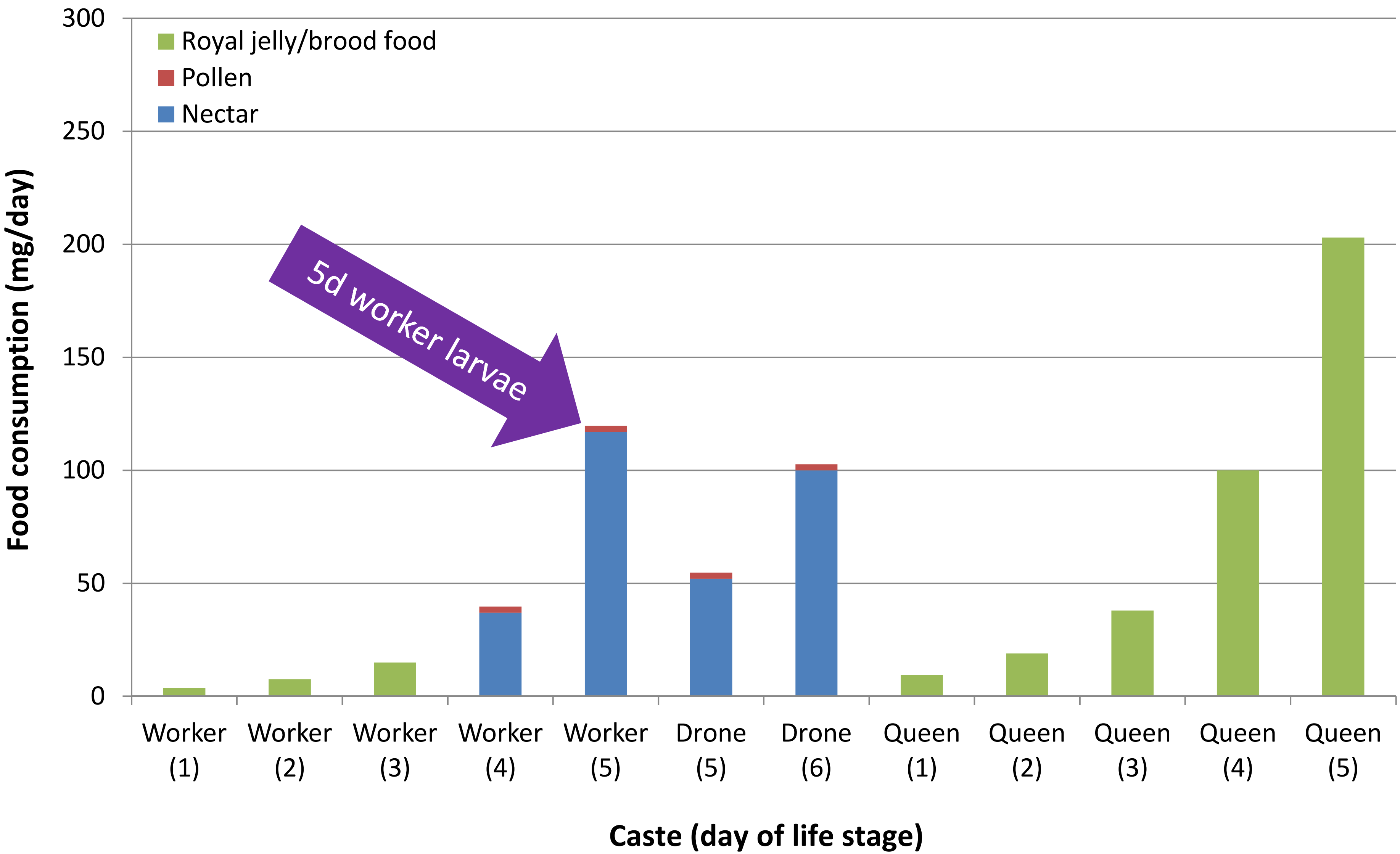
Honey, pollen and brood food or royal jelly consumption rates of larvae of different castes and ages.



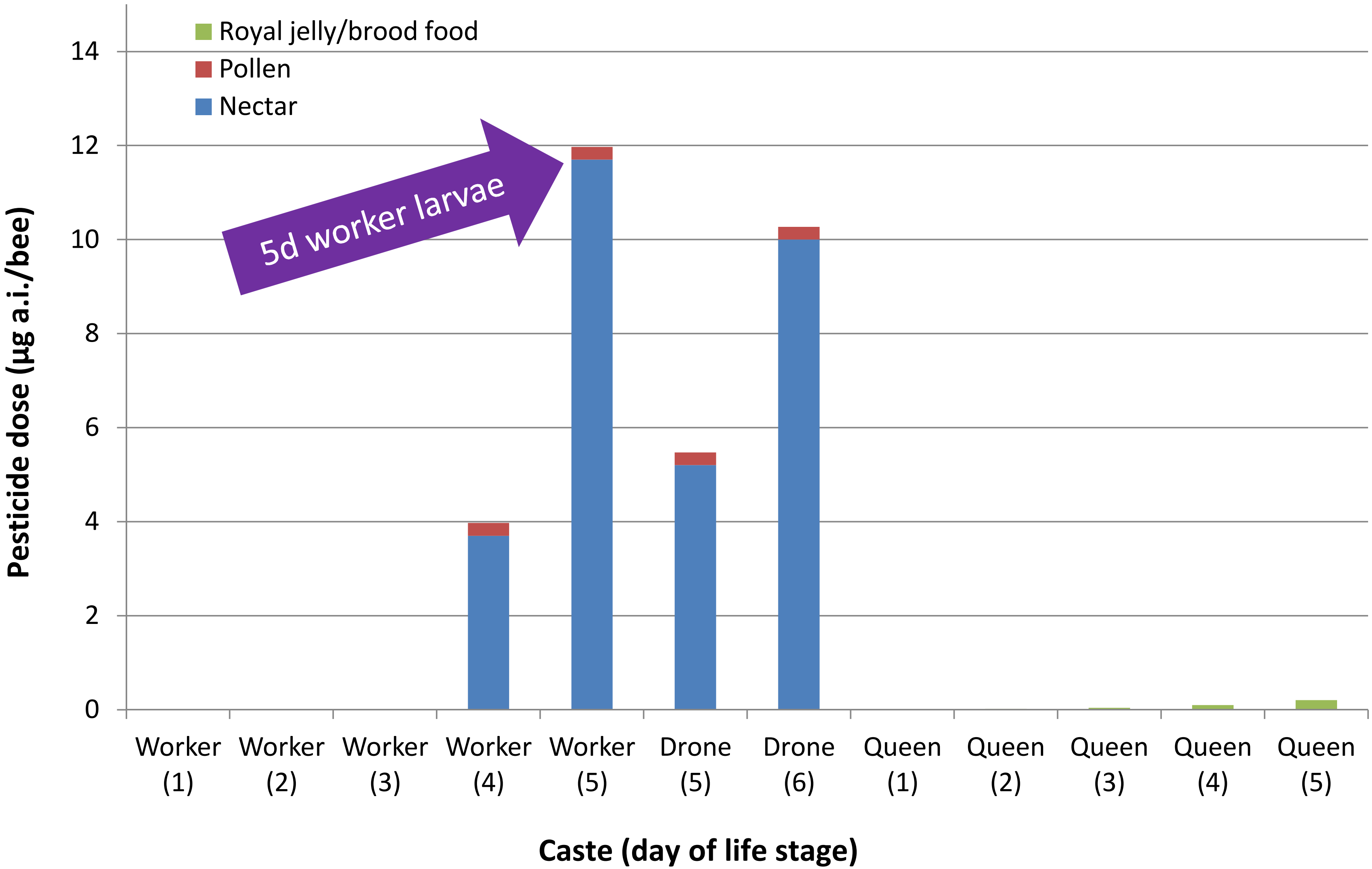
Honey, pollen and brood food or royal jelly consumption rates of larvae of different castes and ages.



Nectar, pollen and brood food or royal jelly consumption rates of larvae of different castes and ages.



Pesticide doses received by larvae of different castes and ages through consumption of pollen and nectar containing 100 µg a.i./kg and royal jelly containing 1 µg a.i./kg.



Comparison of proposed food consumption rates (mg/day) to non-*Apis* bees: Larvae

Species	Male/ female	Nectar	Pollen	Total food
Honey bee *(Apis mellifera)*	Female	117	2.7	120
Bumblebee *(Bombus spp.)*	unknown	60	22-23	82-83
European mason bee *(Osmia cornuta)*	Female	1.8	16.3	18
	Male	1.1	9.5	11
Alfalfa leaf-cutting bee (*Megachile rotundata*)	Female	6.2	3.1	9.3
	Male	5.2	2.6	7.8

Summary of Food Consumption Analysis

- Assume that pesticide doses received through consumption of pollen and nectar can be used to conservatively represent other types of food

- Proposed food consumption rates
  - Adults = 292 mg/day (nectar forager)
  - Larvae = 120 mg/day (5 day old)
  - Appear to be protective for other honey bees and some non-*Apis* bees

- Interested in SAP comments on proposed food consumption rates, related assumptions, strengths and limitations
  - Charge question 5

- Interested in SAP comments on relative protectiveness of proposed food consumption rates in representing exposures to non-Apis bees
  - Charge question 3

Tier I methods for estimating pesticide concentrations on bees and in pollen and nectar

Estimating pesticide exposures for Tier I assessment

- Foliar applications
  - Contact EEC- Koch and Weisser 1997
  - Dietary EEC- T-REX tall grass upper bound

- Seed treatments
  - Dietary EEC - EPPO default value of 1 mg a.i./kg

- Soil treatments
  - Dietary EEC - Modified Briggs' Model

- All dietary EECs converted to a dose using proposed food consumption rates for adult (292 mg/day) and larval (120 mg/day) workers

Identification and Evaluation of Methods

- Methods considered
  - Many are currently used for regulatory purposes
  - Other methods available in the open literature

- Evaluation of Methods
  - Compared to empirical data from scientific literature and unpublished registrant studies
  - Amount of data available to evaluate each method varied

Application type (route)	Method	Number of studies
Foliar spray (contact)	Koch and Weisser	2
Foliar spray (diet)	T-REX (tall grass)	11
Seed treatment (diet)	EPPO (1 mg/kg)	12
Soil treatment (diet)	Briggs' Model	6

Estimating Contact Exposures for Foliar Spray Applications

- Description of Proposed Method

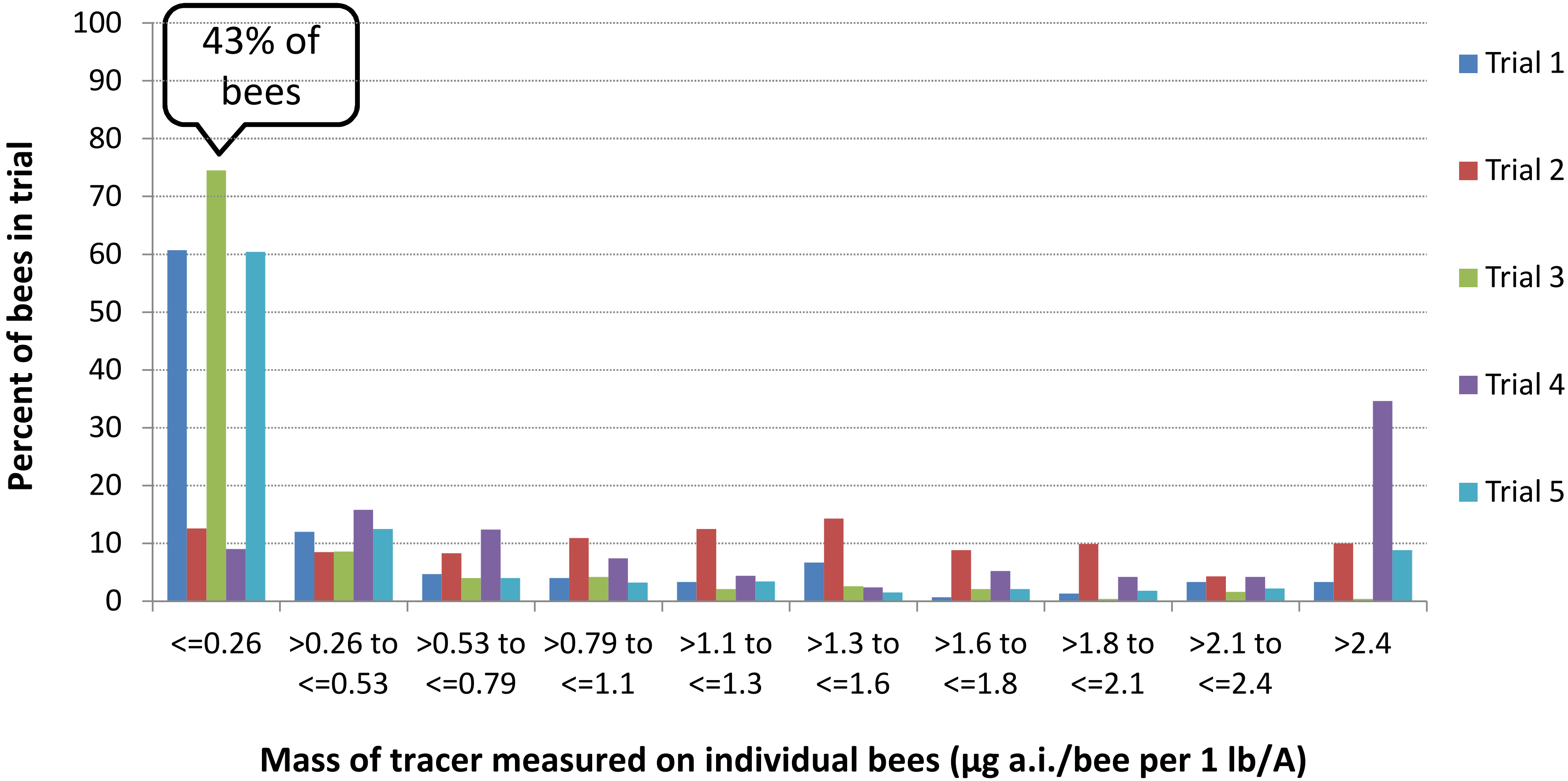
  - Contact Dose = 2.7 µg a.i./bee * Application rate (in lb a.i./A)

  - From Koch and Weisser (1997)

  - Based on maximum concentration of chemical tracer measured on bees foraging on treated areas
    - 5 trials on *Phacelia* fields (total number of bees analyzed = 1724)
    - 9 trials on apple orchards (total number of bees analyzed = 4316)

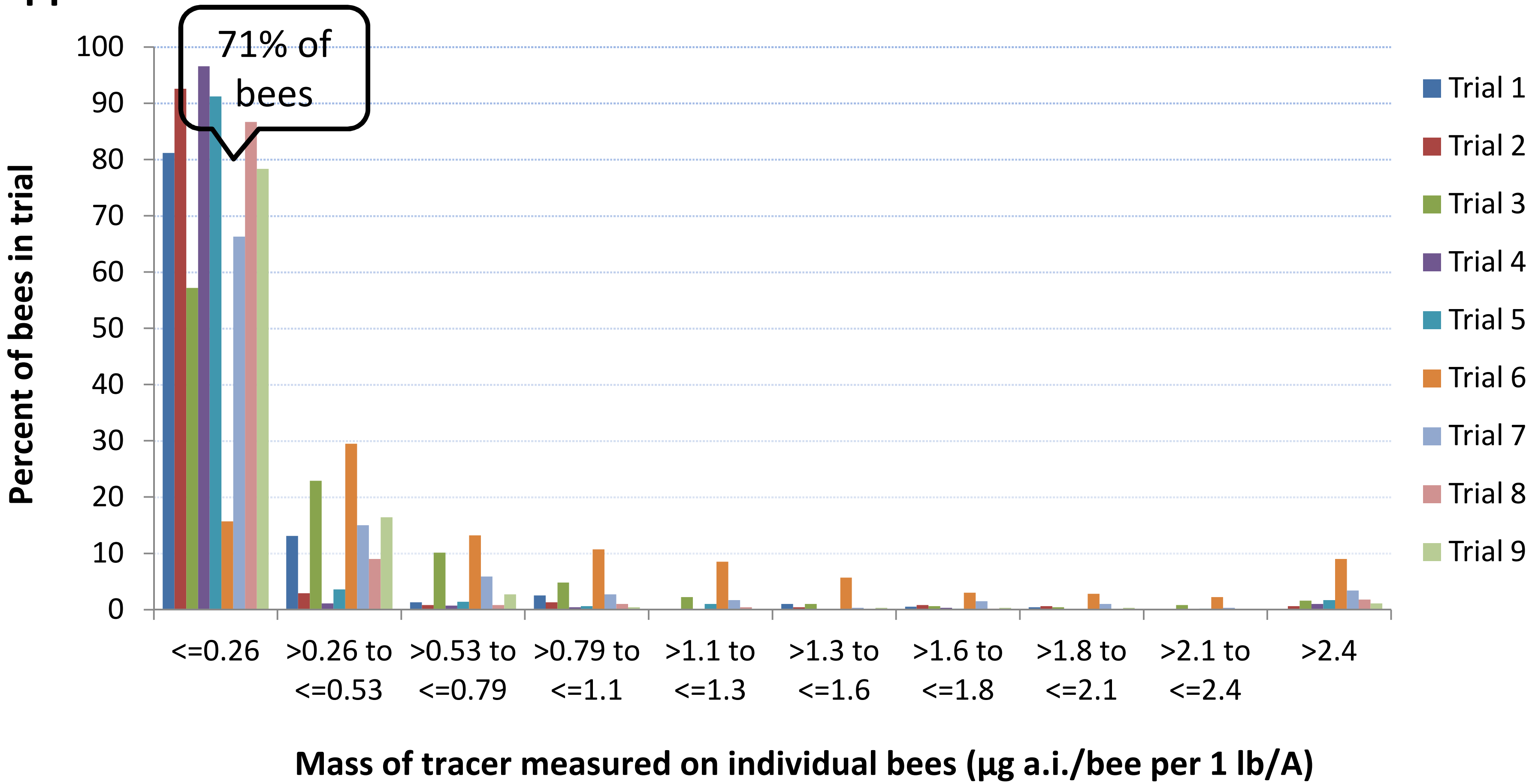
Estimating Contact Exposures for Foliar Spray Applications

Frequency distribution of measured tracer on individual bees during 5 trials with *Phacelia* fields.



Estimating Contact Exposures for Foliar Spray Applications

Frequency distribution of measured tracer on individual bees during 9 trials with apple orchards.

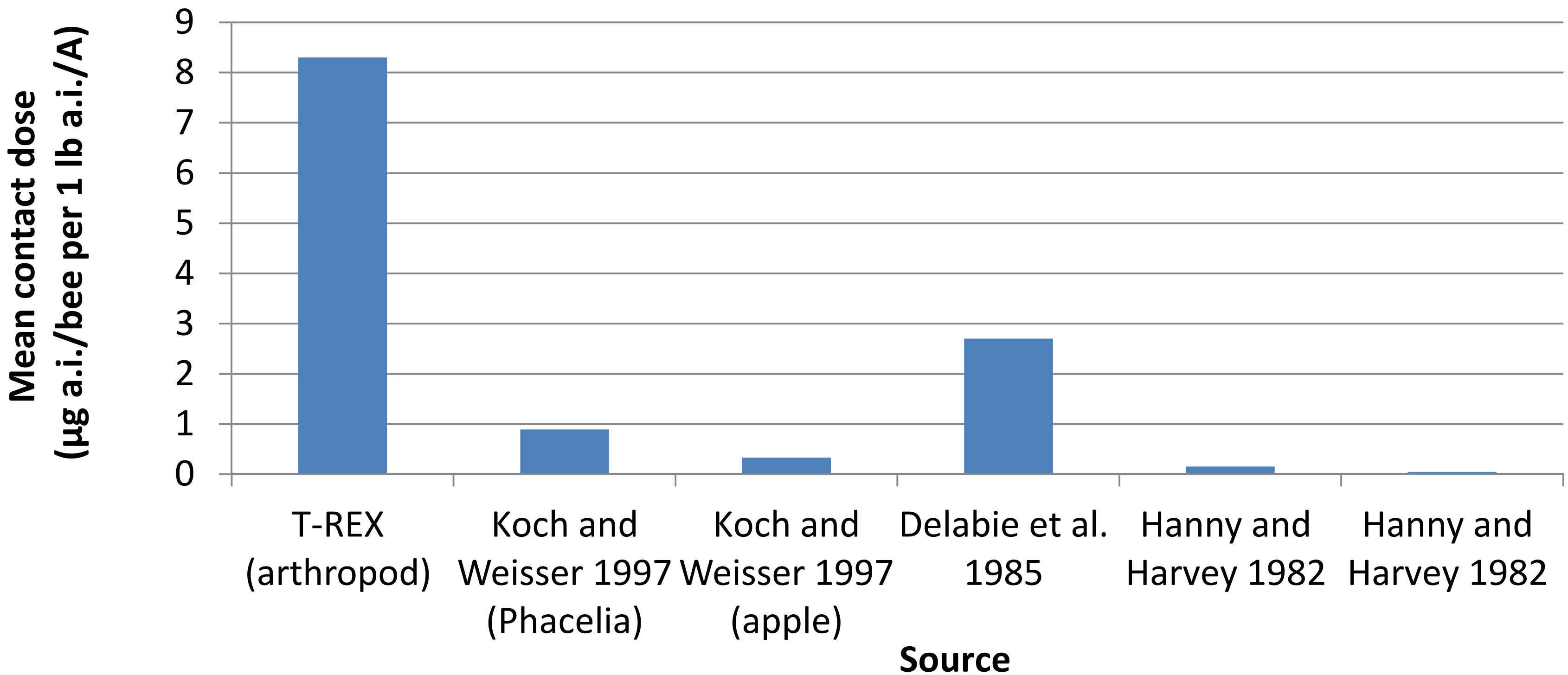


Estimating Contact Exposures for Foliar Spray Applications

- Discussion of Relevance of T-REX arthropod residue value
  - Contact Dose = 12 µg a.i./bee * Application rate (in lb a.i./A)
    - Value represents 95th percentile residue value (94 mg a.i./kg) converted to a dose using weight of a bee (0.128 g)
  - Based on analysis of pesticide residues on crickets, grasshoppers, beetles, etc. located on treated field at the time of the application
    - Limitation: data set does not include residue data for honey bees

Estimating Contact Exposures for Foliar Spray Applications

- Method Evaluation
  - No upper bound residues available to evaluate proposed value
  - Mean Koch and Weisser (1997) data and T-REX arthropod residue values are consistent with means of empirical data from 2 other studies



Estimating Contact Exposures for Foliar Spray Applications

- Assumptions and Uncertainties
  - Limited number of studies available for evaluation of method
  - Based on only two crops
  - Based on one study site

- Strengths of proposed method
  - Koch and Weisser (1997) maximum value appears to be conservative
  - Robust study design
    - Maximum value is based on measurements of >6000 bees
    - Tracer did not impact study results
  - Consistent with other methods that are empirically based
    - T-REX arthropod residue value (factor of 5 different)
    - Atkins et al. 1981

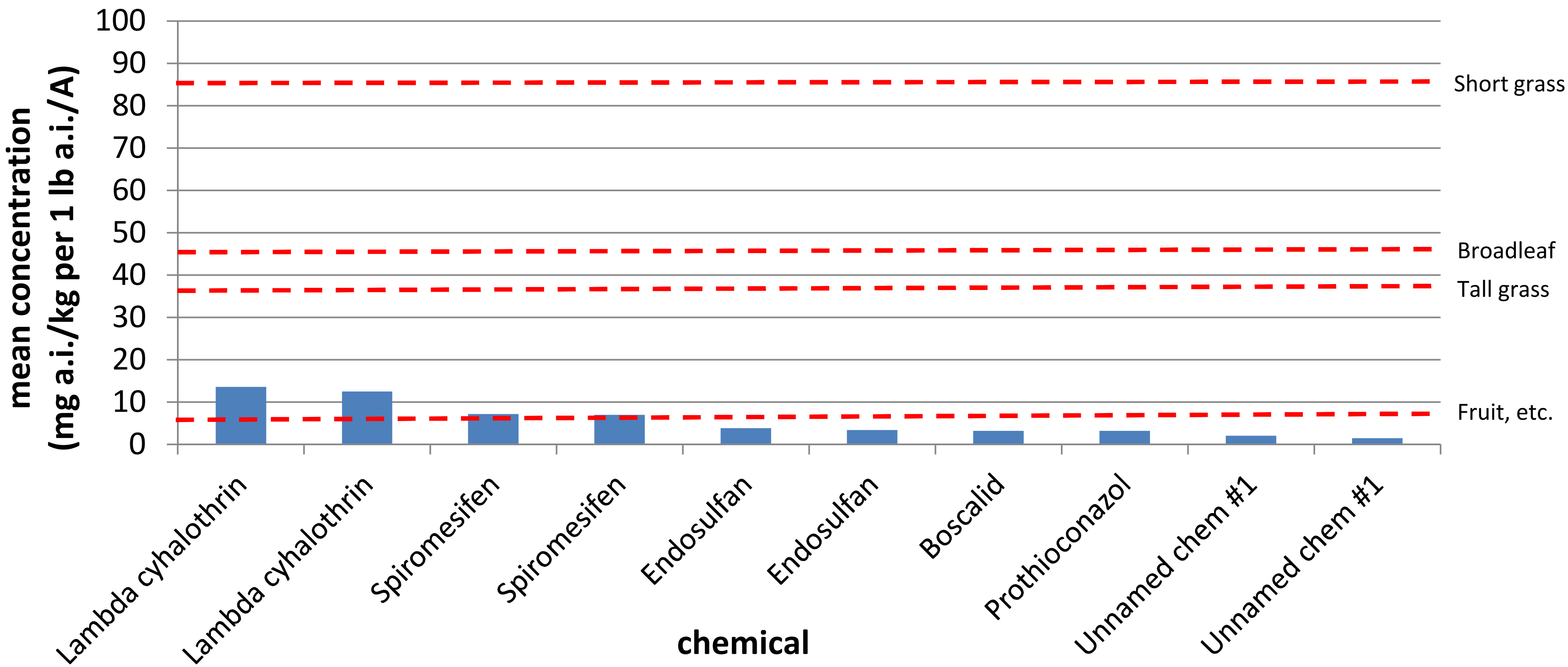
Estimating Dietary Exposures for Foliar Spray Applications

- Description of Proposed Method
  - Use T-REX upper bound residue value on foliage as a surrogate for pollen and nectar
  - Sufficient data are not available to derive nectar or pollen specific residue values

Plant Description	Concentration (mg a.i./kg per 1 lb a.i./A)	
	Upper-bound	Mean
Short grass	240	85
Broadleaf plants	135	45
Tall grass	110	36
Fruit, pods and seeds	15	7

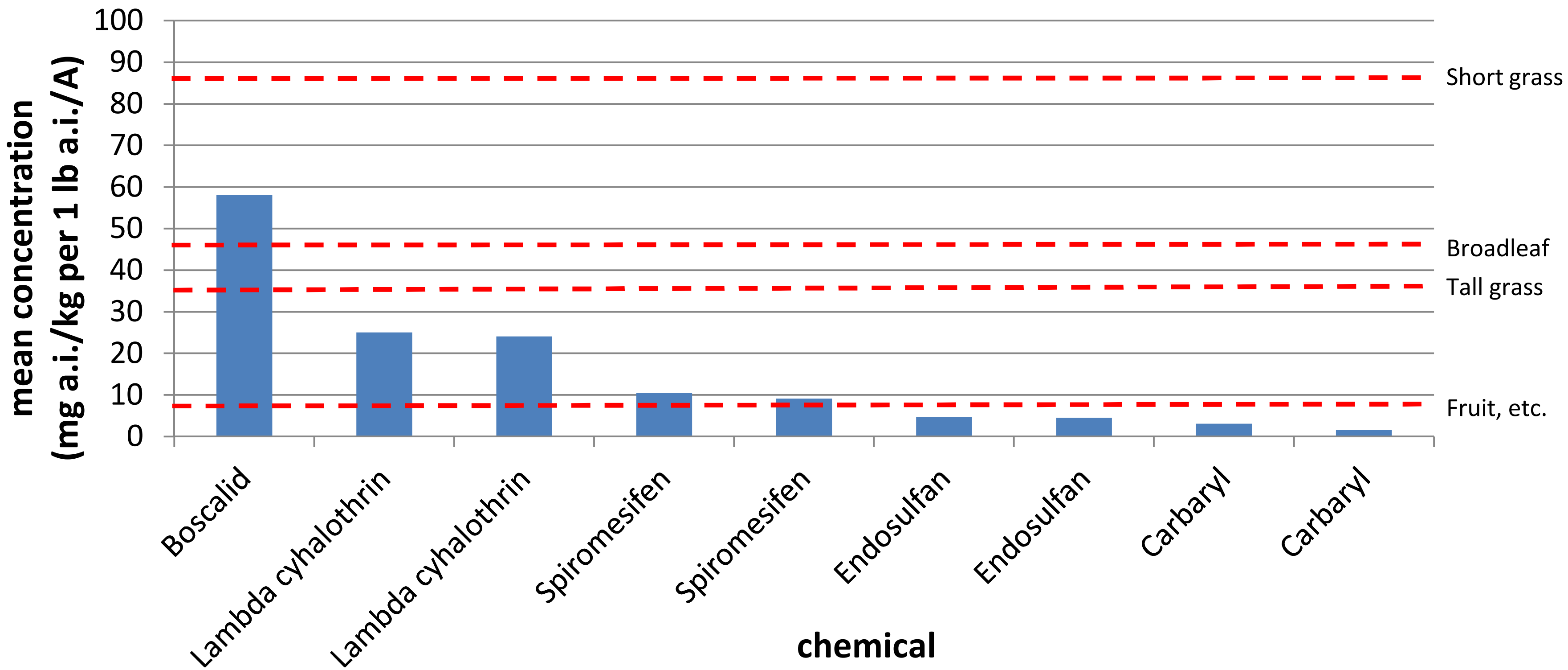
Estimating Dietary Exposures for Foliar Spray Applications

- Method Evaluation: mean empirical data for nectar (n = 10)
  - Mean residues for short grass, broad leaf plants and tall grass are all higher than mean empirical data
  - 4 empirical values exceed the mean residue for fruit, pods and seeds
  - Maximum residues only available for some studies (0.17-2.2 mg a.i./kg per 1 lb a.i./A)



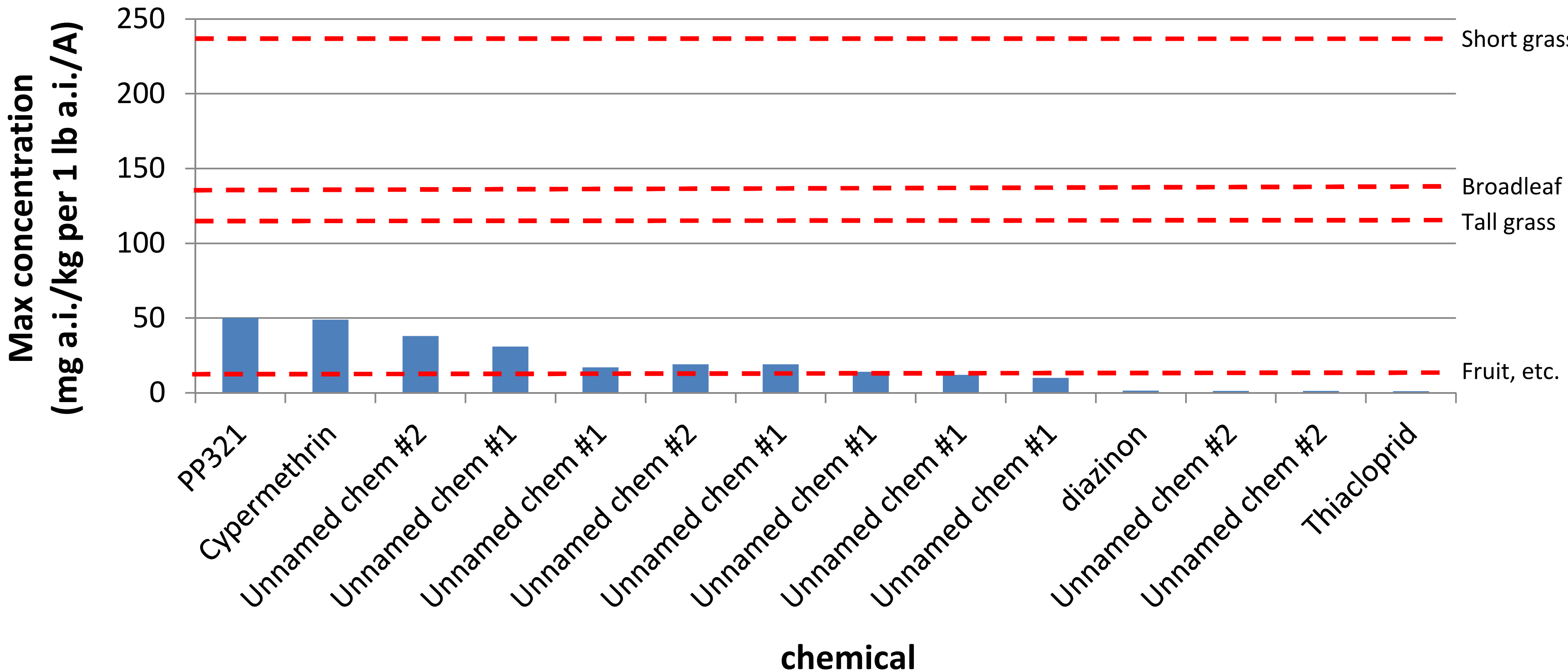
Estimating Dietary Exposures for Foliar Spray Applications

- Method Evaluation: mean empirical data for pollen (n = 9)
  - Mean residue for short grass is higher than mean empirical data
  - Mean residues for broad leaf plants and tall grass higher than all but one residue value
  - 5 empirical values exceed the mean residue for fruit, pods and seeds



Estimating Dietary Exposures for Foliar Spray Applications

- Method Evaluation: maximum empirical data for pollen (n = 14)
  - Upper bound residues for short grass, broadleaf plants and tall grass are higher than empirical data
  - 7 empirical values exceed the mean residue for fruit, pods and seeds



Estimating Dietary Exposures for Foliar Spray Applications

- Summary of Evaluation and Proposed Method

  - Short grass, broad leaf plant and tall grass residues are consistently conservative relative to mean and maximum residue data for pollen and nectar
    - Only one value exceeds tall grass and broad leaf plant residues

  - Tall grass value is closest to empirical data
    - Proposed residue concentration is 110 mg a.i./kg per 1 lb a.i./A
      - Adult dose: 32 µg a.i./bee per 1 lb a.i./A
      - Larval dose: 13µg a.i./bee per 1 lb a.i./A

Estimating Dietary Exposures for Foliar Spray Applications

- Assumptions and Uncertainties
  - Assume that tall grass upper bound is representative of pollen and nectar
  - Assume that concentration from direct foliar spray at time of application exceeds later concentration resulting from systemic transport

- Strengths of proposed method
  - Tall grass upper bound concentration appears to be reasonably conservative compared to empirical concentrations on pollen and nectar

Estimating Dietary Exposures for Seed Treatments

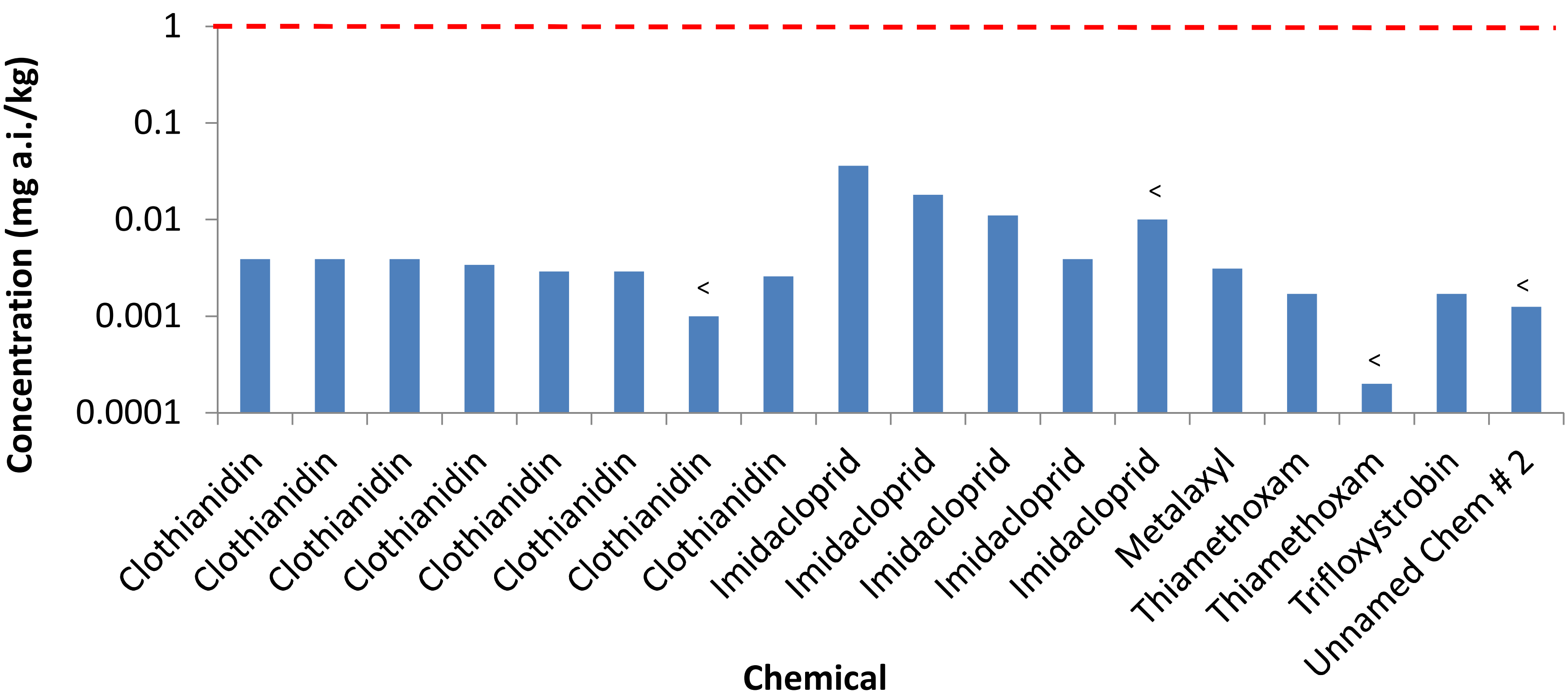
- Description of Proposed Method

  - Assume that pesticide concentration in pollen and nectar of seed treated crops is 1 mg a.i./kg (1 µg a.i./g)
    - No adjustment is made for application rate
    - Based on EPPO's recommended screening value

  - Final doses calculated by multiplying 1 µg a.i./g by food intake rates
    - Adult Dose = 0.29 µg a.i./bee
    - Larval Dose = 0.12 µg a.i./bee

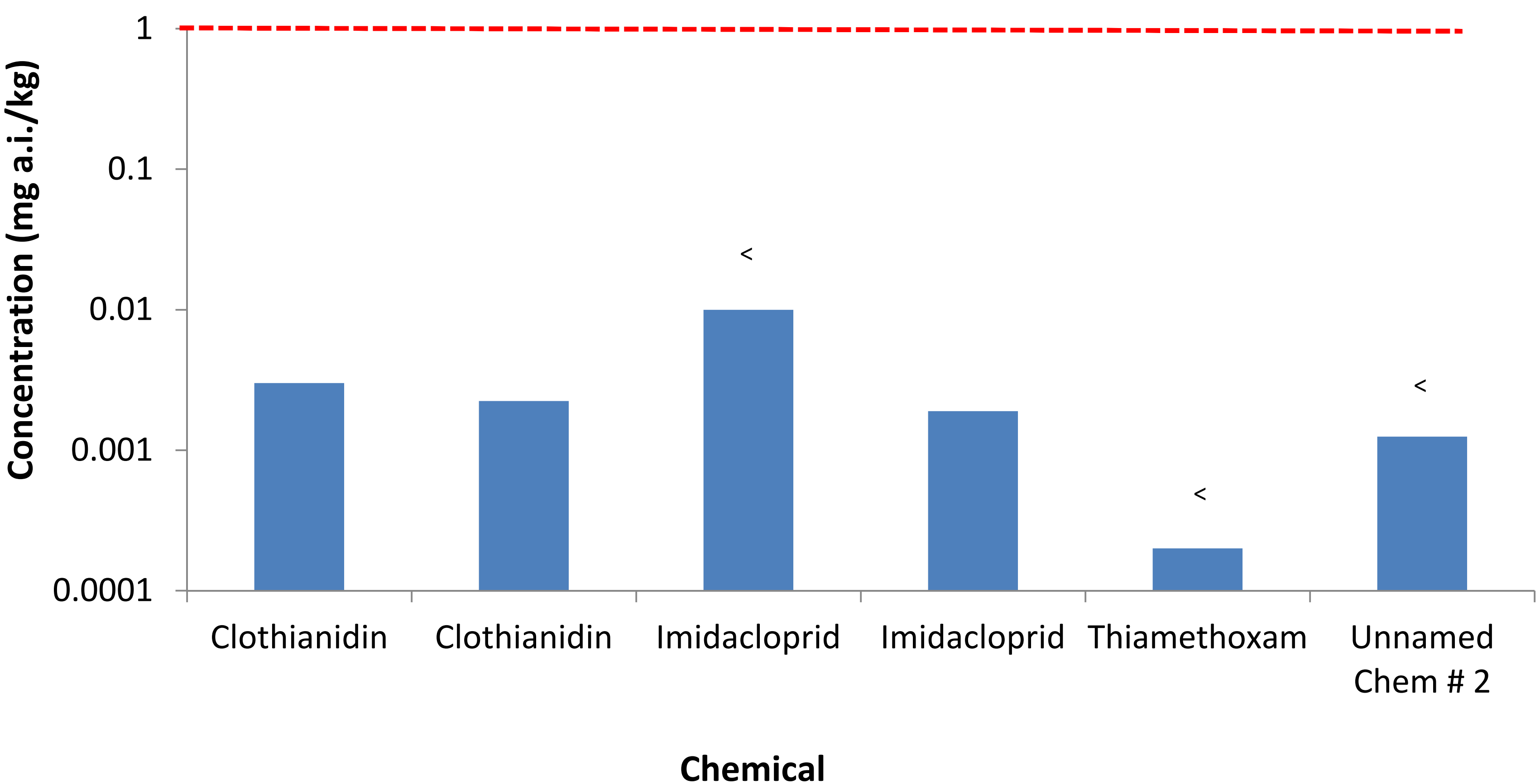
Estimating Dietary Exposures for Seed Treatments

- Method Evaluation: empirical data for pollen (n = 18)
  - 1 mg a.i./kg screen is factor of 28 above highest concentration



Estimating Dietary Exposures for Seed Treatments

- Method Evaluation: empirical data for nectar (n = 6)
  - 1 mg a.i./kg screen is 3 orders of magnitude above empirical data



Estimating Dietary Exposures for Seed Treatments

- Assumptions and Uncertainties
  - Assumed that pesticides applied to seeds are systemically transported
  - Does not account for application rate
  - Does not account for fate of pesticide

- Strengths of proposed method
  - 1 mg a.i./kg value is conservative relative to empirical data
    - By a factor of 28 for pollen
    - By a factor of 333 for nectar

Estimating Dietary Exposures for Soil Applications

- Description of Proposed Method
  - Based on Briggs' model (Briggs et al. 1982, 1983)
    - Predicts concentration in stems using:
      - Octanol-water partition coefficient (Kow)
      - Concentration in water (C_{water})
      - Transpiration Stream Concentration Factor (TSCF)
        - Calculated using Kow

$$C_{stem} = TSCF * \left[10^{(0.95*LogKow-2.05)} + 0.82\right] * C_{water}$$

Estimating Dietary Exposures for Soil Applications

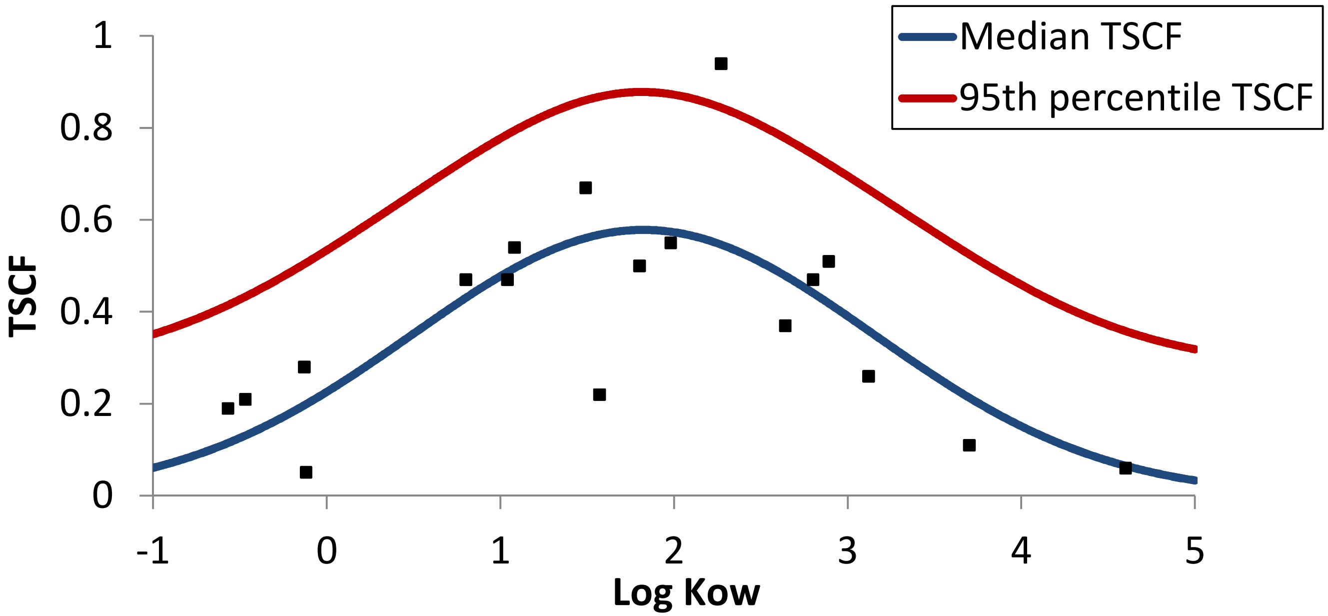
- Description of Proposed Method (continued)
  - Includes soil water partitioning as proposed by Ryan et al. (1988)
    - Requires organic-carbon partition coefficient (Koc) or soil partition coefficient (Kd)
    - Requires concentration in soil (C_{soil}) instead of C_{water}
    - Requires basic soil properties
      - Soil bulk density (ρ)
      - Soil water content (θ)
      - Fraction of organic carbon (foc)

$$C_{stem} = TSCF * \left[10^{(0.95*LogKow-2.05)} + 0.82\right] * \boxed{C_{soil} * \left[\rho \Big/ \theta + \rho * Koc * foc\right]}$$

Estimating Dietary Exposures for Soil Applications

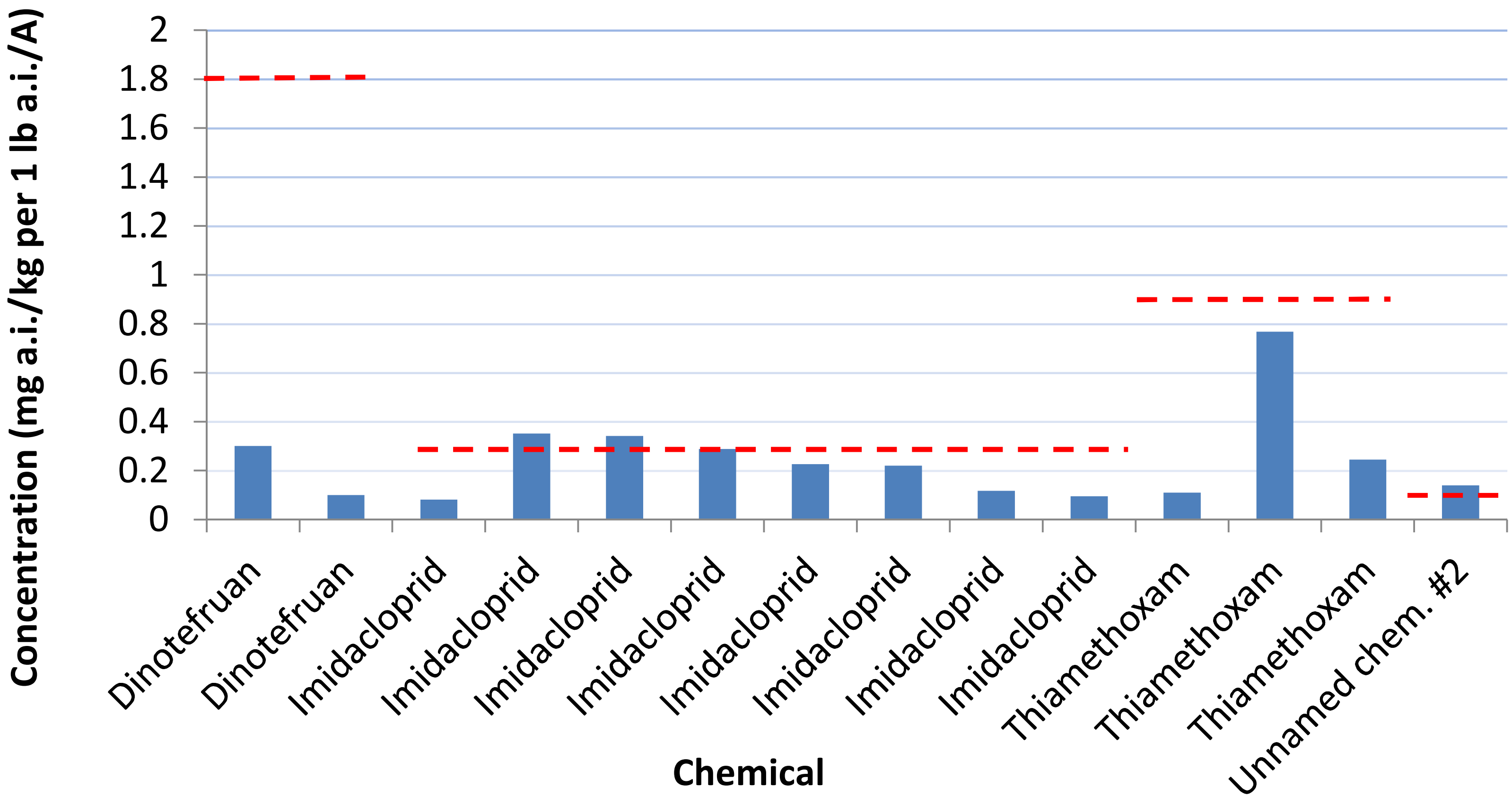
- Description of Proposed Method (continued)
  - Modifications to the TSCF calculation were made by EPA to generate more conservative estimates of the concentration in stems (Appendix 5)

Estimates of median and 95th percentile TSCF values based on empirical dataset reported by Briggs et al. 1982.



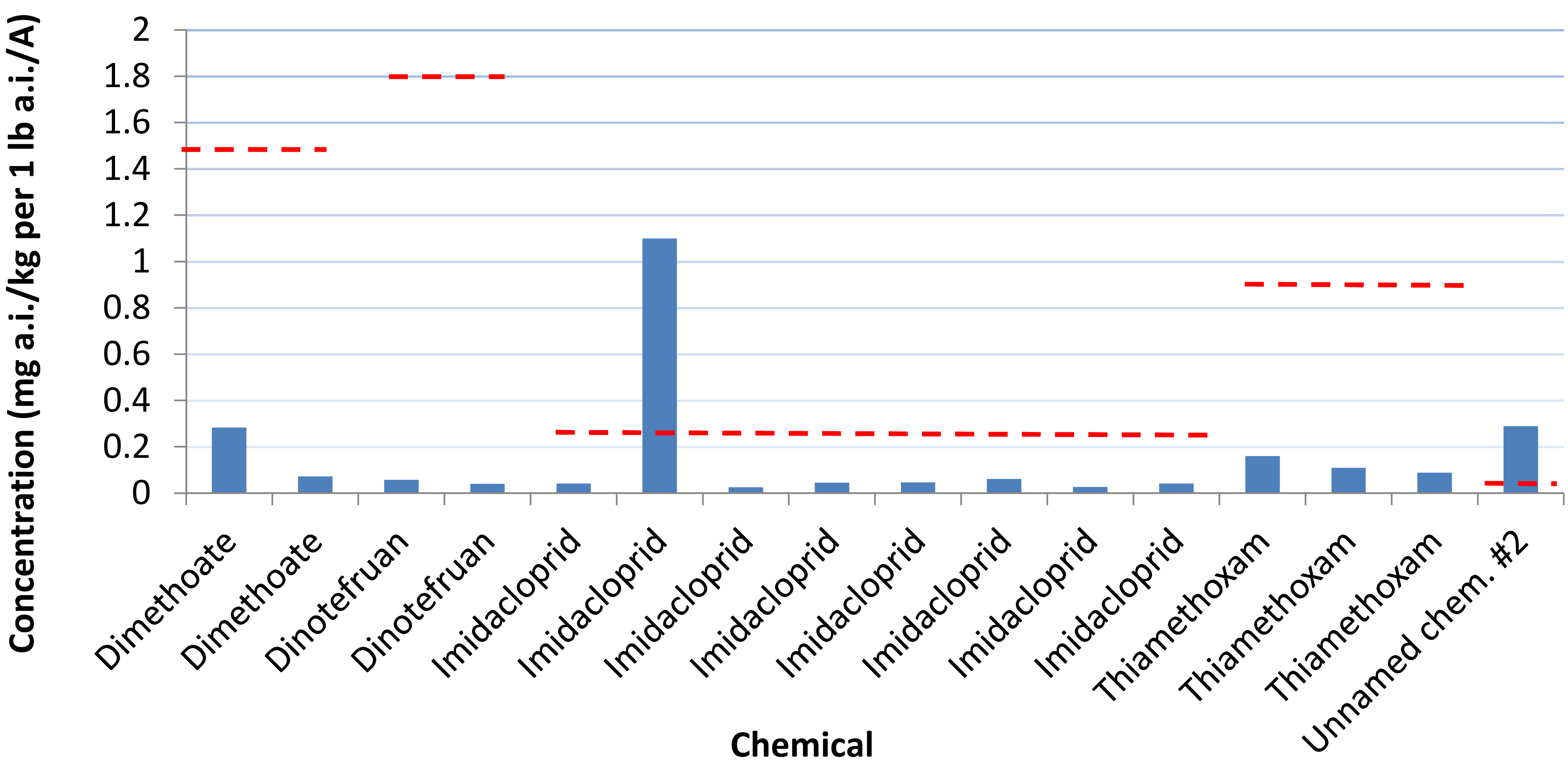
Estimating Dietary Exposures for Soil Applications

- Method Evaluation: empirical data for pollen (n = 14)
  - Model predictions are generally conservative compared to empirical data



Estimating Dietary Exposures for Soil Applications

- Method Evaluation: empirical data for nectar (n = 16)
  - Model predictions are generally conservative compared to empirical data



Estimating Dietary Exposures for Soil Applications

- Consideration of EPPO’s 1 mg a.i./kg screen
  - Conservative for all but one value from empirical data set
    - Dimethoate concentration in nectar (4.82 mg a.i./kg; Lord et al. 1968)
      - High application rate (17 lb a.i./A)
  - Does not account for application rate
  - Does not account for fate of chemical

Estimating Dietary Exposures for Soil Applications

- Assumptions and Uncertainties of modified Briggs' Model
  - Uses stem concentrations as surrogates for pollen and nectar
  - Assumed that pesticides applied to soil are systemically transported
  - Data from barley only
  - Limited number and type of chemicals (2 classes of non-ionic pesticides)
    - May have limited application to ionic chemicals
  - Xylem based

- Strengths of proposed method
  - Estimates appear to be reasonably conservative
  - Accounts for some basic chemical specific parameters
    - Application rate
    - Kow
    - Koc (or Kd)

Summary of Proposed Tier I Exposure Assessment Methods

Application Type	Exposure Route	Method Description	Exposure Estimate	Example Dose (μg a.i./bee) From 1 lb a.i./A application
Adult Bees				
Foliar spray	Contact	Koch and Weisser (1997) Max	(2.7 μg a.i./bee)*App. rate	2.7
Foliar spray	Diet	T-REX tall grass upper bound	(32 μg a.i./bee) *App. rate	32
Seed Treatment	Diet	EPPO screen	0.29 μg a.i./bee	0.29
Soil Treatment	Diet	Modified Briggs model	(Briggs EEC)(0.29 g/day)	0.42
Larvae				
Foliar spray	Diet	T-REX tall grass upper bound	(13 μg a.i./bee) *App. rate	13
Seed Treatment	Diet	EPPO screen	0.12 μg a.i./bee	0.12
Soil Treatment	Diet	Modified Briggs model	(Briggs EEC)*(0.12 g/day)	0.18

Summary of Tier I Methods for estimating pesticide concentrations on bees and in pollen and nectar

- Estimated concentrations on bees, pollen and nectar are reasonably conservative relative to empirical data

- As more data become available, EPA may re-evaluate methods

- Interested in SAP comments on the proposed methods for estimating tier 1 exposure values
  - Contact exposure: charge question 4
  - Dietary exposure: charge question 6

Questions