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**RESEARCH ARTICLE**

# AGRICULTURAL LAND COVER STRUCTURE RATHER THAN CROP-FIELD SIZE DETERMINES CORN CONSUMPTION BY EASTERN WILD TURKEY *MELEAGRIS GALLOPAVO*– STABLE ISOTOPE EVIDENCE

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**ABSTRACT**

Eastern Wild Turkey is considered a corn pest across its range despite lack of solid evidence. Analyses of $\delta^{13}C$ and $\delta^{15}N$ isotopes in EWT feather tissues and food sources were used to test influence of key land cover features on EWT assemblage and corn consumption within 3 focal regions across farmlands of south-eastern Quebec, using Mixing Model tools and 3-year fall and winter observation datasets from 29 sites. Mean EWT abundance was highest in the most structurally heterogeneous Asbestos region (50.5±6.2).Contribution of corn to EWT diet was influenced by forest cover proportion ($R^2$ = 0.650, p = 0.046) but not crop-field size. Accordingly, most corn was consumed across the most forested Dunham region. Although crop-field size strongly influenced EWT abundance ($R^2$ = 0.451, p < 0.016) it was unrelated to corn consumed indicating EWT's non-attraction to corn. Conversely, total road network length negatively affected EWT corn consumption ($R^2$ = -0.764, p = 0.033) suggesting impact of hunter traffic.$C_3$ plants were the most important food source for adult EWT while juveniles mostly consumed invertebrates. In conclusion, EWT consumed corn only opportunistically when corn neighboured forest, and are potentially more important as natural pest controllers rather than as corn pests.



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## INTRODUCTION

Eastern Wild Turkey *Meleagris gallapavo silvestris* (Viellot 1817) is a generalist feeding Phasianidbird that ranges across agricultural landscapes throughout much of North America (US Department of Agriculture, 1999; Thorgmartin, 2000; Hughes *et al*., 2007). Across its range the species majorly occurs in habitats in which farmlands are interspersed with considerable cover stands of non-closed mature hardwood, pine or mixed forest and open country with at least some proximity to water bodies (US Department of Agriculture, 1999; Miller *et al*., 2000). Such a diverse spatial matrix within its range helps to ensure optimal conditions for the species' generalist and opportunistic foraging requirements while also providing habitat diversity necessary for roosting, nesting, rearing of young and refuge from predators (Thorgmartin, 2000; Hughes *et al*., 2007). Within these habitats, Eastern Wild Turkey, hereafter, EWT, forages variously on vegetation material such as tree acorns, beechnuts, berries, cherries or mast; fruits, leaves and seeds of various woody plants, grasses, ferns, herbaceous plants, grains and other crops (Vangilder and Kurzejeski, 1995; Yarrow, 2009). In addition, in forest edges, crop-fields, field margins, pasture land and open fields as well as water edges and along streams, EWT flocks may wander widely while foraging for various invertebrates such as grasshoppers and crickets (Orthoptera); beetles (Coleoptera); spiders (Aranea); snails and slugs (Gastropoda) or vertebrate prey like frogs and salamanders (Amphibia), or rodents (Muridae) (Humberg *et al*., 2009). To meet their water needs, the birds also make occasional use of nearby spring seeps, streams, lakes, ponds, rivers, dams or other artificial open water sources like livestock troughs. Although EWT generally wanders freely and widely along its habitat, flock sizes and home ranges vary with season. Smaller flocks of 5-20 birds during spring and summer when food is abundant, diverse and widely available across the foraging range (Hughes *et al*., 2007; Yarrow, 2009) while larger flocks of up to 100 birds may be formed during fall and winter when food is scarce, with clumped distribution (Badyaev *et al*., 1996). Type and range of food items consumed also varies among the age groups. For

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instance poults (young chicks) predominantly feed on insect and other small invertebrate sources that are both rich in protein for faster growth needs and also small enough to be easily ingested, while adults mainly consume plant food but occasionally also larger animal prey such as salamanders, tadpoles, frogs and rodents in addition to insects, snails, earthworms and millipedes (Thorgmartin, 2000; Yarrow, 2009). Adults tend to prefer more pine acorns, beechnuts and mast just before winter as these are rich in energy and helps to sustain them during the food-scare and harsh winter period (Yarrow, 2009). The mean EWT home range varies between 1.2-4.0 $km^2$ though in early summer small groups may wander over a distance as far as 15 km (Badyaev *et al*., 1996). Mature hens tend to range wider than gobblers (adult males) especially in early summer when the former have to guide poults through open habitat such as pastures, crop-fields or edge habitat to obtain invertebrate food (Lehman *et al*., 2003; Yarrow, 2009). Agricultural intensification in temperate regions characteristically involves agronomic practices that include reduction of natural habitat cover and use of pesticides which substantially reduces abundance of arthropods and other macro-invertebrate fauna across the crop-fields (Radford and Bennett, 2007; Dobrovolski *et al.,* 2011).

Such degradation makes the agricultural landscapes largely unsuitable for the foraging needs of most ground- and invertebrate-feeding birds (Radford and Bennett, 2007) instead attracting graniviorous and omnivorous species many of which may constitute crop pests. For omnivorous birds, it might even be expected that they would exhibit behavioural diet shifts to become more dependent on crops either with increase in crop-field cover or during periods when the invertebrate food sources are limiting from insecticide use (Riley *et al*., 2014). In the case of EWT for instance, there is a common perception amongst farmers throughout North America that the species is a serious corn pest during summer and early spring, and several of anecdotal reports exist in support of the claim (Miller *et al*., 2000; New York Bureau of Wildlife, 2005; Ontario Department of Natural resources, 2012). Such claims are founded on two main facts. Firstly, EWT are often more easily observed foraging in many small groups widely dispersed across cornfields during summer when they have to range wider in order to diversify food sources and enable poults to obtain invertebrate food abundant that are mostly abundant in such open areas as croplands (US Department of Agriculture, 1999).

During this time, EWT adults may consume wasted corn seeds left on the ground surface after being dug out by rodents, crows or pheasants; leaves of stalks knocked down by raccoons or deer; or grains or corn ears dropped by blackbirds, ground hogs or squirrels. This might give the impression that EWT is heavily dependent on and destructive of corn while in fact most of the actual vertebrate pests are seldom encountered since they mainly forage nocturnally (Yarrow, 2009). Secondly, during the winter when food is often scarce, EWT may at times gather in larger flocks than during other seasons, so as to take advantage of locally abundant food, including wasted grain on cornfields, that is otherwise distributed in widely-dispersed clumps(Easton, 1992). Such conspicuous flocks might also give the impression of strong dependence on corn for food. No observational evidence exists, however that EWT destroys corn at any stage in its growth, nor is there a clear understanding of species' level of dependence on corn as a source of food. Conventionally, studies on composition of a consumer's diet would involve capture of individuals and intrusive sampling to examine contents of its stomach or crop (Peterson, 1970).Apart from their destructive nature, such a technique would still only yield results that are applicable to a limited or localised geographical and time span, with no reflection of the full range of actual foraging dynamics typical of such a widely ranging opportunistic feeder as EWT (Easton, 1992). As a solution, analyses of $\delta^{13}C$ and $\delta^{15}N$ stable isotope signatures in the bird's tissues provides a means for more accurately tracking the range of food sources they consume, their origin as well as an evaluation of contributions of the various food sources to the consumer's diet (Rubenstein and Hobson, 2004). A study of trophic relations using the stable isotope analysis (SIA) starts with establishment of a baseline isotopic ratios of food sources, which refers to the ratios of isotopes of $\delta^{13}C$ ($^{13}C/^{12}C$), $\delta^{15}N$ ($^{15}N/^{14}N$) or $\delta^{34}S$ ($^{34}S/^{32}S$) in the original food source, such as a primary producer (Post, 2002; Woodcock *et al*., 2012).

The isotopic signatures essentially derive from the standard empirical equation: $\delta^{n}X = [(R_{sample}/R_{standard} - 1)]*1000$ where $\delta^{13}X$ is the parts per thousand difference (‰) between the $^{n}X$ isotope in the sample and that in the standard; $R_{sample}$ is the ratio of heavier to the lighter isotope of the element carbon, $R_{standard}$ = the ratio of the heavier to the lighter isotope in the standard (Fry, 2006). These ratios, expressed as parts per thousand (‰)are relative values based on comparison to known standard values (Post, 2002; Fry, 2006). Based on these baseline ratios (baseline "iso-scapes") isotopic signatures of these elements can then be tracked up the trophic levels by correcting for known and empirically predictable incremental values, or trophic enrichment factors (TEF) that represent a change in ratio from food source to consumer (Post, 2002; Caut *et al*., 2010). For instance $\delta^{15}N$ is useful in determining trophic positions of consumers because its TEF increases by an average of 3.40‰ while $\delta^{13}C$ is useful in distinguishing various primary producer (plant) food sources and with an average of increment of 0.45‰ (Fry, 2006; Ferger *et al*., 2013). Subsequently, appropriate statistical mixing model analysis techniques may be applied to integrate the various combinations of $\delta^{13}C$ and $\delta^{15}N$ signatures so as to identify various food sources in consumer diets and to quantify contributions from the various sources to the consumer diet by factoring in the corresponding TEFs (Phillips and Gregg, 2003; Bond and Jones, 2009).

The SIA technique, is a more advantageous option for tracking trophic relations in ecological systems for a number of reasons. First, it is more robust in being less intensive because it relies on smaller sample size than traditional sampling and field observation methods (Post, 2002; McKechnie, 2004). Secondly, its mechanistic approach to sample assessment provides more reliable analytical results (McKenchnie, 2004; Pokrovsky, 2012). Thirdly, it provides a more time-integrated measure of energy fluxes across trophic levels because dietic isotope levels remain stable once assimilated into organic tissues (McKechnie, 2004; Fry, 2006; Ferger *et al.,* 2013). However, efficient application of the technique requires that various basic food sources should have isotope ratios or ranges that are distinct enough to allow their tracking through the food chains or webs with reasonable precision (Hobson, 1999; Birkhofer *et al*., 2011). Therefore the objectives of the study were to 1) assess assemblage patterns of EWT on the various farms across the three focal regions during the period from 2010 to 2012; 2) assess relative cover proportions of cornfields, forest and other key landscape elements across the study sites; 3) use analyses of $\delta^{13}C$ and $\delta^{15}N$ stable isotope signatures to determine relative contribution of corn in the diet of EWT; and 4) evaluate relative roles of the various agricultural land cover elements on contribution of corn in the diet of EWT, so as to test if consumption of corn by EWT is influenced by relative sizes of crop-fields or forest cover across the landscape. We expected that as crop-field sizes s increase relative to forest cover, EWT would consume more corn. Conversely, we also expected that if the landscape is predominated by other non-agricultural anthropogenic cover features, EWT dispersal and access to corn food would be limited.

The study is significant in a number of ways. Firstly, although EWT is commonly cited by farmers across North America as a significant corn pest during the spring and summer seasons with most damage complaints referring to seeds (newly planted) and grain (period from ear-head formation to harvest), no evidence exists that EWT either damages or is strongly dependent on corn as a food source. Second, perceived damage to corn or other crops by EWT might be associable to a range of alternative herbivorous wild vertebrates which share the same habitat with EWT, including many small and large mammals; pheasants or other non-game birds like crows and blackbirds (Hvenegaard, 2011) many of which may consume corn right from germination stage through ear formation to maturity. The results of the study contribute to elucidation and evaluation of the scale of this perceived problem through application of stable isotope analytical procedure. Third, this is the first study using stable isotope analysis for determining contributions of major food items in EWT diet and is expected to contribute significantly to application of this robust evidence-based method in the understanding avian trophic dynamics across agro-ecosystems not only in North America but also with potential for application in Africa where use of the technique is still limited.

## METHODS

### *Study area*

The study was based on three distinct local focal regions or sectors across an intensively-farmed agricultural landscape in south-eastern region of Quebec Province, with the regions selected along a gradient of relative forest-cropfield cover sizes. The first focal region, Asbestos, at which there were 11 bird capture sites, is located in the Estrie area between 45°39'15"-45°50'46"N and 72°13'30"-71°44'02"W. The region which also includes the mining town of Asbestos and encompasses part of Nicolet River, had an intermediate or moderate overall proportion of forest cover. The second focal region, Dunham which forms part of Brome-Missisquoi Regional County Municipality, lies between 45°04'47"-45°14'28"N and 72°51'33"-72°34'03"W had 10 capture sites and the highest overall forest cover and least density of built-up area; while the third region Huntingdon, located within the Montérégie area in the Haut-Saint-Laurent Regional County Municipality between 45°02'54"-45°09'38"N and 74°26'10"-74°06'11"Whad 8 capture sites (see Fig 1).

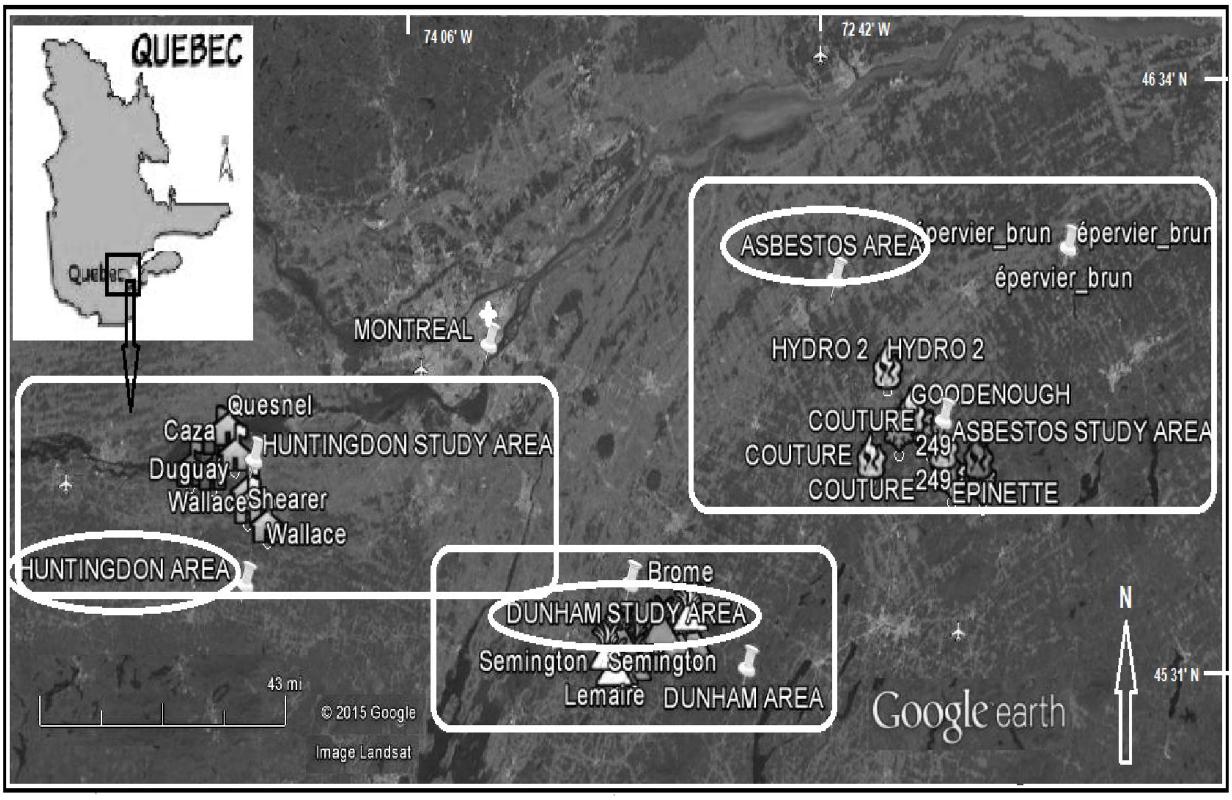


**Fig. 1**. **Map of study area location showing the cluster of sampling sites (farms) within each of the three focal regions**

The average summer and winter temperatures in southern Quebec are 20°C and -8°C, respectively though temperatures may drop to as low as -26°C in February, while mean annual precipitation is 450 mm in the summer and 350 mm in rain and snow equivalent (Brown, 2010). The weather is continental, with four seasons varying from hot summers (June to August) to cold, snowy winters and lots of rain between late December and early March. The whole of southern Quebec is a region of fertile soils of the lowland which supports a robust agricultural economy, forestry and dairy industry. Large-scale intensive farming landscapes typically comprises of cornfields, soybean fields, pastures, farm houses, hardwood, mixed or pine forest stands with networks of access roads (Behiels, 2014). In this study, the terms "cornfield" and "crop-field" are used interchangeably most of the times because across the entire area where the study was based, every crop-field in each farm typically also has at least one cornfield, with corn crop planted almost every year.

The three focal regions were suitable for the study for three main reasons. First, they had nearly the same general agricultural landscape or habitat features conducive for EWT foraging characteristics, that is, crop-fields interspersed with forest cover, edge habitat, open fields, water bodies and artificial features such as built up areas. This selection design thereof ore facilitated sampling independence (Zar, 1996). Secondly, the focal regions were far enough from each other to guarantee that despite the wide ranging nature of EWT, there would still be no ranging overlaps or exchange of EWT populations and as such the samples would be effectively unbiased (Sutherland, 1996; Zar, 1996). Thirdly, the sites were in the same climatic region, making datasets ecologically, spatially and statistically comparable (Økland, 2007).

### *Sampling*

Sampling was centered around the three focal regions (Asbestos, Dunham and Huntingdon) at specific sites that were established for routine EWT observations, capture and marking with many of them fitted with telemetry equipment for purposes of monitoring on a parallel project started earlier in 2010 by the Quebec Government's Ministry of Wildlife and Natural Resources. Observation data and capture samples for which the present study were based, were collected during fall and winters of 2010, 2011 and 2012.

### *Assessment of land cover and EWT assemblages*

To characterize landscape structure, sizes of each selected major land cover type were determined around each of the bird capture and observation sites within each focal region. Land cover elements determined were forest cover, total crop-field cover, distance of capture site to nearest forest stand, distance of capture site to nearest water body, total length of linear water bodies, perimeters of non-linear water bodies, total number of water bodies, total length of roads and total number of settlements or clusters of built up areas. These were determined within a radius of 1.3 km around each capture site (Morelli, 2013) from Google Earth areal images generalized for the dates or periods of the observation with resolution averaging3 km eye altitude (Hu *et al*., 2013). Ground-truthing at the Quebec Ministry of Agriculture office confirmed that although cover sizes for other crops changed from season to season, total crop-field and cornfield sizes remained fairly constant during the period of the study while forest sizes never changed during the period considered for this study. The 1.3-km radius ensured no sampling overlaps amongst capture sites that were at least 3 km apart and at the same time covered more than the average daily EWT ranging area of 1,000 acres (5 $km^2$). Sizes of land cover elements were determined by subdividing the circle around the capture site into smaller square grids of 0.1 km using Google Earth Grid tool, from which total number of full squares or those more than half, covering each of the land cover types were counted, and tallied into total area in $km^2$. Sizes or lengths of water bodies were determined using polygon and path tools in Google Earth (Ghobarni *et al*., 2013; Hu *et al*., 2013). The population structure of EWT was deduced from observation data collected from 2010-2012 at the 29 capture sites to which the bird flocks appeared to show regular temporal fidelity, and which thus served as point counts. The information captured included sexes and age as well as movement patterns from telemetry and ringing records.

### *Turkey feather tissues and food source sampling*

Two wing feathers were collected from each of a total of 152 birds on diverse dates during the period between October to February 2010, 2011 and 2012 at the various capture sites across the three focal regions. The feathers were cleaned using clean dry cotton wool dipped in a solution of formalin before being enclosed in paper envelopes which were then sealed to keep them dry and then labelled and kept in waterproof containers for later test for stable isotope signatures. Feather tissues were most suitable for stable isotope tests because unlike blood and muscle, feathers are stable and inert enough after they grow to depict the true signatures of $\delta^{13}C$ and $\delta^{15}N$ stable isotope derived from the diet integrated across all seasons over at least the previous several months for small birds of up to 3 kg and for at least the previous one year for larger birds such as EWT (Rohwer *et al*., 2009; Symes and Woodborne, 2011), and yet not as non-variable as signatures obtainable from bone tissue. Furthermore, as EWT are non-migratory across wide geographic regions, feather tissues reflect accurate diet compositions within the confines of their foraging ranges (Bond and Jones, 2009).

The sampling for food sources for isotope signatures was conducted in 2013 across each of the the three focal regions. For plant food sources, there were only two major categories: plants with the $C_4$ photosynthetic pathway, represented in Quebec only by corn, and those following the $C_3$ photosynthetic pathway, represented by all other plant material including grasses, woody plants and legumes (Osborne *et al*., 2008). These were collected and identified from multiple sites within several farms and from soybean fields, forage fields, forest and field margins including buffer strips. The samples were oven-dried at $60^0$ C for 12 hours to constant mass before being ground under pestle and mortar into powder for analysis of $\delta$ $^{13}C$ and $\delta$ $^{15}N$ isotopes using a mass spectrometer. Invertebrate food sources including ground beetles, grasshoppers, crickets and snails, were sampled using pitfall traps set for 24 hours (Schmidt *et al*., 2006; Karanja *et al*., 2011). Earthworms were sampled using a solution of 40 mg of mustard powder dissolved in 4 litres of water, poured over 50 cm x 50 cm of cleared ground marked out using quad rats (East and Knight, 2010). Whole bodies of arthropods, snails and earthworms (dissected and gutted to remove ingested soil)were then sorted and identified, oven-dried to constant mass, ground into powder and tested for isotope ratios (Girard and Mineau 2012).

### *Analyses*

Data were all analysed for the entire period of sampling and for EWT observation records from 2010 to 2012. Turkey feathers and food sources samples were weighed in a digital balance (5 mg for invertebrate and feather tissue material and 10 mg for plant material) to the nearest 0.01 mg, packed into tin capsules, arranged and labelled in 96-well plates and delivered for analysis. Isotope tests on the samples were conducted at the Stable Isotopes in Nature Laboratory (SINLAB) at the Canadian Rivers Institute (CRI) and the University of New Brunswick in Fredericton, Canada. At the laboratory 0.4 mg and 3.1 mg of animal and plant material, respectively, were combusted in a Carlo Erba NC 2500 Elemental Analyzer and then run through the Finnigan MatDeltaPlus Mass Spectrometer (Thermo Finnigan Bremen, Germany). The resulting isotope ratios were displayed as parts per thousand or per mil (‰) based on reference against the standards belemnite carbonate for δ13C and atmospheric nitrogen for δ15N (Post, 2002). The number of square grids covered by each land cover element with the 1.3 km radii around the sampling points for EWT, were tallied up and the totals expressed in $km^2$ to determine the cover sizes for each of the cover types. These were then converted to proportions of the sampling area. Linear measurements such as total road lengths or waterbody lengths were expressed to the nearest km. Cover proportions of the various land cover elements were then compared amongst the three study sectors/regions.

### *Quantifying food source contributions and applying trophic enrichment factors*

Bayesian mixing model technique (BMM) were used with Stable Isotope Analysis in R (SIAR V4) statistical software, (Parnel, *et al*., 2010; Hopkins and Ferguson, 2012; R Core Team, 2013) to assess relative contributions of the various food sources to the diet of EWT (Fry, 2006; Girard and Mineau, 2011). These models are founded on the isotopic mass balance equation: $\delta_{sample}= [\delta_{sourse1}*f1 + \delta_{source2}*f2 \ldots + \delta_{source}n*fn]$ where $\delta_{sample}$ =isotope ratioin the sample; $\delta_{source}$ = isotope ratio from the first, second to nth source and $f$ is the proportional/fractional contribution of sources 1, 2….n to the sample (Fry, 2006; Girard and Mineau, 2011; Hopkins and Ferguson, 2012). BMM technique in SIAR involves incorporating datasets from isotope signatures of consumers and food sources along with trophic enrichment factors (mean ± SD) for each of the food sources (Hobson and Clark., 1992; Ostrom *et al*., 1996). Incorporation of the TEFs allows the model to estimate proportional contributions of the various food sources into the diet of the consumer (Vanderklift and Ponsard, 2003; Currier, 2007; Hopkins and Ferguson 2012). The model functions on the assumption that a plot of δ15N against δ13C for food sources will create an iso-space polygon within which food sources isotopic ratios will fall (Bod and Jones, 2009). Due to lack of published data on trophic enrichment factors(TEF) for experimental studies specific for EWT, we used the standard mean values for domestic chicken *Gallus gallus domesticus* as presented by Hobson and Clark (1992) for feathers, in order to minimize inaccuracies that would otherwise be associated with applying non-species-specific and non-tissues-specific TEF values (Ferger *et al*., 2013). Similarly, we used other published literature to obtain appropriate TEF values for arthropods, corn and $C_3$ plants as food sources for EWT. Because diet composition of adult EWT are known to be comparatively different from that of juveniles (Easton, 1992) we analysed contributions of the various food sources for the two age groups separately (Zar, 1996). Relative contributions of the various food sources to EWT diet were analysed both by source (food sources) and by group (focal regions).

### *Role of land cover on EWT assemblage and consumed corn*

From observation and census data records, assemblage patterns and population of EWT across the focal regions were assessed for the period between 2010 and 2012 in terms of age and sex structure to deduce abundance and movement patterns within the three individual regions. For the purpose of relationship between land cover and proportion of food sources in EWT diet, both predictor or independent (land cover pattern) and response variable data (proportion of corn in EWT diet) were pooled into 7 hierarchical partition intervals on the basis of actual forest sizes in each bird capture site, the intervals being of 0.5 $km^2$. From these, regression was used to test overall relationship between the various land cover elements and the proportion of corn in EWT diet and determine best predictors of corn amount in EWT diet (Chevan and Sutherland, 1991).

## RESULTS

Of all the land cover features examined, only proportion of forest cover, proportion of overall crop-field cover and total length of road networks had significant bearing on either EWT dispersal patterns or contribution of corn to EWT diet. For instance, forest cover proportion was highest in Dunham and lowest in Dunham region, respectively, with Asbestos in the intermediate (Fig. 2). Conversely, crop-field cover proportion was highest in Asbestos and lowest in Dunham. Asbestos region had the highest total length of road networks followed by Huntingdon while Dunham region had the least, owing to the more irregular and forested terrain (Fig. 3). Distances between landscape features, or from the EWT capture sites to the various features, were not significantly related to contribution of corn to EWT diet. EWT populations were predominated by poults (juveniles) while there were significantly more females than gobblers (adult males) in overall (Table 1) confirming a polygamous social structure (Vande-Haegen *et al.,* 1989). The highest overall and adult abundance was observed in Asbestos region and the lowest in Dunham region. Asbestos also recorded the highest abundance of gobblers while females and juveniles were more liberally distributed across the three focal regions suggesting wider

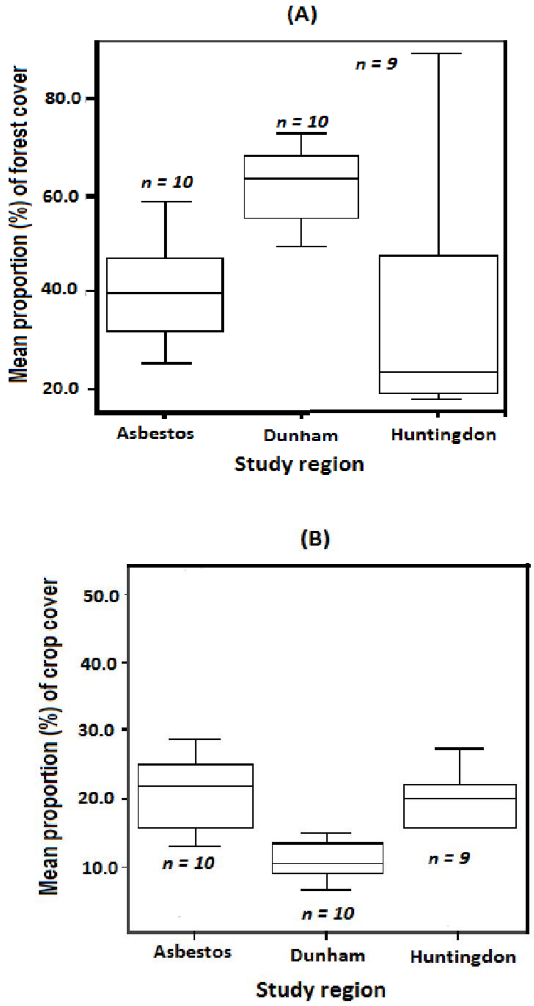


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**Fig. 2**. **Box plotcomparing relative proportions of (A) forest cover and (B) crop-field cover across the three focal regions. Top and bottoms represent the second and third quartiles of total road length frequencies, the horizontal**

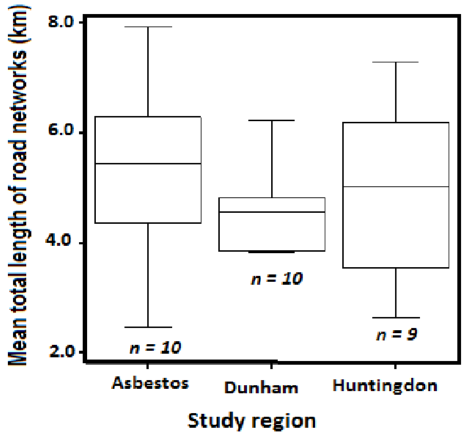


**Fig. 3. Box plot of total road lengths across the three focal study regions**

Overall isotopic ratios of EWT showed no significant bias or trophic dependence on corn as a source of food either age-specifically of across the regions studied. This is because the $\delta^{13}$C isotopic signatures ranged from $\delta^{13}$Cof -24.4 to -18.32 (Table 2) while normal values for corn vary from $\delta^{13}$C of -16.0 to -9.0 (Girard and Mineau, 2011). $C_3$ plant provided the widest variety of food sources for EWT in general across all sites and regions (Fig 4) though juveniles consumed proportionately more invertebrate than vegetation food material as compared to adults (Fig. 4). While $C_3$ plants constituted the most important overall food sources for EWT across all sites and regions, the highest amount of corn was consumed within the Dunham region where proportion of forest cover was highest, but the lowest in Huntingdon region which had the lowest forest cover proportion (Fig. 5). Contribution of corn to EWT diet was influenced positively by the relative proportion of overall forest cover ($R^2$ = 0.650, p = 0.046) see Fig. 6, but negatively by total length of road dispersal with minimal spatial fidelity, even though there were slightly fewer females in the most forested Dunham region (Table 1).

**Table 1. Sightings of EWT sighted during the 2010-2012 observation period, showing the sex and age structures**

| Focal region | Category | Period | | Mean | N | SD |
|---|---|---|---|---|---|---|
| | | 2010/2011 | 2012 | | | |
| Asbestos | Females | 10 | 29 | 19.5 | | |
| | Males | 0 | 19 | 9.5 | | |
| | Juveniles | 24 | 19 | 21.5 | | |
| | Total | 34 | 67 | 50.5 | 15 | 4.71 |
| Dunham | Females | 12 | 13 | 12.5 | | |
| | Males | 7 | 0 | 3.5 | | |
| | Juveniles | 26 | 21 | 23.5 | | |
| | Total | 45 | 34 | 39.5 | 11 | 4.29 |
| Huntingdon | Females | 21 | 18 | 19.5 | | |
| | Males | 2 | 3 | 2.5 | | |
| | Juveniles | 29 | 19 | 24 | | |
| | Total | 52 | 40 | 46 | 10 | 3.26 |
| Overall | TOTAL | 131 | 141 | 136 | 36 | 4.24 |

**Table 2. Summary of mean isotopic ratios of EWT across the three focal regions and between the two age groups**

| Focal region | Age group | $\delta^{13}$C | $\delta^{15}$N | Mean $\delta^{13}$C | Mean $\delta^{15}$N |
|---|---|---|---|---|---|
| Asbestos | Adults | -22.64 | 6.85 | -22.70 SD 2.75; n = 64 | 6.73 SD 1.24; n= 64 |
| | Juvenile | -22.77 | 6.60 | | |
| Dunham | Adults | -22.59 | 5.75 | -22.17 SD 2.73; n = 38 | 6.18 SD 1.90; n = 38 |
| | Juvenile | -21.75 | 6.61 | | |
| Huntingdon | Adults | -19.78 | 6.44 | -19.22 SD 3.04; n = 50 | 6.56 SD 1.01; n = 50 |
| | Juvenile | -18.66 | 6.67 | | |
| Overall | - | | | -21.36 SD 3.04; n = 152 | 6.49 SD 1.34; n = 152 |

networks across the study area ($R^2$ = 0.764, p = 0.033). Conversely, although overall sizes of crop-fields was strongly correlated to EWT abundance across all focal regions, it showed no influence on contribution of corn to the species' diet ($R^2$ = 0.182, p = 0.490).

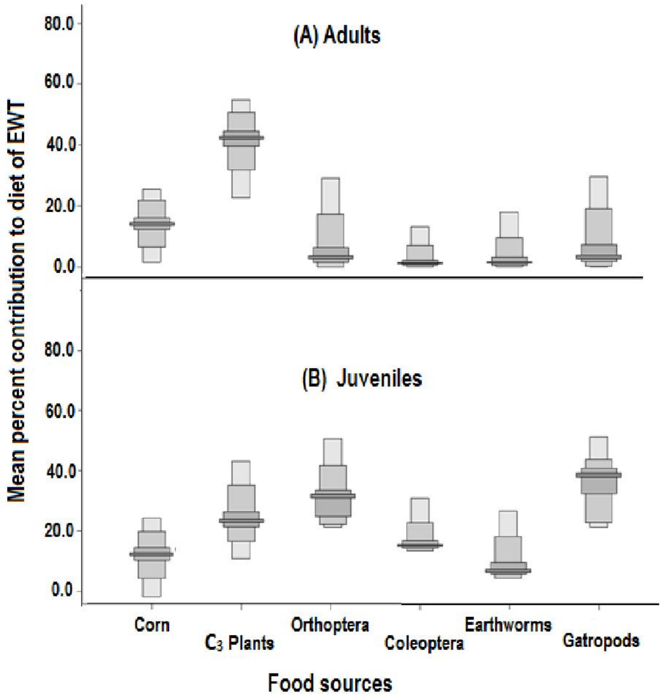


**Fig. 4**. **SIAR proportion plots by food sources comparing relative contributions of various food sources to adult and juvenile EWT diets across all sites and regions. Plots show 5%, 25%, 75% and 95% confidence intervals**

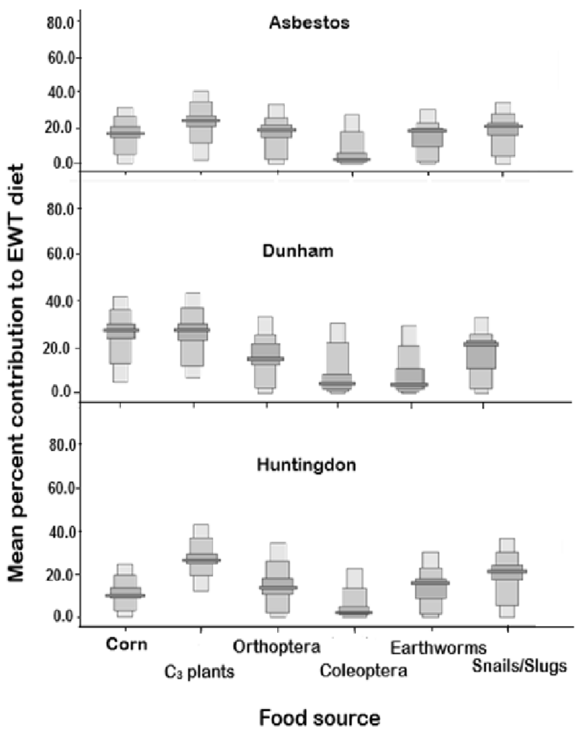


**Fig. 5**. **SIAR proportion plots by sources showing contributions of the various food sources to the diet of EWT across farms in each of the three focal regions. Plots show 5%, 25%, 75% and 95% confidence intervals**

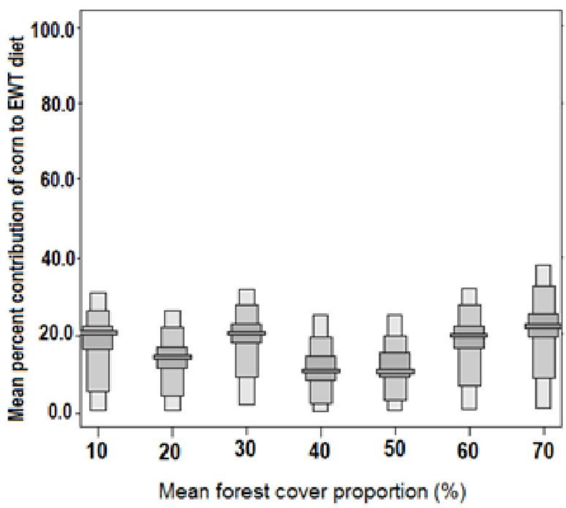


**Fig. 6**. **SIAR proportion plots by group showing influence of forest cover proportion on contribution of corn to the diet of EWT across both age groups. Plots show 5%, 25%, 75% and 95% confidence intervals**

## DISCUSSION

Forests are an important component of the EWT habitat because among other uses, they facilitate dispersal, are used major foraging areas, for breeding, roosting and as refuges from predators in between foraging trips into open crop-fields, edge habitats or watering points (Radford and Bennett, 2007). Due to this multiplicity of uses, the practical importance of forests to EWT is with respect to their arrangement relative to other landscape features rather than by mere sizes (Vangilder and Kurzejeski, 1995; Whittingham *et al*., 2004; Fleming and Porter, 2007). Thus a larger relative proportion of forest across the agricultural landscape interspersed with crop-fields and other open areas, is more favourable to EWT's requirements than a larger contiguous overall forest stand. This is because forest-predominant landscapes with little edge and open habitats pose higher risks of predation and lower reproductive success owing to lower chances of food source diversification (Hughes *et al*., 2007; Humberg *et al*., 2009). For this reason, there was a positive influence of crop-field size on abundance of EWT (Fig. 2B) with most birds observed and frequently encountered in the Asbestos focal region which had the most heterogeneous mosaic of forest cover, crop-fields and other open areas, as compared to Dunham with largest overall forest cover or Huntingdon which was predominated by open habitat.

Landscape structure also had an influence on assemblages of the age and sex groups of EWT. The lower overall abundance of observed adult male compared to adult female birds across the three regions, for instance confirms that polygamous nature of EWT as well as the relatively lower home range of males compared to females (Easton, 1992; Badyaev *et al*., 1996; Thorgmartin, 2000). Similarly, the significantly lower abundance of adult females in the more forested Dunham region, coupled with no difference in abundance of juveniles across the three regions, underscores the patriarchal system in which adult females' play the sole role of guiding the poults by, for instance, spending most time traversing the less forested crop-field where the latter can obtain the necessary invertebrate food (Thorgmartin, 2000; Lehman *et al*., 2003). However, cover proportions of the various land cover features such as water bodies, settlements, roads, forests and crop-fields, from the EWT observation or capture points were not themselves related to EWT assemblages mainly because the species exhibits wide dispersal by foraging groups across the home ranges (Easton, 1992; Fleming and Porter, 2007). In the same way, interspersion distances between of the various anthrpogenic landscape features other than crop-fields did not have any significant bear on EWT abundance or dispersal, implying considerable EWT tolerance of such features. Overall, EWT has a preference for the more heterogeneous landscape mosaics, which enable it to meet all its proximate and ultimate requirements without having to range too widely (Whittingham and Evans, 2004; Fleming and Porter, 2007). This is evidenced by its highest numbers across farms in the most structurally integrated region of asbestos. In terms of the EWT diet, vegetation material constituted the most significant source of food for adults and invertebrates the source of food for juveniles (Fig. 4).

However, the bulk of EWT vegetation food comprised of $C_3$ plants, with very little corn (Fig. 5). The proportionately lower corn in EWT diet compared to $C_3$ vegetation is attributable to two main factors. Firstly, EWT has higher preference for $C_3$ plants compared to corn as a source of food, the latter being reliably available almost year round. This is why despite the much higher abundance of EWT in the more open and larger cropland areas such as in Asbestos and Huntingdon regions, and despite presence of corn in all the regions, there were much lower contributions of corn to EWT diet in comparison to the more forested Dunham region with much higher forest cover proportion relative to open crop-fields (Fig. 5 and Fig. 6). Secondly, more open landscapes are generally unfavourable as habitat for a range of corn pests, mainly small mammals many of which cause considerable damage to corn at various stages in its growth leaving behind much of the plant unconsumed. Since EWT is not known to deliberately destroy corn in order to consume it (Miller *et al*., 2000) and given that the most forested Dunham region contributed most to EWT diet, it is reasonable to infer that much of the corn consumed by EWT was obtained opportunistically from corn parts left behind by the mammal predators which occur there in the largest densities and which proximately use forest as cover against diurnal human disturbance, coming out, as observed by MacGowan *et al*. (2006) and Michel *et al*. (2007) to raid corn nocturnally

Although total length of road networks generally did not have any correlation to EWT assemblage patterns across the study area, it was negatively associated with proportion of corn in EWT diet suggesting that even in the areas where EWT consumed corn, they did so away from roads and paths. This implies a conditioned strategy by EWT to avoid sections of the foraging range that pose higher risk of mortality from hunters who drive through such roads during the annual Turkey hunting season(Whittingham and Evans, 2004; Humberg *et al*., 2009). It might also suggest that most roads used for Turkey hunting do not typically pass through or around cornfields as it is relatively more difficult to sight and stalk the bird in such a closed habitat as compared to the more open legume and livestock forage fields (Casada, 1994).

**Conclusion**

The study shows that EWT prefer more heterogeneous landscapes and are generally tolerant of anthropogenic disturbance although, they avoid regions with greater road networks owing to hunting pressure. They feed predominantly on vegetation food sources, particularly $C_3$ plants in the case of adults with comparatively very little intake of corn which is consumed only opportunistically especially in more forested areas where corn is eaten as left-overs from damage by other vertebrate corn pests. Juveniles consume comparatively less vegetation food, relying more on invertebrate food that is important for early growth. However, although EWT adults eat less invertebrate food compared to juveniles, the combined intake of arthropods, gastropods and possibly rodents by all wandering flocks, potentially make EWT a significant player in natural crop pest control, especially in early spring and early summer when most poults are recruited into the population, coinciding with the critical period of crop growth when plants are most vulnerable to such pests.

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