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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: PS2327

2. Project title: Improving assessments of the risk to birds from pesticide contaminated drinking water.

3. Contractor organisation(s):
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4. Total Defra project costs (agreed fixed price): £ 10012

5. Project: start date .... 01 January 2006

end date .... 31 March 2006

6. It is Defra's intention to publish this form.
   Please confirm your agreement to do so.. **YES** ☒ **NO** ☐

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   (b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

1. Annex VI to EU Directive 91/414 requires that plant protection products should not be authorised for sale if they pose unacceptable risks to birds and other non-target terrestrial vertebrates. Following pesticide application, birds may be exposed to pesticides via drinking water. While exposure via these routes is possible there is a need to critically assess the likelihood of these occurring under current UK practices. Where assessment of such a risk is required it is necessary to be able to predict how much water a bird might drink to determine the potential exposure.

2. The objectives of the study were to (1) Assess the potential for pesticide exposure via sources of drinking water in the UK, (2) Review methods used to estimate the drinking water requirements of birds and identify any improvements that could be made to current guidance, and (3) Produce a final report including any recommendations for improvements to risk assessment procedures.

3. Only one UK Wildlife Incident Report was found that raised the possibility that contaminated water may have contributed to mortality following normal use of a pesticide rather than for example abuse or deliberate poisoning. Other incidents that are more firmly linked to drinking pesticide-contaminated water were reported in Germany and followed applications of insecticides against caterpillars on cabbage plants and involved several species, mainly small seed eating birds. It was proposed birds found and drank pesticide-contaminated water collected in puddles on the lower leaves of the plants.

4. Information on application methods in the UK including application rates and details of best practice were collated. This indicated that puddles formed by spray liquid alone are very unlikely given the application volumes. However, it is possible that under some conditions existing puddles or water bodies may be oversprayed, although spraying in such a way or under such conditions would not be good practice and may therefore not be considered in risk assessment. Should existing bodies of water be sprayed, given the application rates used it is likely that any water of sufficient depth to be attractive as a drinking source would lead to substantial dilution. Overspray of larger water bodies would obviously lead to even greater dilution.

5. The one set of conditions that are known to have caused incidents in Germany, where contaminated water had collected on the leaves of cabbage plants was very specific and followed a long dry period such that the plants were attractive as a water source. This may be a particular risk that should be considered where plants are irrigated after application. In this scenario birds may actively seek the treated field as a source of water rather than drinking incidentally as they fed.

6. Current methods of estimating the drinking water requirements of birds were considered unsatisfactory as they do not take account of the water in the food so that a bird eating dry seeds would appear to have the same drinking water requirements as a bird feeding on leaves. A more satisfactory method is to use data on total water flux from doubly labelled water (DLW) studies on birds in the wild. Thus the total daily water use by a bird can be adjusted to allow for the water in its food and metabolic water to estimate how much water it would need to drink. The results of these calculations assuming different diets were compared with the current method to highlight where this may over- or underestimate the drinking water requirements of birds.

7. Daily drinking water requirements for a range of UK species relevant to risk assessment feeding on a range of foods was calculated to determine those species/diet combinations that present the greatest risk (e.g. have the greatest drinking water requirements). The results of these calculations indicate that those animals feeding on plant material such as crop leaves, aquatic vegetation and top fruit can obtain more than their daily water requirements from their food and are therefore at less risk. For birds feeding on invertebrates the picture is somewhat more mixed. Feeding on earthworms, slugs and snails, bugs and caterpillars provides sufficient water while for species feeding solely on other arthropods, up to 50% of water requirements may need to be obtained from drinking. As might be expected, the worst case was found for those species feeding on seeds where up to 90% of water requirements may need to be satisfied by drinking.

8. It is therefore recommended at this stage that drinking water estimates should be based on estimates of water influx rate (WIR) from DLW studies combined with estimates of water in food and metabolic water production as described above. This provides a more realistic estimate of drinking water requirements than the existing method which takes no account of the differences in water content of different diets. Where WIR estimates from studies on the species of concern are available, these should preferably be used in any risk assessment. Where WIR estimates for the species of concern are not available, estimates should be based on appropriate allometric equations.

9. Given the relative lack of actual measured WIR values for UK species, and the large number of DLW studies conducted since the late eighties when the existing allometric equations for water flux were developed, it is also recommended that these are updated to include this new information in line with those currently used to estimate daily energy expenditure and food intake.

Note: This work has now been completed (see Project PS2330, Improved estimates of food and water intake for risk assessment) and it is recommended that these updated equations be used in future assessments.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

INTRODUCTION

Annex VI to EU Directive 91/414 requires that plant protection products should not be authorised for sale if they pose unacceptable risks to birds and other non-target terrestrial vertebrates. Following pesticide application, birds may be exposed to pesticides via drinking water. Possible scenarios include:

- Direct ingestion of spray liquid from plants after spraying (e.g. in axils/whorls).
- Drinking from oversprayed puddles on the field.
- Drinking from spray drift contaminated puddles/water bodies.
- Drinking from run-off contaminated puddles/water bodies.

While exposure via these routes is possible there is a need to critically assess the likelihood of these occurring under current UK practices. For example, while direct ingestion of spray liquid has been implicated in large incidents (e.g. Hommes *et al* 1990) lower spray volumes may make this kind of event less likely. Also, spraying only in dry conditions may reduce the potential for drinking from oversprayed puddles or the formation of puddles contaminated with run-off. The aims of this project were to collate information on (1) the conditions which have led to past incidents (2) typical application conditions in the UK (e.g. spray volume), (3) risk assessment approaches and scenarios used by other regulators (e.g. US EPA), and (4) estimates of drinking water requirements for a representative range of species, to make an assessment about the potential for exposure through drinking water in the UK.

OBJECTIVE 1: ASSESS THE POTENTIAL FOR PESTICIDE EXPOSURE VIA SOURCES OF DRINKING WATER IN THE UK.

Incidents involving drinking water

Only one UK Wildlife Incident Report has been found that raises the possibility that contaminated water may have contributed to mortality following normal use of a pesticide, rather than for example abuse or deliberate poisoning. This incident involved 22 shelduck and 2 mallard that were found dead on and near a field which had been sown with sugar beet and Yaltox (carbofuran) granules. The field report indicated that the weather had been very dry and these conditions continued for over a month before heavy rainfall just before the deaths of the birds. This rainfall is said to have caused the formation of small pools. Analysis of one of the birds indicated depressed brain cholinesterase activity and large residues of carbofuran in the gizzard indicating oral exposure. While this is not conclusive evidence of exposure via drinking (e.g. exposure could have been due to contaminated food or following dermal exposure and preening) the circumstances described indicate one potential scenario that might lead to such exposure.

Other incidents that are more firmly linked to drinking pesticide-contaminated water were reported by Schietinger and Hofman (1984). These followed applications of insecticides against caterpillars on cabbage during late summer/autumn following long periods without rainfall and involved greenfinches (*Carduelis chloris*), serins (*Serinus serinus*), goldfinches (*Carduelis carduelis*), sparrows (*Passer sp*.) and bramblings (*Fringilla montifringilla*). It was proposed that following irrigation, birds could find and drink pesticide-contaminated water collected on the lower leaves of the plants. Further such incidents were reported by Hommes *et al* (1990) which involved most of the above species with the addition of linnets (*Carduelis cannabina*), siskins (*Carduelis spinus*), yellowhammers (*Emberiza citrinella*), robins (*Erithacus rubecula*) and blackbirds (*Turdus merula*). Several of these incidents involved over 100 birds.

The lack of recorded incidents in the UK, and the very specific set of conditions that led to the small bird incidents in Germany may indicate that the risk of mortality via exposure through drinking water is low, and this may very well be the case. However, where incidents do occur following approved use of a pesticide and a residue is found in the gizzard it is possible that at least some of this could have come from contaminated drinking water but it would in most cases not be possible to determine this. This route of exposure may therefore be missed in the absence of field information that highlights this possibility as in the duck incident described above. Also, if small birds are at more risk due to drinking from plants, they may well go unnoticed as small bird deaths are reported far less than larger birds (Baillie 1993).

Application of pesticides in the UK

Application volumes

Reports produced for the Pesticide Usage Survey contain statistics on spray volumes for various classes of pesticides applied to arable and outdoor vegetable crops.

Table 1. Percentage of area of arable crops sprayed at volumes >200 l/ha in 2004. Approximate data from graphs in Garthwaite *et al*. (2005).

	% area of applications with volume > 200 l/ha			
Crop	Fungicide	Growth regulator	Herbicide	Insecticide
Wheat	3.8	3.3	3.9	3.3
Winter barley	7.6	8.5	5.8	5
Oilseed rape	2.8	-	4.8	2.9
Ware potatoes	13.9	53.4	24.0	11.2
Sugar beet	0	-	0.8	0

Clearly the majority of applications are made at low volume (see classification in Table 2.) with the exception of potatoes where especially for growth regulators, a large proportion are applied at medium volumes (or higher).

Table 2. Classification of spray volumes (from Matthews' 2000)

Class	Field crops (l/ha)	Tree and bush crops (l/ha)
High volume (HV)	>600	>1000
Medium volume (MV)	200-600	500-1000
Low volume (LV)	50-200	200-500
Very-low volume (VLV)	5-50	50-200
Ultra-low volume (ULV)	<5*	<50

For outdoor vegetable crops, most applications exceed 200 l/ha and often exceed 500 l/ha (Table 3).

Table 3. Percentage of area of arable crops sprayed at volumes >200 l/ha and >500 l/ha in 2003. Approximate data from graphs in Garthwaite *et al*. (2004).

	% area applied at each volume range							
	Fungicide		Growth regulator		Herbicide		Insecticide	
Crop(s)	>200 l/ha	>500 l/ha	>200 l/ha	>500 l/ha	>200 l/ha	>500 l/ha	>200 l/ha	>500l/ha
Brassicas etc.	96.5	5.7	-	-	88.5	5.8	95.1	7.6
Root crucifers	96.0	12.4	-	-	73.6	5.6	96.4	25.8
Peas and beans	38.7	0.0	-	-	49.8	0.6	53.2	0.0
Onions and leeks	79.6	0.8	93.6	3.6	77.5	0.8	76.2	0.7
Carrots, parsnips, celery	98.9	8.8	100.0	0.0	95.9	2.1	95.9	6.9
Lettuce, endive etc.	98.3	5.6	-	-	95.9	4.1	100.0	8.0
Sweetcorn	-	-	-	-	86.2	1.5	82.2	0.0
Beetroot	75.4	0.0	-	-	37.9	1.9	92.1	1.0
Cucurbitis	97.9	27.1	-	-	99.5	3.4	100.0	0.0
Other outdoor vegetables	89.3	0.0	-	-	92.0	1.0	81.5	1.2

Applications at these volumes are extremely unlikely to produce standing bodies of spray liquid on the ground. Table 4 illustrates the depth of spray liquid that would be found on the surface after application at different volumes assuming no drainage into the soil (impervious surface). Also illustrated is the depth that would occur should all the spray liquid run off and accumulate in a smaller area (e.g. in a hollow or a plant leaf).

Table 4. Depth of spray liquid that would form on an impervious surface after spraying at a range of spray volumes. Also shown is the depth that might be expected should spray liquid accumulate in a smaller area (e.g. in the base of a hollow).

	Depth of spray liquid on the surface (mm)		
Application rate l/ha	As applied (over 100% of area)	Assuming accumulated in 10% of area	Assuming accumulated in 1% of area
1000	0.1	1	10
900	0.09	0.9	9
800	0.08	0.8	8
700	0.07	0.7	7
600	0.06	0.6	6
500	0.05	0.5	5
400	0.04	0.4	4
300	0.03	0.3	3
200	0.02	0.2	2
150	0.015	0.15	1.5
100	0.01	0.1	1
75	0.0075	0.075	0.75
50	0.005	0.05	0.5
25	0.0025	0.025	0.25
10	0.001	0.01	0.1
5	0.0005	0.005	0.05
4	0.0004	0.004	0.04
3	0.0003	0.003	0.03
2	0.0002	0.002	0.02
1	0.0001	0.001	0.01

Clearly, even in this unrealistic scenario a significant depth of spray liquid such that may form an attractive drinking source to a bird (e.g. at least a few mm deep) could only occur at medium to high application volumes and only then if the spray liquid was channelled into a far smaller area. This would indicate that puddles of spray liquid on the ground are unlikely to form without the addition of more water (e.g. dew, precipitation or irrigation) in which case the resulting water source would be substantially diluted compare to spray liquid.

Approved conditions for application

In the UK best practice such as that described in the 'Voluntary Initiative' (see http://www.voluntaryinitiative.org.uk/Content/Water_BP.asp) should limit the availability of pesticide contaminated surface water. For example the 'Best Practice' stewardship messages relevant to the field are:

- Know your field and take care to avoid spills during transit
- Do not spray if ground is frozen, waterlogged or heavy rain is forecast in the next 3 days
- Respect buffer zones and don't over spray them or watercourses
- Understand LERAP and follow advice sheets
- Use low drift nozzles, check flow rates and avoid conditions where drift can occur
- Spray the middle of the field first and use headlands to spray out tank washings
- Wash the outside of the sprayer in the field
- Don't forget to clean the mud off tyres before leaving the field"

Avoiding spills and not applying to frozen or waterlogged ground, or when rain is due should limit the potential for the formation of contaminated puddles.

Approaches used by other regulators

Risk assessment

The issue of exposure via drinking water and methods of assessing it have been discussed at at meetings of the FIFRA Scientific Advisory Panel (FIFRA 2001). The probabilistic model developed by Fite *et al*. (2001) was presented at the March 2001 meeting of the panel. The model included methods of estimating the water intake of birds using the allometric equations for total daily water flux developed by Nagy and Peterson (1988) adjusted for water in the food to provide an estimate of drinking water requirements. This approach differs from the one in the current guidance document for bird and mammal risk assessment method (Anon 2002) and is discussed further below under Objective 2. The model also included methods for estimating the concentration of pesticide in field puddles and dew on plants that may be drunk by birds. These approaches were generally considered reasonable but suggestions were made about refining the puddle estimates including consideration of rainfall amount, rainfall duration, evaporation, soil infiltration rates, plant cover, temperature, chemical partitioning, chemical degradation, and topography. These were further developed and presented as the 'Puddle Model' in Version 2.0 of the model at the March 2004 meeting of the SAP (see USEPA 2004).

Risk reduction

The main method of risk reduction would be to follow the kind of general 'best practice' approach detailed above to limit the potential for exposure. A more specific example of an area where the risk of exposure via drinking water has affected the way in which pesticides are used is that of application of certain pesticides to vegetable crops in Germany. The incidents involving small birds reported in Shietinger and Hofman (1984) and Hommes *et al*. (1990) led to label instructions that attempt to limit the risk by indicating that pesticides that present a risk to birds should only be applied during early growth stages on vegetable crops for which there was the potential for the formation of pools of contaminated plants on the leaves (Table 5).

Table 5. BBA label codes and decoding for labels relevant to application of spray formulations identified as poisonous to birds to vegetable crops which form pools of water on their leaves.

Code	Decoding
NT6933	The product is poisonous for birds; therefore, use only up to the 16-leaf stage in all vegetables which form pools of water on their leaves (especially headed cabbage, kale and lettuce) or under crop or bird protection nets.
NT6934	The product is poisonous for birds; therefore, use only up to the 16-leaf stage in all vegetables which form pools of water on their leaves (especially headed cabbage, Brussels sprouts and lettuce) or under crop or bird protection nets.
NT6937	The product is poisonous for birds; therefore, use only up to the 16-leaf stage in all vegetables which form pools of water on their leaves, and do not sprinkle on the day of application; this restriction is not applicable if crop or bird nets are used.

Hommes *et al* (1990) list the following as compounds that were covered by the requirement at the time of writing; chlorfenvinphos, dimethoate, endosulfan, heptenophos, methamidophos, methomyl, mevinphos, oxydemeton-methyl, parathion, pirimicarb, pirimiphos-methyl and propoxur.

Potential for exposure via drinking water

Drinking from directly contaminated puddles or waterbodies

The above calculations indicate that puddles formed by spray liquid alone are very unlikely given the application volumes. However, it is possible that under some conditions existing puddles or water bodies may be oversprayed, although spraying in such a way or under such conditions would not be good practice. Should existing bodies of water be sprayed, given the spray volumes used, it is likely that any water of sufficient depth to be attractive as a drinking source would lead to substantial dilution. Theoretical dilution factors for different application rates and depths of water are shown in Table 6.

Table 6. Calculated dilution factors for different depths of water and application volumes based on data in Table 4 above.

App. rate l/ha	Dilution factors for existing water bodies/puddles of depth:							
	30cm	15cm	10cm	5cm	2.5cm	1cm	0.5cm	1mm
1000	3000	1500	1000	500	250	100	50	10
900	3333	1667	1111	556	278	111	56	11
800	3750	1875	1250	625	313	125	63	13
700	4286	2143	1429	714	357	143	71	14
600	5000	2500	1667	833	417	167	83	17
500	6000	3000	2000	1000	500	200	100	20
400	7500	3750	2500	1250	625	250	125	25
300	10000	5000	3333	1667	833	333	167	33
200	15000	7500	5000	2500	1250	500	250	50
150	20000	10000	6667	3333	1667	667	333	67
100	30000	15000	10000	5000	2500	1000	500	100
75	40000	20000	13333	6667	3333	1333	667	133
50	60000	30000	20000	10000	5000	2000	1000	200
25	120000	60000	40000	20000	10000	4000	2000	400
10	300000	150000	100000	50000	25000	10000	5000	1000
5	600000	300000	200000	100000	50000	20000	10000	2000

Estimated concentration would be determined by dividing the spray concentration by the dilution factor listed e.g., at 200l/ha an existing puddle of depth 1cm would lead to a 250 fold dilution of the original spray concentration (spray concentration/250). This is likely to be a very worst case estimate as the active ingredient may be broken down or bind to the substrate. While it is possible that puddles may evaporate and concentrate the active, degradation may reduce the impact of this. Also, where plants are present, interception of spray would reduce the amount reaching the ground.

It may also be possible that a puddle would form after application due to dew, rainfall or irrigation. It would be possible to estimate the concentration in the same way, assuming that all of the product on the area covered by water is dissolved into it. In this case it seems even less likely that the calculated concentration could be achieved due to initial drainage into soil, binding to substrate and degradation.

Where a more realistic estimate of concentration is required it may be more useful to use methods that take account of factors such as precipitation, soil type, degradation etc. such as the puddle model developed for use by the EPA (USEPA 2004).

One potentially higher risk might be the formation of puddles (e.g. following precipitation) at sites of spillage (e.g. during loading of granules/treated seeds/pellets) or locally high concentrations of product due to poor application. However, at least in the UK this type of event is not considered in risk assessment. Another possibility is the formation of puddles of spray liquid while filling application machinery that may occur in farmyards. Again, leaving such spills available for birds to drink would be against best practice as they should be cleared up immediately.

Drinking from spray drift or run-off contaminated puddles or waterbodies

The presence of spray drift or run-off contaminated water bodies is perhaps the most likely scenario and is obviously considered in aquatic risk assessment. For water bodies it would seem appropriate to use the methods for determining the PEC for aquatic studies. For existing puddles away from the main field it may be appropriate to use the spray drift estimates (e.g. 2.7% of application rate) and depth of puddle to estimate concentration. While the most likely, the dilution factor in larger water bodies is likely to reduce exposure far below levels that may lead to acute poisoning in birds that drink from them. Also, some water bodies such as ditches may not be very attractive drinking sites for birds due to their steep sides.

Drinking from plants after spraying

This scenario seems to be the one that presents the most risk based on the incidents that have occurred in Germany (Schietinger and Hofman 1984, Hommes *et al*. 1990), albeit under a very specific set of circumstances. Here birds were apparently poisoned during dry periods in late summer when they drank from contaminated puddles, which had formed on cabbage plants. Hommes *et al* (1990) measured the volume of these puddles and dewdrops that formed on the plants. Puddles ranged in size from 0.5ml to 71.1ml with a mean of 20 ml, and a 95% value of 49.5ml. Concentration of pesticide in the puddles was also measured following applications at a volume of 600l/ha. These ranged from 0.8% to 22% of the original spray concentration with a mean of 11%. Based on this the authors suggested the use of a dilution factor of 5 as a worst-case estimate of puddle concentration. Measurement of residues over time indicated a rapid decline in residue. Mean concentration by day 1 was 19% of day 0 levels falling to 5.4% by day 3 and 3.2% by day 4. This suggests that for many compounds the risk may be short term. Thus, while it is clear that puddles containing spray material can form on plants, in most cases the residues appear to be much lower than the initial spray liquid concentration and may only present a risk for a short period.

Assessment of risk under UK conditions

While certain sets of conditions may suggest that risk could occur such as oversprayed puddles, spraying waterlogged or frozen ground, application under these conditions would not be considered good practice and may therefore not be considered in risk assessment. The one set of conditions that are known to have caused incidents in Germany where contaminated water has collected in the leaves of cabbage plants was very specific and followed a long dry period such that the plants were attractive as a water source. This may be a particular risk where plants are irrigated following application. In this example birds may have actively sought the treated field as a source of water rather than drinking incidentally as they fed. Combined with active ingredients of relatively high toxicity and concentrations up to 20% of spray concentration it is perhaps not surprising that incidents occurred among small birds. These were mostly seedeaters or omnivores and may therefore have had the highest need for drinking water. It is possible that risk may be reduced at high concentrations if birds find contaminated water repellent although this clearly did not occur in the German incidents.

OBJECTIVE 2: REVIEW METHODS USED TO ESTIMATE THE DRINKING WATER REQUIREMENTS OF BIRDS AND IDENTIFY ANY IMPROVEMENTS THAT COULD BE MADE TO CURRENT GUIDANCE.

Current approaches for estimating drinking water intake

The above section indicates that conditions that could lead to exposure to pesticide-contaminated water may be rare. However, should conditions arise for which an assessment is required it would be necessary to estimate the degree of exposure based on data on the drinking requirements of birds.

The current approach to assessing the water intake of birds (Anon 2002) is to use the allometric equation for water ingestion developed by Calder and Braun (1983) based on data from Calder (1981) and Skadhauge (1975).

$$\text{Total water ingestion rate (l/day)} = 0.059W^{0.67}$$

Where W is the body weight in kg.

However, a bird can obtain water from other sources (Table 7) and the relative amounts obtained from each will be different for different species and diets. For example birds feeding on large quantities of succulent food will have far less need for drinking water than one that is feeding on dry seeds.

Table 7. Water intake and loss in birds.

Water in	Water out
Water in food Metabolic water Drinking water	Faeces Pulmocutaneous evaporation

A far more useful approach would be to use data on the total daily water influx and combine this with data on preformed water in the diet and metabolic water production to determine how much water a bird would need to drink to achieve water balance.

e.g. Drinking water (g/d) = Total water influx – [Food water + Metabolic water]

This type of approach was suggested by Fite *et al*. (2001) as part of their probabilistic model to assess acute lethal risk to birds. They proposed using an allometric equation for water influx rate (WIR) in birds in the field developed by Nagy and Peterson (1988) using data on water influx from doubly labelled water (DLW) studies on free-living birds:

$$\text{Daily water influx rate (ml)} = 1.180 \times BW^{0.874}$$

where BW is the bodyweight in grams. They then assume that a bird in water balance obtains a portion of its water from its food (calculated from the estimated food intake and the fractional water content of that food) with the remaining need met by drinking. However, this method takes no account of metabolic water. Nagy and Peterson (1988) themselves indicate that water is gained from (1) external sources and (2) metabolic processes. Also, the allometric equation used is one developed for passerines and so may not be suitable for other species (Table 8).

Table 8. Nagy and Peterson (1988) allometric equations for water flux in birds. Equations have the form $y = ax^b$ where y is the predicted water flux (ml/day) and x is the bodyweight (in g).

			95% CI of predicted water flux as % of predicted	
Category	a	b	lower	upper
In captivity	0.874	0.694	-78	+350
In field	1.369	0.694	-78	+350
Passerines	1.180	0.874	-73	+270
Carnivores	0.981	0.746	-86	+630
Desert birds	0.944	0.676	-77	+340
Seabirds	0.270	0.902	-88	+730

Estimates of drinking water requirements based on WIR – (metabolic water + food water) have been made in previous studies (e.g. Weathers and Stiles 1989).

Improved estimates of drinking water requirements

As described above an improvement to current methods of estimating drinking water requirements would be to use the appropriate allometric equations for water flux developed by Nagy and Peterson (1988) and combine these with estimates of food water and metabolic water production to predict daily drinking water requirements. Methods of estimating food water content and metabolic water production are described below along with a comparison of the results with the current method in the mammals and birds guidance document.

Water in food

To determine how much of a birds daily water requirement might obtained from its food it is necessary to determine how much food is eaten in a day and combine this with the fractional water content. Methods for estimating food intake have already been developed (Crocker *et al*. 2002) based on daily energy expenditure (DEE) estimates from allometric equations, energy contents of different foods and assimilation efficiency (see Crocker *et al*. 2002 for equations and necessary data). Data on the moisture content of foods is used to calculate the wet weight daily food requirements. The best approach would therefore be to use the output of these calculations to determine the amount of water that may be obtained from food.

e.g. Food water (g) = Daily food intake (g) x Fractional water content

For a mixed diet it would be necessary to calculate the water content for each type and sum to estimate total daily food water intake.

Metabolic water

Different food constituents (fats, proteins, carbohydrates) produce different amounts of water when metabolised (Table 9).

Table 9. The relationship between energy and water produced when various classes of food materials are oxidized to CO_2, and that proteins go as far as urea (adapted from Edney and Nagy 1976).

Food	g water per g food	kJ per g food	g water per kJ
Carbohydrates	0.56	17.58	0.032
Fats	1.07	39.94	0.027
Proteins	0.40	17.54	0.023

While different foods yield different amounts of water per g of food metabolised, these differences are reduced when the water produced per kJ is considered. This would also simplify the calculation of metabolic water produced as it could be estimated directly from the estimate of DEE. In the absence of detailed information about the relative amounts of carbohydrate, fats and proteins in a given food it may be appropriate to use a mean value (0.0273 g water/kJ) or, more conservatively, the lowest value (proteins 0.023 g water/kJ).

e.g. Metabolic water production (g) = DEE (kJ) x 0.023 (g/kJ)

Alternatively, it would be possible to estimate metabolic water production from daily food intake provided energy content, fractional water content and assimilation efficiency are known.

e.g. metabolic water (g) = DFI x [1 – FWC] x AE x EC x MWP

where:
DFI = Daily food intake (g wet weight)
FWC = Fractional water content of food (unit less proportion)
AE = Assimilation efficiency (unit less proportion)
EC = Energy content of food (kJ/g dry weight)
WP = Metabolic water production (g/kJ see above)

Comparison with existing method

The above method was used to estimate drinking water requirements for birds between 5g and 500g feeding on either cereal seeds (13.3% water content), arthropods (70.5% water content) or dicotyledonous crop leaves (88.6% water content). The allometric equations for passerines from Crocker *et al*. (2002) and Nagy and Peterson (1988) were used to estimate DEE and WIR respectively. Metabolic water was estimated as 0.023 g/kJ. The same calculations were made using the current method (Anon 2002) for comparison and the results are shown in Figure 1.

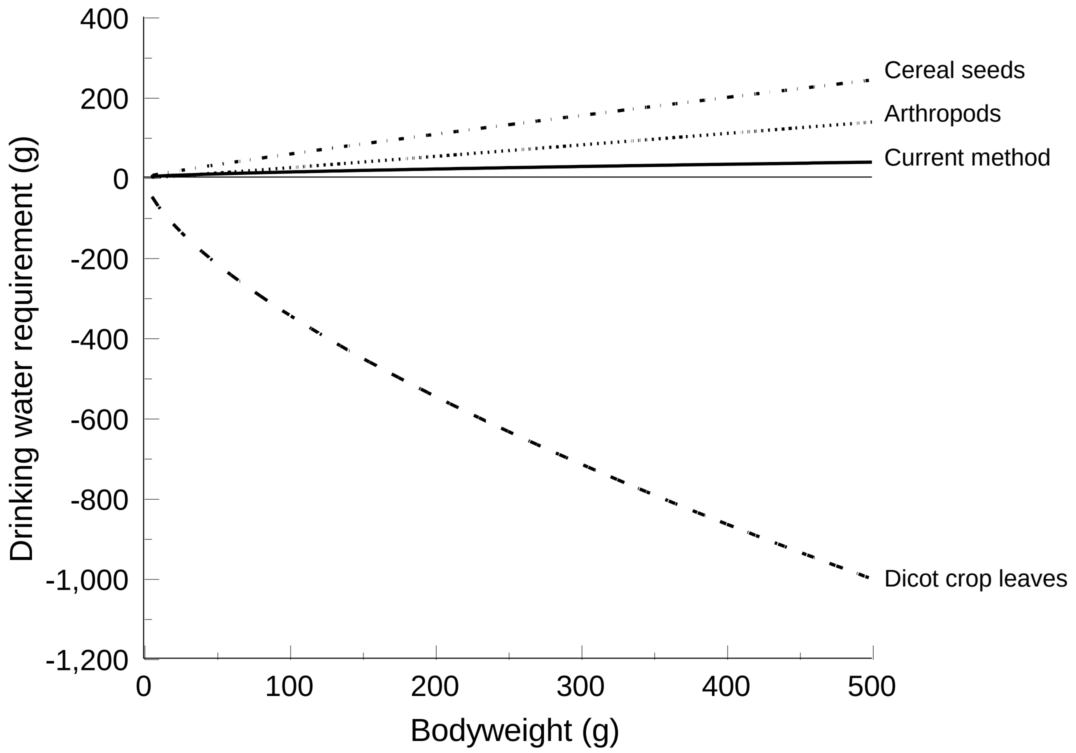

Figure 1. Comparison of estimates of drinking water requirements for birds feeding on different diets using the Nagy and Peterson equations, estimates of food water and metabolic water production. The results using the current method in the mammals and birds guidance document are also shown.

This indicates that the current method would overestimate the drinking water requirements for birds feeding on dicotyledonous crop leaves, and underestimate the requirements for birds feeding on cereal seeds. The comparison with birds feeding on arthropods seems more complex, at least for the estimate of food water content used here (Figure 2).

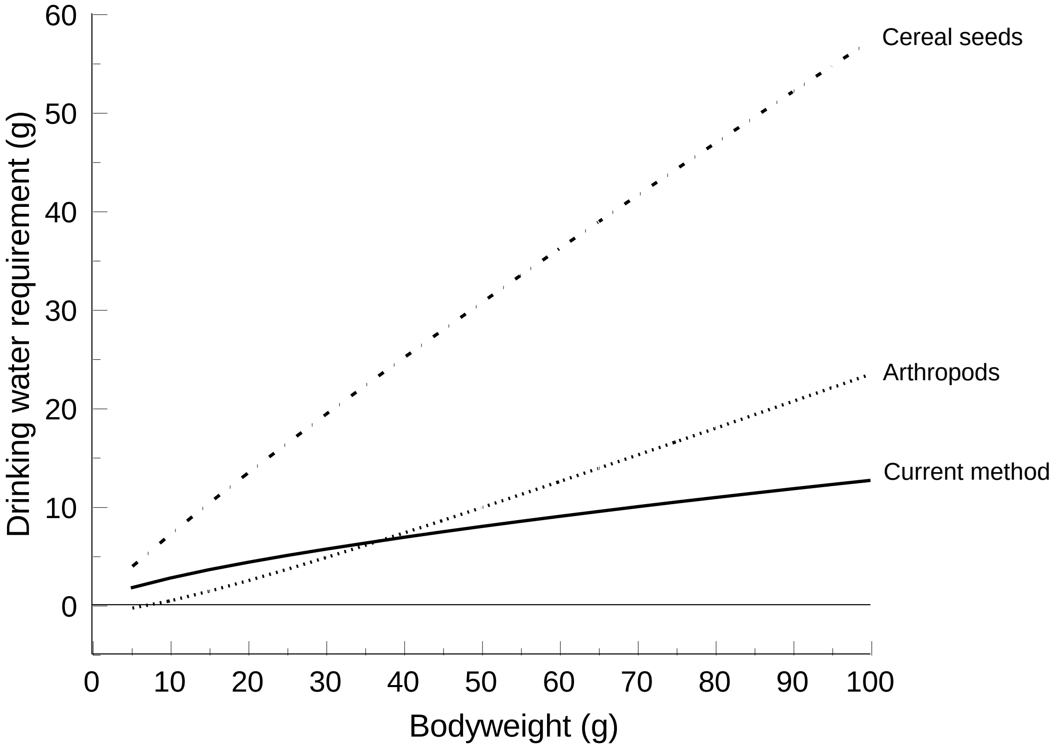

Figure 2. Comparison of estimates of drinking water requirements for small birds feeding on cereal seeds or arthropods using the Nagy and Peterson equations, estimates of food water and metabolic water production. The results using the current method in the guidance document are also shown.

For birds around 35 to 40g in weight, both methods give similar results. However, for smaller birds the current method would overestimate drinking water requirements, while for larger birds it would provide an underestimate.

Estimating drinking water intake of birds in the UK

Available data for UK species

While allometric equations are useful, the ones developed by Nagy and Peterson (1988) were developed from a wide range of species, few of which are found in the UK, and even fewer that are relevant to risk assessments for pesticides. It would be far more satisfactory to use WIR values from DLW studies on species found in the UK. A search of the literature revealed there was little published data on WIR from DLW studies on species found in the UK that are relevant for risk assessment as most studies were on non-UK species or seabirds. The data that was obtained is shown in Table 10.

Table 10. Reported WIR from published DLW studies on species found in the UK.

Species	Mass (g)	WIR (g/d)	Reference	Notes
Field studies				
Leach's petrel	45.6	25.1	Montevecchi *et al* (1992)	some time at sea
Leach's petrel	48	2.9	Ricklefs *et al*. (1986)	incubating eggs
Leach's petrel	48	21.8	Ricklefs *et al*. (1986)	away from nest
Northern gannet	3210	475.1	Birt-Friesen *et al*. (1989)	
Marsh harrier	661.5	172.7	Riedstra *et al*. (1998)	female nestlings
Marsh harrier	529.2	144.0	Riedstra *et al*. (1998)	male nestlings
Turnstone	108. 4	96.6	Piersma and Morrison (1994)	Incubating (arctic)
Kittiwake	386	124.0	Gabrielsen *et al*. (1987)	breeding
Skylark	33.6	23.6	Tieleman *et al*. (2004)	breeding
Woodlark	27	16.4	Tieleman *et al*. (2004)	breeding
Pied flycatcher	14.3	9.9	Moreno and Sanz (1994)	breeding females
Wheatear	24.3	20.4	Moreno (1989)	nesting
Coal tit	9.5	3.6	Moreno *et al*. (1988)	winter
Crested tit	11.07	4.5	Moreno *et al*. (1988)	winter
Willow tit	11.31	4.9	Moreno *et al*. (1988)	winter
Starling	85	62.7	Ricklefs and Williams (1984)	females incubating stage
Starling	78.7	77.7	Ricklefs and Williams (1984)	females early nesting stage
Starling	74.1	79.7	Ricklefs and Williams (1984)	females middle nestling stage
Starling	76.9	80.3	Ricklefs and Williams (1984)	males middle nesting stage
Captive studies				
Cormorant*	2122	235.7	Keller and Visser (1999)	Phalacrorax carbo sinensis*
Canada goose	3650	278.0	Nagy and Peterson (1988)	
Mallard	1190	158.0	Nagy and Peterson (1988)	
Partridge	161	41.1	Nagy and Peterson (1988)	
House sparrow	23.43	9.3	Williams (1985)	
Starling	69.76	39.9	Williams (1985)	

* continental race

Of these only the passerines, ducks and geese are likely to feature regularly in UK risk assessments for pesticides. Given this, it will be necessary to rely on allometric equations to estimate drinking water requirements in most cases. To determine how closely estimated values match those obtained directly, measured values for the most relevant species were compared with estimated values using Nagy and Peterson (1988) equations (Table 11).

Table 11. Comparison of measured WIR and estimated WIR using Nagy and Peterson (1988) equations for the most relevant species. All estimates are based on equations derived from DLW studies with free-living birds.

Species	Mass (g) [x]	Measured WIR (g/d)	Nagy equation	a	b	Estimated WIR (g/d) [WIR = ax^b]	Measured WIR as % estimated
Field							
Skylark	33.6	23.6	Passerine	1.180	0.874	25.5	92.7
Woodlark	27.0	16.4	Passerine	1.180	0.874	21.0	78.0
Pied flycatcher	14.3	9.9	Passerine	1.180	0.874	12.1	81.8
Wheatear	24.3	20.4	Passerine	1.180	0.874	19.2	106.2
Coal tit	9.5	3.6	Passerine	1.180	0.874	8.4	42.6
Crested tit	11.1	4.5	Passerine	1.180	0.874	9.6	46.6
Willow tit	11.3	4.9	Passerine	1.180	0.874	9.8	49.4
Starling*	76.6	79.2	Passerine	1.180	0.874	52.3	151.5
Captive							
Canada goose	3650.0	278.0	Field (all)	1.369	0.694	406.1	68.5
Mallard	1190.0	158.0	Field (all)	1.369	0.694	186.6	84.7
Partridge	161.0	41.1	Field (all)	1.369	0.694	46.6	88.3
House sparrow	23.4	9.3	Passerine	1.180	0.874	18.6	50.0
Starling	69.8	39.9	Passerine	1.180	0.874	48.2	82.7

* mean value from Table 10 excluding data from incubating females

All measured values clearly fall within the wide 95% confidence intervals described in Table 8 (average for all field species was 81.1% of the estimated value) providing some confidence in the estimates as the UK species for which data is available do not seem to fall at the extremes of the distribution of values. Field values for all species measured during the breeding period (all except the tit species) showed a close correlation with estimated values except for starlings where measured values exceeded estimates by over 50%. For these species it may be appropriate to use the measured values in any assessment. Those species measured during winter (coal tit, crested tit and willow tit) had measured values around 40-50% of estimated values. In these cases it would be more conservative to use the estimated value unless a winter scenario is specifically being assessed.

As expected measured values in captivity were all below the estimates particularly for the house sparrow and it is most appropriate to use estimated values for these. The measured value for captive starlings was close to the estimated value but around half of the measured value in the field.

Given the paucity of data for UK species and the reasonable agreement between measured and estimated values it seems reasonable to use estimated values for other species and measured values where we have them (e.g. starlings). Using these methods it is possible to estimate drinking water requirements for the scenarios listed in Crocker *et al*. (2002) to indicate which species/food type combinations present the greatest risk of exposure via drinking water (Table 12).

Table 12. Results of calculations of drinking water requirements for a range of scenarios based on DEE and food intake estimates from Crocker *et al* (2002) and WIR estimated from Nagy and Peterson (1988). Metabolic water estimates are based on DEE and the most conservative estimate of water production (0.023 g/kJ). Shaded lines indicate scenarios where drinking is required to achieve water balance. For non-passerines the overall equation for all birds based on field studies was used to estimate WIR.

Food	English	Species	Body weight (g)	Equation	WIR (g/d)	Food water (g)	Metabolic water (g)	Drinking water (g/d)	Drinking as % WIR
Aquatic invertebrates	Dipper	*Cinclus cinclus gularis*	101.0	Passerine	66.6	69.5	5.9	-8.8	-13.2
	Mallard	*Anas platyrhynchos*	1082.0	Field	174.6	217.7	24.1	-67.1	-38.4
Aquatic vegetation	Mallard	*Anas platyrhynchos*	1082.0	Field	174.6	690.3	24.1	-539.8	-309.1
Arthropods	Chaffinch	*Fringilla coelebs*	20.9	Passerine	16.8	12.2	2.0	2.7	15.8
	Corn bunting	*Miliaria calandra*	43.9	Passerine	32.2	20.6	3.3	8.3	25.7
	Goldcrest	*Regulus regulus*	5.7	Passerine	5.4	4.9	0.8	-0.3	-5.9
	Great spotted woodpecker	*Dendrocopus major*	81.6	Field	29.0	20.0	3.3	5.8	20.0
	Grey partridge	*Perdix perdix*	381.0	Field	84.6	68.8	10.8	5.1	6.0
	Lapwing	*Vanellus vanellus*	211.0	Field	56.2	69.3	6.8	-20.0	-35.5
	Nuthatch	*Sitta europaea*	22.0	Passerine	17.6	12.7	2.0	2.9	16.3
	Pheasant	*Phasianus colchicus*	953.0	Field	159.9	139.7	21.8	-1.6	-1.0
	Rook	*Corvus frugeligus*	488.0	Passerine	264.0	112.2	18.0	133.8	50.7
	Skylark	*Alauda arvensis*	37.2	Passerine	27.8	18.3	2.9	6.6	23.6
	Starling*	*Sturnus vulgaris*	82.0	Passerine	55.5	35.9	6.0	13.7	24.6
	Tree sparrow	*Passer montanus*	22.0	Passerine	17.6	12.7	2.0	2.9	16.3
	Wren	*Troglodytes troglodytes*	8.9	Passerine	8.0	6.7	1.1	0.2	2.5
	Yellowhammer	*Emberiza citrinella*	26.5	Passerine	20.7	14.5	2.3	3.9	19.0
Birds	Sparrowhawk	*Accipiter nisus*	149.0	Field	44.1	31.2	5.2	7.8	17.6
Bugs	Blue tit*	*Parus caeruleus*	11.5	Passerine	10.0	9.9	1.5	-1.4	-14.2
Carrion	Buzzard	*Buteo buteo*	781.0	Field	139.3	94.7	18.7	25.8	18.5
	Crow	*Corvus corone corone*	570.0	Passerine	302.4	111.6	20.0	170.7	56.5
Caterpillars	Blue tit*	*Parus caeruleus*	11.7	Passerine	10.1	15.1	1.5	-6.5	-63.9
Cereal seeds	Corn bunting	*Miliaria calandra*	43.9	Passerine	32.2	1.6	3.3	27.2	84.6
	Grey partridge	*Perdix perdix*	381.0	Field	84.6	6.7	10.8	67.1	79.3
	Pheasant	*Phasianus colchicus*	953.0	Field	159.9	13.7	21.8	124.4	77.8
	Rook	*Corvus frugeligus*	488.0	Passerine	264.0	9.0	18.0	237.0	89.8
	Tree sparrow	*Passer montanus*	22.0	Passerine	17.6	1.0	2.0	14.5	82.7
	Woodpigeon	*Columba palumbus*	490.0	Field	100.8	7.1	13.1	80.7	80.0
	Yellowhammer	*Emberiza citrinella*	26.5	Passerine	20.7	1.2	2.3	17.2	83.2
Dicot crop leaves	Skylark	*Alauda arvensis*	37.2	Passerine	27.8	199.2	2.9	-174.3	-626.2
	Woodpigeon	*Columba palumbus*	490.0	Field	100.8	885.8	13.1	-798.1	-791.9
Earthworms	Blackbird	*Turdus merula*	113.0	Passerine	73.5	99.7	6.4	-32.6	-44.4
	Buzzard	*Buteo buteo*	781.0	Field	139.3	264.3	18.7	-143.8	-103.2
	Lapwing	*Vanellus vanellus*	211.0	Field	56.2	118.0	6.8	-68.6	-122.2
	Starling*	*Sturnus vulgaris*	82.0	Passerine	55.5	89.4	6.0	-39.8	-71.7
Fish	Goosander*	*Mergus merganser*	1440.0	Field	213.0	298.0	45.1	-130.2	-61.1
	Heron	*Ardea cinerea*	1443.0	Field	213.3	195.0	30.1	-11.8	-5.5
	Kingfisher	*Alcedo atthis*	27.0	Field	13.5	9.3	1.4	2.8	20.6
Fruit buds	Bullfinch	*Pyrrhula pyrrhula*	21.8	Passerine	17.4	56.1	2.0	-40.6	-232.9

Food	English	Species	Body weight (g)	Equation	WIR (g/d)	Food water (g)	Metabolic water (g)	Drinking water (g/d)	Drinking as % WIR
Monocot leaves	Canada Goose	*Branta canadensis*	3314.0	Field	379.8	1090.1	57.2	-767.5	-202.1
	Greylag Goose	*Anser anser*	3108.0	Field	363.2	1037.4	54.4	-728.5	-200.6
	Mallard	*Anas platyrhynchos*	1082.0	Field	174.6	459.2	24.1	-308.7	-176.8
Oilseed rape grain	Linnet	*Carduelis cannabina*	15.3	Passerine	12.8	0.6	1.6	10.6	83.2
Slugs & snails	Lapwing	*Vanellus vanellus*	211.0	Field	56.2	123.1	6.8	-73.7	-131.3
	Song thrush	*Turdus philomelos*	66.6	Passerine	46.3	71.7	4.4	-29.9	-64.5
Small mammals	Barn Owl	*Tyto alba*	294.0	Field	70.7	50.0	8.8	11.9	16.8
	Kestrel*	*Falco tinnunculus*	209.0	Field	55.8	54.1	8.5	-6.8	-12.1
	Little owl	*Athene noctua*	164.0	Field	47.2	31.8	5.6	9.7	20.6
	Tawny Owl	*Strix aluco*	426.0	Field	91.5	66.6	11.7	13.1	14.3
Top fruit	Blackbird	*Turdus merula*	113.0	Passerine	73.5	185.3	6.4	-118.2	-160.9
	Song thrush	*Turdus philomelos*	66.6	Passerine	46.3	127.7	4.4	-85.9	-185.4
Tree seeds	Great spotted woodpecker	*Dendrocopus major*	81.6	Field	29.0	1.2	3.3	24.6	84.7
	Nuthatch	*Sitta europaea*	22.0	Passerine	17.6	0.6	2.0	14.9	84.8
Weed seeds	Chaffinch	*Fringilla coelebs*	20.9	Passerine	16.8	0.7	2.0	14.2	84.2
	Goldfinch	*Carduelis carduelis*	15.6	Passerine	13.0	0.6	1.6	10.9	83.5
	Linnet	*Carduelis cannabina*	15.3	Passerine	12.8	0.5	1.6	10.7	83.4

* Species for which DEE was derived from published values rather than allometric equations.

The results of the above calculations indicate that those animals feeding on plant material such as crop leaves, aquatic vegetation and top fruit can obtain more than their daily water requirements from their food. For birds feeding on invertebrates the picture is somewhat more mixed. Feeding on earthworms, slugs, snails, bugs and caterpillars provides sufficient water while for species feeding solely on other arthropods, up to 50% of water requirements may need to be obtained from drinking. As might be expected, the worst case is found for those species feeding on seeds where up to 90% of water requirements may need to be satisfied by drinking. While this exercise is useful for identifying those species that may be at most risk, it must be remembered that this is a very simplistic example which considers only one food type in the diet. Considering a more realistic mixed diet may change the estimated water requirements for a species considerably. Also, while seedeaters in this example appear to have dramatically higher water requirements, this is based on the water content of dry seeds. At some stages they may feed on seeds in the ‘milky’ state where moisture content may be far higher than the 13.3% value used here for cereal seed.

Patterns of drinking

It would seem sensible to assume that water is taken incidentally from treated areas pro rata with food based on the fraction of diet obtained from the treated area (PT) so this may be used as a starting point to determine how much contaminated water may be drunk. However, evidence from earlier incidents (e.g. Hommes *et al*. 1990) indicates that conditions can exist where the treated area becomes a more important source of water during dry periods due to irrigation or collection of dew on plants. In this case it is possible that a far larger proportion of the daily requirements would be taken from the treated area. As a worst-case initial estimate of exposure, the assumption that all water is taken from the treated area may then be reasonable, refining this if calculated exposure causes concern. Conversely, it is possible that the treated area provides no obvious suitable sources of drinking water.

Limitations of the method

This method of estimating drinking water requirements provides a useful indication of those species/food type combinations that present the most risk. However, the lack of actual WIR data for most of the UK species that might be considered in risk assessment leads to a heavy reliance on published allometric equations which have limitations in providing accurate values as follows:

- The estimates are based on the existing Nagy and Peterson equations developed from data for a broad range of species, very few of which are found in the UK. The mean estimates of drinking water provided by these equations may not always be robust indicators of drinking water requirements for UK species as in most cases we do not know where these fall in the distribution of WIR values for a given bodyweight. For example, birds from arid environments have far lower WIR values than those from temperate regions (e.g. Tieleman *et al* 2004).

- Similarly the food water and metabolic water estimates for those species where mean energy requirements are based on the allometric equations may underestimate the water available to the bird due to feeding alone if actual energy demands are higher.

- The nature of DLW studies means that the data used to develop these equations would have been collected for only one short period at one part of the year. For example, many of these studies are on breeding birds as discussed in Crocker *et al*. (2002) and so may not be good indicators of water requirements at other times of year.

- The estimates of drinking water requirements assume that all of the water in the food is extracted by the birds which may not be the case. This becomes most important where birds are feeding on drier foods where actual drinking requirements may be even larger than estimated. However, where food contains large amounts of water such as plant material birds should be capable of achieving water balance without extracting all of the water present.

- Estimates of food water content are likely to be worst case for seeds as the data are based on ripe dry seed at harvest whereas birds may be at least partly feeding on ‘milky’ seeds (e.g. linnets feeding young) with a much higher water content. This would clearly reduce the need for drinking water.

- Estimates of water content for invertebrates, plant material, carrion etc. may be best case as they are most likely based on fresh material in good condition. In dry periods water content may be less (e.g. wilted leaves) or food may be at least partially desiccated (e.g. dead or dying invertebrates, old carcasses).

One of the main issues is that the equations for WIR were developed by Nagy and Peterson several years ago when DLW studies that reported WIR were relatively scarce. Several DLW studies have been conducted since this study that provide estimates of WIR for a much wider range of species. If these methods of estimating water intake are to be used on a regular basis it would be extremely useful if the data produced since this period could be included in the analysis to broaden the applicability of the data and allow improved estimation of worst case values much as was achieved for DEE estimation to allow improved estimates of food intake in project PN0908.

OBJECTIVE 3. RECOMMENDATIONS FOR IMPROVEMENTS TO RISK ASSESSMENT PROCEDURES.

The above findings suggest that with best practice the availability of pesticide contaminated drinking water of sufficient concentration to cause acute poisoning should be low and this appears to be supported by the lack of confirmed incidents (although poisoning by drinking would be difficult to detect and small birds are less likely to be found). However, one set of conditions has been demonstrated to present a significant risk based on the incidents in Germany, and has caused several large incidents involving small birds. It is not clear how likely such an event would be in the UK as it involved specific high risk pesticides on crops that could form large puddles on the leaves, combined with climatic conditions that made the crop an attractive source of drinking water. The risk was short lived due to the rapid decline in residue. The BBA changed label instructions to prevent this from recurring and this might be one option should such a risk be considered likely.

It has also been shown that the current method of estimating drinking water requirements is unsatisfactory as it does not accurately predict the water requirements of free living birds or take account of other sources of water such as water in the food or metabolic water. This means that for some situations it will overestimate drinking water requirements (for herbivores) or underestimate them (e.g. seedeaters). The proposed method based on (a) the Nagy and Peterson equations, (b) food intake and food moisture content information from Crocker et al.(2002), and (c) estimated metabolic water production should address some of these issues although the allometric equations may need updating.

Despite the possibility that the risk of formation of contaminated puddles may be low, it may occasionally be necessary to consider the possibility during risk assessment. The following section indicates how simple estimates could be made and provides examples of the risk posed by combinations of application rate and toxicity for a puddle of a given depth to a small bird feeding on different diets. It must be remembered that these are very simplistic point in time estimates and do not take account of the many factors that could affect the concentration either immediately after application, or over time. For a more refined estimate it would be necessary to consider these factors by using a method such as the puddle model being developed by the EPA.

The final section provides recommendations about how the risk from drinking water could be assessed and suggestions for further work.

Assessment of risk from contaminated puddles

If the risk presented by a contaminated puddle is to be considered, a simple calculation of predicted concentration can be made and combined with estimated drinking requirements to estimate the TER. For a given spray liquid concentration, the concentration in a puddle can be estimated from the dilution factors in Table 6. For application rates of active substance (kg/ha), puddle concentration can be estimated using:

$$\text{Concentration (mg/ml)} = \text{Application rate (kg/ha)}/(100 \times \text{depth (cm)})$$

Exposure can be calculated as:

$$\text{ETE} = \frac{\text{Drinking water requirement (ml)} \times \text{Concentration (mg/ml)}}{\text{Bodyweight (kg)}}$$

Estimated TER for a range of application rates and toxicity values for a 25g passerine feeding on cereal seeds with a daily drinking water requirement of 16.56 ml/day is shown in Table 13. Estimated TER for a range of application rates and toxicity values for a the same size bird feeding on arthropods with a daily drinking water requirement of 6.90 ml/day is shown in Table 14.

Table 13. Relationship between application rate, toxicity and TER for a puddle concentration assuming a 10mm deep puddle containing all a.i. applied and a 25g seed eating bird with a daily drinking water requirement of 16.56 ml. Shaded cells indicate TER < 10.

Application rate (kg/ha)	Toxicity (LD50 mg/kg)							
	10	25	50	100	250	500	1000	2000
0.05	30.2	75.5	151.0	302.0	755.1	1510.1	3020.2	6040.5
0.1	15.1	37.8	75.5	151.0	377.5	755.1	1510.1	3020.2
0.25	6.0	15.1	30.2	60.4	151.0	302.0	604.0	1208.1
0.5	3.0	7.6	15.1	30.2	75.5	151.0	302.0	604.0
1	1.5	3.8	7.6	15.1	37.8	75.5	151.0	302.0
1.5	1.0	2.5	5.0	10.1	25.2	50.3	100.7	201.3
2	0.8	1.9	3.8	7.6	18.9	37.8	75.5	151.0
2.5	0.6	1.5	3.0	6.0	15.1	30.2	60.4	120.8
3	0.5	1.3	2.5	5.0	12.6	25.2	50.3	100.7
3.5	0.4	1.1	2.2	4.3	10.8	21.6	43.1	86.3
4	0.4	0.9	1.9	3.8	9.4	18.9	37.8	75.5
4.5	0.3	0.8	1.7	3.4	8.4	16.8	33.6	67.1
5	0.3	0.8	1.5	3.0	7.6	15.1	30.2	60.4

Table 14. Relationship between application rate, toxicity and TER for a puddle concentration assuming a 10mm deep puddle containing all a.i. applied and a 25g bird feeding on arthropods with a daily drinking water requirement of 6.90 ml. Shaded cells indicate TER < 10.

Application rate (kg/ha)	Toxicity (LD50 mg/kg)							
	10	25	50	100	250	500	1000	2000
0.05	72.5	181.2	362.3	724.6	1811.5	3623.1	7246.2	14492.3
0.1	36.2	90.6	181.2	362.3	905.8	1811.5	3623.1	7246.2
0.25	14.5	36.2	72.5	144.9	362.3	724.6	1449.2	2898.5
0.5	7.2	18.1	36.2	72.5	181.2	362.3	724.6	1449.2
1	3.6	9.1	18.1	36.2	90.6	181.2	362.3	724.6
1.5	2.4	6.0	12.1	24.2	60.4	120.8	241.5	483.1
2	1.8	4.5	9.1	18.1	45.3	90.6	181.2	362.3
2.5	1.4	3.6	7.2	14.5	36.2	72.5	144.9	289.8
3	1.2	3.0	6.0	12.1	30.2	60.4	120.8	241.5
3.5	1.0	2.6	5.2	10.4	25.9	51.8	103.5	207.0
4	0.9	2.3	4.5	9.1	22.6	45.3	90.6	181.2
4.5	0.8	2.0	4.0	8.1	20.1	40.3	80.5	161.0
5	0.7	1.8	3.6	7.2	18.1	36.2	72.5	144.9

While these estimates apply to a very narrow range of conditions in terms of puddle depth etc., they provide some indication of where the combination of application rate and toxicity present a risk.

It must be remembered that these estimates assume that all of the applied pesticide over a given area is available in the drinking water and that the birds obtain all of their drinking water from the treated area (PT=1 for drinking water). For other values of PT the TER estimates would be scaled up by dividing by the PT value (e.g. TER = [worst case TER]/PT). Similarly if a dilution factor is to be applied such as the factor of 5 described in the mammals and birds guidance document the TER can be adjusted accordingly (e.g. TER = [worst case TER] x 5).

Exposure scenarios

The following are the exposure scenarios for birds described in the current mammals and birds guidance document (Table 15).

Table 15. Indicator bird species for crops/stages from the birds and mammals guidance document (adapted from Anon 2002).

Crop	Crop stage	Indicator species	Example
Grassland	-	Large herbivorous bird – 3000g	Goose
		Insectivorous bird – 10g	Wren, tit
Cereals	Early	Large herbivorous bird – 3000g	Goose
		Insectivorous bird – 10g	Wren, tit
	Late	Insectivorous bird – 10g	Wren, tit
Leafy crops	Early / late	Medium herbivorous bird – 300g	Partridge, pigeon
		Insectivorous bird – 10g	Wren, tit
Orchard / vine / hops	Early / late	Insectivorous bird – 10g	Wren, tit
Seed treatment	-	Granivorous bird – 15g	Linnet

The estimated drinking water requirements of the indicator species are shown in Table 16.

Table 16. Estimated drinking water rate (DWR) for indicator species of bird in the birds and mammal guidance document (Anon 2002).

Indicator species	Example	Body weight	Food type	FIR (fresh weight)	Moist-ure	Food water	WIR (Table 8)		Metabolic water*	DWR**	$\frac{\text{DWR}}{\text{bw}}$
		(g)		(g/day)	(%)	(g)	Equation	WIR (g/day)	(g)	(g/day)	
Medium herbivorous bird	Partridge /pigeon	300	Non-grass herbs	227.8	82.1	187.0	Field	71.7	8.9	None required	-
Large herbivorous bird	Goose	3000	Grasses, cereal shoots	1322	76.4	1010.0	Field	354.4	53.0	None required	-
Insectivorous bird	Wren	10	Arthropods	10.33	70.5	7.28	Passerine	8.83	1.17	0.38	0.04
Granivorous bird	Linnet	15	Cereal seeds	5.82	13.3	0.77	Passerine	12.58	1.55	10.26	0.68

* estimated from DEE using a conversion value of 0.023 g water/kJ

** DWR = WIR - [Food water] - [Metabolic water]

This indicates that herbivorous birds are unlikely to require drinking water while feeding on plant material and so an assessment of exposure via this route would not be necessary. This would leave insectivorous and granivorous birds as appropriate for each scenario. This could be done on the basis of the above crop/species combinations but given the known risk to granivorous birds drinking from some leafy crops (Hommes et al 1990) it would be appropriate to consider these species as well where it is considered that the crop could provide an attractive source of drinking water (e.g. following irrigation during dry weather). Suggested drinking water exposure scenarios and notes on how exposure could be estimated are provided in Table 17.

Table 17. Suggested drinking water scenarios based on the food intake scenarios but excluding those species/crop combinations that are unlikely to lead to a need to drink from the treated area (PT_{food} is the value of PT used for estimation of dietary exposure, C_{puddle} is the estimated concentration in an over-sprayed puddle of given depth e.g. 1cm).

Crop	Crop stage	Indicator species	Example	Source	Notes
Grassland	-	Insectivorous bird – 10g	Wren, tit	Puddles	Use PT_{food} to adjust daily intake and C_{puddle}
Cereals	Early	Insectivorous bird – 10g	Wren, tit	Puddles	Use PT_{food} to adjust daily intake and C_{puddle}
	Late	Insectivorous bird – 10g	Wren, tit	Puddles	Use PT_{food} to adjust daily intake and C_{puddle}
Leafy crops	Early / late	Insectivorous bird – 10g	Wren, tit	Puddles^a	Use PT_{food} to adjust daily intake and C_{puddle}
		Granivorous bird – 15g	Linnet	Leaf puddles^b	Use PT = 1^c Use C = (spray concentration)/5^d
Orchard / vine / hops	Early / late	Insectivorous bird – 10g	Wren, tit	Puddles	Use PT_{food} to adjust daily intake and C_{puddle}
Seed treatment	-	Granivorous bird – 15g	Linnet	Puddles	Use PT_{food} to adjust daily intake and C_{puddle}

[a] during normal conditions if treated crop should be no more attractive to birds as a drinking source than normal foraging areas.

[b] assuming dry periods when irrigation makes treated crop attractive as a source of drinking water.

[c] assuming treated crop is the main source of water.

[d] based on Hommes et al (1990).

The use of PT_{food} to adjust daily drinking water intake assumes that drinking is incidental while the bird is feeding on the field and is in direct proportion to the amount of food taken there. Clearly if the availability of water on the treated field is higher than in surrounding areas this may underestimate exposure. This would seem to be most likely following irrigation rather than rainfall (unless soil conditions increase the likelihood of puddle formation) and under these circumstances the field may become an attractive water source to other species. Again, it may be more appropriate to consider granivorous birds as a worst case using PT = 1.

Where evidence or opinion suggests that granivorous birds may also be present on treated fields it may be more appropriate to consider drinking from puddles for these species rather than insectivores. Again an appropriate value of PT for these species should be used if available.

Estimation of exposure (ETE)

Exposure can be calculated as:

$$ETE = \frac{(DWR \times C \times PT \times 1000)}{bw}$$

Or

$$ETE = (DWR/bw) \times C \times PT \times 1000$$

(This approach is similar to that described above (Assessment of risk from contaminated puddles) except that a simple DWR/bw factor is not used.

Where:

DWR = Drinking water rate (g/d)
C = Concentration (mg/ml)
PT = Proportion of water obtained from treated area
bw = Bodyweight (g)
1000 = Adjusts units to mg/kg

For an oversprayed puddle:

$$C = [\text{Application rate (kg/ha)}/(100 \times \text{depth (cm)})] \text{ mg/ml}$$

(or see Table 6 for dilution factors)

For a puddle formed on a leaf:

$$C = [(\text{Spray concentration (mg/ml)}) / 5)] \text{ mg/ml}$$

Recommendations

Where estimates of the risk of exposure via drinking water are required it is necessary to estimate drinking water requirements and concentration in the water. While methods for estimating concentration fall outside the scope of the current project, the findings allow some suggestions of how estimates could be made.

Estimation of drinking water requirements.

- It is recommended at this stage that drinking water estimates should be based on estimates of WIR from DLW studies combined with estimates of water in food and metabolic water production as described above. This provides a more realistic estimate of drinking water requirements than the existing method that takes no account of the differences in water content of different diets.
- Where WIR estimates from studies on the species of concern are available, these should preferably be used in any risk assessment.
- Where WIR estimates for the species of concern are not available, estimates should be based on the appropriate allometric equation.

Note: This study reports estimates based on the allometric equations for WIR from Nagy and Peterson (1988) and DEE equations from Crocker et al.(2002). However, these equations have now been updated in Project PS2330 and it is recommended that these updated equations are used in future assessments.

Estimation of concentration in drinking water.

- Simple estimates of concentration can be made from spray liquid concentration (where direct consumption is considered possible), or a combination of spray liquid concentration or application rate and the depth of water in the drinking source being considered (e.g. 10mm deep puddle). Where these simple estimates indicate a risk then more refined estimates could be made as follows:

- Puddles on fields: Consider using the EPA puddle model (USEPA 2004) which takes account of factors such as run-off, rainfall, soil type etc.

- Leaf puddles: Use the worst-case dilution factor of 5 for the spray concentration as developed by Hommes *et al* (1990).

- Other water bodies: Use existing estimates (e.g. for spray drift, run-off etc.) from aquatic risk assessments.

Note: Methods for the calculation of exposure concentrations for a puddle scenario are now available in the EFSA scientific opinion on the science behind the guidance document on risk assessment for birds and mammals (EFSA (2008) Scientific Opinion of the Panel on Plant protection products and their residues on a request from the EFSA PRAPeR Unit on risk assessment for birds and mammals. The EFSA Journal 734:1-181).

Consideration of associated risks

- Where pesticide contaminated water is available to birds they may also be exposed dermally by walking through the water or bathing in puddles, and orally following preening. The potential for exposure via these routes should also be considered

Future work

Given the relative lack if actual measured WIR values for UK species and the large number of DLW studies conducted since the late seventies when the existing allometric equations for water flux were developed, it is recommended that these are updated to include this new information in line with those currently used to estimate DEE and food intake.

Note: This work has now been completed as part of Project PS2330 and updated equations for WIR and DEE are now available for use in risk assessment.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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