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**Preventing the Risk to Migratory Birds from Poisoning by Agricultural Chemicals:
Guidance for Countries on the Rift Valley/Red Sea Flyway**



Preventing the Risk to Migratory Birds from Poisoning by Agricultural Chemicals: Guidance for Countries on the Rift Valley/Red Sea Flyway

Migratory Soaring Birds Project

www.migratorysoaringbirds.undp.birdlife.org

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Foreword

Bird migration is an old and well known phenomenon and one of the greatest spectacles of the world. Various migratory species, over years, have developed ways to overcome natural challenges posed by migration. Migration is, for example, an energy-costly activity that places birds under considerable physiological stress. To overcome this migration hurdle, many smaller species of migratory birds accumulate fat in their bodies in the eve of migration. On the other hand, the larger broad-winged birds such as raptors, storks, cranes and pelicans overcome the huge energy demand of migration by soaring on local rising air currents, either those deflected upwards by hills and mountains or hot air thermals formed over land, to provide uplift, circling in such currents to gain height and, where the lift ceases, gliding slowly down until they reach the bottom of another thermal where they repeat the process. Not every landscape, however, can provide such conditions that are supportive to the soaring birds, hence, the birds have identified traditional routes or flyways that provide favourable conditions to optimize migration.

The Rift Valley/Red Sea region provides some of the excellent conditions that support birds' migration such that this flyway is used by about 1.5 million soaring birds annually to move between Eurasia and Africa, making it the second-most important migratory route for soaring birds on earth.

However, it is unfortunate that in the course of migration, birds encounter many risks of which some are anthropogenic in nature. For example, in a number of countries within the Rift Valley/Red Sea region the migration faces risks which primarily emanate from various sectors including hunting, energy, waste management and agriculture. It is in the interest of BirdLife International that, the risks posed by human development are minimized. This vision is shared with a number of countries within the region and multilateral environmental agreements. In a bold step to realize this vision, Birdlife has, with financial support from GEF-UNDP and in coordination with Convention on the Conservation of Migratory Species of Wild Animals (CMS), produced this Guidance targeting reduction of agrochemical poisoning risks along the Flyway. This Guidance seeks to apply part of Resolution 11.15 of CMS COP 11 which aims to prevent poisoning of migratory birds.

It is my sincere hope that the nations, other stakeholders and processes within the Rift Valley/Red Sea region will find value in using this Guidance by integrating the tool in their policies, development strategies and operations, hence, making the region a better place for biodiversity in general, birds and people in particular.

Thank you.

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Our gratitude goes to participants in the *"Agro-chemical Poisoning and Conservation of Migratory Soaring Birds along the Rift Valley/Red Sea Flyway"* workshop which took place in April 2014 in Addis Ababa, Ethiopia and hosted by Ethiopian Wildlife and Natural History Society (BirdLife in Ethiopia), to whom we are greatly indebted.

For those contributors not mentioned here, we take this opportunity to recognize their direct or indirect input in their either big or small but important ways. Their input has added value and merit to this document which is of its first kind for the Rift Valley/Red Sea Flyway.

List of Acronyms

AEWA	African-Eurasian Waterbird Agreement
AR	Anticoagulant Rodenticide
ASP	Africa Stockpiles Programme
CMS	Convention on the Conservation of Migratory Species of Wild Animals
DDT	Dichlorodiphenyltrichloroethane
DEFRA	Department for Environment, Food and Rural Affairs
ECPA	European Crop Protection Association
FAO	Food and Agriculture Organization
FFS	Farmer Field Schools
FGARs	First-generation anticoagulants
GDP	Gross Domestic Product
GEF	Global Environment Facility
IBAs	Important Bird Areas
IPM	Integrated pest management
IRDNC	Integrated Rural Development and Nature Conservation
IUCN	International Union for Conservation of Nature
LGCs	Local Conservation Groups
MOU	Memorandum of Understanding
MSB	Migratory Soaring Birds
NBSAPs	National Biodiversity Strategies and Action Plans
NGOs	Non-Governmental Organisations
NSAIDs	Non-steroidal anti-inflammatory drugs
OECD	Organisation for Economic Co-Operation and Development
PIC	Prior Informed Consent
SGARs	Second-generation anticoagulants

Guidance to Prevent Risk of Poisoning of Migratory Soaring Birds in the Rift Valley/Red Sea Flyway

SpexNPV	Nucleopolyhedrovirus
SPNL	Society for the Protection of Nature in Lebanon
SSPs	Spray Service Providers
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
VICH	Registration of Veterinary Medicinal Products
WWF	World Wide Fund for Nature

Executive summary

There is increasing concern that poisoning – primarily associated with the agricultural sector - is a significant and avoidable cause of mortality for migratory birds. This issue was highlighted at the 11th Conference of Parties to the Convention on Migratory Species (Quito, Ecuador, November 2014), and a conference resolution was adopted on Preventing Poisoning of Migratory Birds (Resolution 11.15). Importantly, the resolution adopted guidelines to prevent the risk of poisoning of migratory birds (UNEP/CMS/COP 11/doc23.1.2, Annex 2).

In the context of this global concern and commitment to take action, and building on the global guidelines adopted by the Contracting Parties to CMS, this report reviews the risks to migratory birds from poisoning associated with the agricultural sector in the Rift Valley/Red Sea Flyway and provides guidance on how poisoning from agricultural chemicals can be prevented in countries on the Rift Valley/Red Sea Flyway.

Whilst all migratory species are affected by poisoning, migratory soaring birds are particularly vulnerable because of their position at the top of the food chain and as long-lived, slow reproducing species through primary and secondary poisoning. Birds that feed during migratory stopovers are more likely to be exposed to pesticides, which is the case for storks, pelicans, cranes, harriers and falcons.

The use of chemicals toxic to birds in the agriculture environment is often related to the protection of crops and livestock. Chemicals are used to protect crops from insect and rodent pests as well as quelea. Livestock are treated with veterinary pharmaceuticals that may be toxic to birds (e. g, vultures and didofenac in South Asia). Poison-baits are used to protect livestock from predators, such as large mammals and birds of prey.

Likelihood of exposure and toxicity, are indicative of whether the use of agricultural chemicals will result in population-level effects on birds. For example, if the likelihood of exposure is high and toxicity is also high, population-level effects on birds may be more likely to occur.

As a whole, the guidance includes both non-legislative and legislative recommendations (see Table 1 with key recommendations, below) involving communities, industry, non-governmental organisations, and governments to limit impacts of agricultural chemicals on migratory soaring birds. Where possible, priority is given to supplementing existing projects and initiatives to benefit birds and ecosystems generally.

Guidance to Prevent Risk of Poisoning of Migratory Soaring Birds in the Rift Valley/Red Sea Flyway

Table 1: Summary of recommendations to minimise effects on birds from chemicals used in the agricultural environment

Activity	Recommendations to change how chemicals are applied	Type
Crop protection from insect pests using insecticides	Substitute (remove and replace) substances of high risk to birds <ul style="list-style-type: none"> • Include criteria on birds when prioritising areas for obsolete pesticide removal programmes • Incorporate effects on birds into Integrated Pest Management principles 	Non-legislative and legislative with a mix of high level policy and operational recommendations
	Create restricted pesticide zones in high risk areas	Legislative
Crop protection from quelea using pesticides	Apply Integrated Pest Management to change cropping strategies and reduce pesticide use	Legislative and non-legislative; high level policy and operational recommendations
	Harvest quelea as food source	Non-legislative
Crop protection from rodent pests using rodenticides	Use best practice to prevent and manage rodent irruptions (without second generation anticoagulant rodenticides)	Non-legislative
	Restrict/ban second generation anticoagulant rodenticides in open field agriculture	Legislative; operational recommendation
	Prohibit permanent baiting	Legislative and non-legislative; operational level recommendation
Predator control using poison-baits	Apply alternative predator control methods to poison-baits	Legislative
	Provide compensation and/or insurance schemes for predation of livestock	Legislative and non-legislative
	Effective monitoring and enforcement mechanisms	Legislative
Veterinary treatment of domestic livestock with pharmaceuticals	Assess diclofenac use and monitor domestic ungulate carcasses for risky NSAIDs	Legislative and non-legislative
	Immediately substitute (remove and replace) diclofenac for veterinary use in domestic livestock	Legislative
	Mandatory safety-testing of NSAIDs of risk to scavenging birds	Legislative

Introduction

The Rift Valley/Red Sea flyway is the second most important flyway for migratory soaring birds (raptors, storks, pelicans and some ibis) in the world, with over 1.5 million birds of 37 migratory soaring species, including five globally threatened species, using this corridor between their breeding grounds in Europe and West Asia and wintering areas in Africa each year.

The aim of the Migratory Soaring Birds Project is to mainstream migratory soaring bird considerations into the productive sectors along the flyway that pose the greatest risk to the migration of these birds – principally hunting, energy, agriculture and waste management – while promoting activities in sectors which could benefit from these birds, such as ecotourism.

There is increasing concern that poisoning – primarily associated with the agricultural sector - is a significant and avoidable cause of mortality for migratory birds. This issue was highlighted at the 11th Conference of Parties to the Convention on Migratory Species (Quito, Ecuador, November 2014), and a conference resolution was adopted on Preventing Poisoning of Migratory Birds (Resolution 11.15). Importantly, the resolution adopted guidelines to prevent the risk of poisoning of migratory birds (UNEP/CMS/COP 11/doc 23.1.2, Annex 2). In adopting the guidelines, it is recognized that it is “for each Party to determine whether or how to implement the recommended actions, considering the extent and type of poisoning risk, whilst having regard to their international obligations and commitments, including those under the Convention”.

Specifically, the Resolution, amongst other provisions:

Urges Parties and encourages non-Parties to disseminate and implement these Guidelines, as appropriate, across all flyways, where necessary translating the Guidelines into different languages for their wider dissemination and use;

Encourages CMS Parties and invites Parties and Signatories of CMS Family instruments to identify within flyways, those geographical areas where poisoning is causing significant migratory bird mortality or morbidity, and address these as a matter of priority applying the Guidelines as appropriate;

Encourages CMS Parties to monitor and evaluate the impact of poisoning on migratory bird species regularly at national level, as well as the effectiveness of measures put in place to prevent, minimize, reduce, or control poisoning impacts, as appropriate

Calls on Parties and non-Parties, including inter-governmental organisations and other relevant institutions to elaborate strategies to address poisoning or to include measures contained in this Resolution and in the Guidelines in their National Biodiversity Strategies and Action Plans (NBSAPs) or relevant legislation as appropriate to prevent, minimize, reduce or control the impact of poisoning on migratory bird species

Calls on Parties and invites non-Parties and stakeholders, with the support of the Secretariat, to strengthen national and local capacity for the implementation of this Resolution

including, *inter alia*, by developing training courses, translating and disseminating examples of best practice, sharing protocols and regulations, transferring technology, and promoting the use of online tools to address specific issues that are relevant to prevent, reduce, or control poisoning of migratory birds protected under the Convention

In the context of this global concern and commitment to take action, and building on the global guidelines adopted by Contracting Parties to CMS, this report reviews the risks to birds from poisoning associated with the agricultural sector in the Rift Valley/Red Sea Flyway and provide guidance on how poisoning from agricultural chemicals can be prevented in countries on the Flyway. The report has been commissioned by the BirdLife/UNDP/GEF Migratory Soaring Birds project, which covers 11 countries on the Red Sea-Rift Valley Flyway. Table 2 provides information on the extent to which countries covered by this project are Parties to the Convention on Migratory Species (CMS), the African-Eurasian Waterbird Agreement (AEWA) and the Raptor Memorandum of Understanding (Raptor MOU).

Table 2: BirdLife/UNDP/GEF Migratory Soaring Birds project countries and their Party statuses to the Convention on Migratory Species (CMS), the African-Eurasian Waterbird Agreement (AEWA) and the Raptor MOU.

Country	CMS	AEWA	Raptor MOU
Egypt	Yes	Yes	Yes
Sudan	No	Yes	Yes
Eritrea	Yes	No	No
Ethiopia	Yes	Yes	No
Djibouti	Yes	Yes	Yes
Yemen	Yes	No	Yes
Saudi Arabia	Yes	No	No
Jordan	Yes	Yes	No
Palestine	No	-	No
Lebanon	No	Yes	No
Syrian Arab Republic	Yes	Yes	No

Source: CMS and AEWA websites accessed on 25th November 2014

Whilst all migratory species are affected by poisoning, migratory soaring birds are particularly vulnerable to poisoning because of their position at the top of the food chain and as long-lived, slow reproducing species through primary and secondary poisoning. Primary poisoning occurs as a result of direct ingestion of poison (Sánchez-Bayo 2011); whereas, secondary poisoning occurs when predators are exposed to physiologically damaging concentrations of poisons by ingesting contaminated prey (Spurgeon and Hopkin 1996).

The use of chemicals toxic to birds in the agriculture environment is often related to the protection of crops (food crops and non-food crops) and livestock. Chemicals are used to protect crops from insects as well as rodent pests. Livestock are treated with veterinary pharmaceuticals that may be

toxic to birds (e.g., vultures and diclofenac in South Asia). Poison-baits are used to protect livestock from predators, such as large mammals and birds of prey.

In the African-Eurasian region, toxic pesticides continue to be manufactured and used in developing countries. Pesticide problems have decreased in some Middle Eastern countries since the 1980s, but there are still cases of raptor mortality from pesticides, including the death of 30 Eurasian Griffons (*Gyps fulvus*) in a single day in 1998 (Shlosberg and Bahat 2001). Pesticide poisoning is also thought to occur in Saudi Arabia, although it is rarely detected as a cause of death (Tucker 2005; Ostrowski and Shobrak 2001).

Indirect effects of pesticides on birds, such as the loss of habitat/cover and invertebrates which lead to reduced feeding opportunities and breeding success, are well documented (Devine and Furlong 2007), but will not be considered in detail here, as indirect effects are beyond the focus of this review. This study seeks to understand the scale and severity of the direct effects through primary and secondary poisoning of MSBs relating to pesticides used in agriculture.

Situation and context analysis

Agriculture is an important sector in most of the regional economies as a contributor to gross domestic product (GDP) and employment, and as a main source of income generation and livelihood for the majority of the rural population. The sector also plays a key role in maintaining public health and nutrition and in providing environmental products and services. Agriculture responds to local demand as well as export markets (Sadik, Nimah and Alaoui 2011).

Ethiopia and Sudan's economy are based on agriculture, accounting for 41 per cent and 40 per cent of GDP, and 85 per cent and 45 per cent total employment, respectively (World Economic Forum, 2011). Syria and Egypt also have a significant proportion of GDP from agriculture at 20 per cent and 13 per cent, respectively, and the sector provides for approximately 30 per cent of total employment in both of these countries (World Bank 2009).

Many of the countries in the region are looking to expand their agricultural sector as a way to increase food stability and reduce poverty for a rapidly expanding population. In nearly all countries of this flyway, agricultural land area and the area under irrigation have both increased (Molfetto 2012).

Enhancing the use of pesticides is often suggested as a key strategy by funders, such as the World Bank, to achieve higher productivity of the agricultural sector (Gebreselassie 2006). Pesticide subsidies are common as a way to increase pesticide use by farmers (World Bank 2008).

Intensively farmed fruits, vegetables and other high-value crops are of dominant importance in Lebanese agriculture. Fruit crops and vegetables are frequently intensively sprayed with various pesticides, often under a "better safe than sorry" mentality. There is limited monitoring of pests and relevant environmental conditions to inform pesticide applications, often resulting in applications at the maximum levels (Zeid 2007).

In Ethiopia, pesticides are used on approximately 20 per cent of cultivated land (World Bank 2005). However, the new policy to increase commercialisation of agriculture throughout Ethiopia (Abebe 2012) may increase pesticide use.

Further country specific information on the agricultural sector is available in a number of reports produced for BirdLife in 2012 and 2013 (see Abebe 2012; Wildlife Palestine 2013; Hassoun and AlHayek 2013; Hashim 2013; Al-Duais 2013).

Pesticide use in the region

Pesticide use in the region is highly varied with some countries using limited amounts of pesticides, although potentially with substances highly toxic to birds, and other countries with heavily developed pesticide regimes. Pesticide intensity (kg/hectare of pesticides used per crop output) is low in Sudan, Yemen and Ethiopia, but is higher in places such as Egypt, Jordan and Lebanon (Schreinemachers and Tipraqsa 2012).

Large-scale irrigated agriculture (cereals, alfalfa and fruit crops) in far South Jordan has high-use of pesticides (Evans, Amr and Al-Oran 2005). Ethiopia is one of the lowest pesticide users in the world as a result of lack of availability of pesticides and widespread small subsistence farming systems

(Ethiopian Institute of Agricultural Research 2009). The state sector is the main user of pesticides in this country. The bulk of pesticide use in the smallholder private sector is accounted for by insecticides used against the African armyworm (*Spodoptera exempta*) and locusts (*Schistocerca gregaria* and *Locusta migratoria*) averaging about 124 and 79 metric tons, respectively, during outbreak or plague years. The lack of pesticide regulation until recent years has resulted in the importation and use of some pesticides that are either banned, restricted or not registered in other countries. Also, it was not uncommon in Ethiopia for pesticides that have not been tested at all to be recommended against certain pests (Abate 1997).

Pesticide regulation and distribution

The regulation of pesticides is managed by each country in the region individually, often drawing on evidence from the United States and Europe when considering whether to approve or revoke products from the market.

In Lebanon, for example, the Pesticide Regulation Committee, under the Ministry of Agriculture, is made-up of members from government, academia and industry and sets conditions for authorisation for pesticide importation, sale, preparation, labelling, and use (Lebanese Government, 1982). Despite the existence of a list of banned pesticides developed by the Ministry of Agriculture, government control and law enforcement are still weak. Even banned products, such as monocrotophos, which is highly toxic to birds, are available by illegal means and used by the untrained public (Salameh, et al. 2004). New developments include the requirement to obtain a prescription to purchase pesticides, such as for organophosphates and carbamates, and training of agricultural personnel within the Ministry of Agriculture is underway (Jawdah 2013).

Often governments in the region distribute pesticides for significant economic crops. For example, rodenticides are distributed by the Ministry of Agriculture for the treatment of field rodents in Lebanon (Jawdah 2013). In some countries, such as Egypt, the government is responsible for all pesticide distribution (Figure 1).

Figure 1: Case study of pesticide regulation in Egypt

Egypt is the most populous country in the Arab world and is heavily reliant on agriculture, particularly cotton. Although grown and harvested by independent farmers, the national government oversees the country's entire production of cotton (Head 2008).

Once farmers agree to plant cotton in their fields, applications of chemicals on those fields come under control of the national Ministry of Agriculture and that control is delegated to the Ministry's District Offices in the individual Governorates. Pesticide application equipment and all pesticides are purchased by the national Ministry of Agriculture; the equipment is calibrated at the Governorate District Office and then distributed to the Governorate field stations (Farahat, et al. 2010).

Thus, all pesticides, application equipment and application procedures used for cotton production are standardised throughout Egypt.

Syria and Jordan, with technical and financial aid from the Swiss government, are establishing a hazardous substance information management system. In 2006, Jordan created a system, which

provides information on banned substances¹ and identifies the authorities in charge of providing licenses. Many challenges remain as reports on early implementation steps reveal the absence of proper mechanisms to cover all stages of chemicals management due to a lack of sufficient resources or knowledge.

Also, Syria has adopted strict legislation (including regulations) to control the use, handling, storing, importing, and exporting pesticides. The registration of pesticides in Syria is mandatory and based on registration system adopted by many developed countries (Hajjar 2012).

Hazardous pesticides covered in the Prior Informed Consent (PIC) procedure under the Rotterdam Convention are more weakly regulated in lower than in higher income countries (Schreinemachers and Tipraqsa 2012).

Weak institutions, regulation and enforcement is a recurring theme amongst the countries in the region and policy solutions should be adopted with this in mind.

¹ Jordan's Environmental Protection Law No 52, Instructions No. 10 of 2009 provide for registration, manufacturing, processing, importing, and trading of pesticides:
http://www.vermontlaw.edu/Academics/Environmental_Law_Center/Institutes_and_Initiatives/Lebanon.htm (accessed on 14/11/2013).

Part one: review of effects of agricultural chemicals on birds

This review aims to estimate the effects of agricultural pesticides on migratory soaring birds. Evidence supporting the claims that agricultural pesticides risk poisoning of migratory soaring birds is from a wide variety of sources including, peer-reviewed journal articles, grey literature, such as regional government and World Bank reports, and personal communication with experts from the agricultural and environmental sector in the Rift Valley/Red Sea region. The Convention on Migratory Species' draft review and guidelines to minimise poisoning of migratory birds has also informed this work.

The review is divided into three components and assesses the effects of chemicals used for (1) the protection of crops from insect and rodent pests, and quelea; (2) protection of livestock from predators; and (3) treatment of livestock with veterinary pharmaceuticals. Each of these components is discussed below in more detail.

The outcomes of this review will determine the need and suitable response to address poisoning of birds associated with the agricultural sector. Recommendations in the form of guidelines are included in Part Two of this report.

1. Protection of crops with pesticides

The protection of crops from insects and rodents using pesticides can have impacts on birds, both lethal and sub-lethal. Whether these are sufficient to result in population declines is largely a topic that needs further research. However, two key factors provide an indication about whether population effects are likely: likelihood of exposure and toxicity.

The likelihood of exposure to pesticides used to protect crops from insects and rodent pests is influenced by a number of factors, including cultivation practices, pest types, crop types, pesticide form, and migratory bird ecology (diet and habitat preferences). For example, birds that feed during migratory stopovers are more likely to be exposed to pesticides, such as storks, pelicans, cranes, harriers and falcons.

Once exposure occurs, the toxicity of the substance to the particular bird species will greatly influence the corresponding effect, whether sub-lethal or lethal. Likelihood of exposure and toxicity, are indicative of whether the use of agricultural pesticides will result in population-level effects on birds. For example, if the likelihood of exposure is high and toxicity is also high, population-level effects on birds may be more likely to occur. Both of these factors are discussed in more detail below.

1.1 Likelihood of exposure to pesticides

1.1.1. Bird ecology

Specific bird ecology, such as diet, foraging behaviour, habitat preferences, and migration behaviour may influence the likelihood of exposure to pesticides. The broad-spectrum nature of organophosphates and carbamates means that any bird in the vicinity of where pesticides are applied is at risk of exposure – typically the likelihood of exposure is increased for birds that use agricultural areas for foraging.

Raptors appear to be more sensitive than other bird species to organophosphates and carbamates (Mineau, Fletcher, et al. 1999). For example, birds of prey in Egypt, particularly around the Suez Canal, had high residues of organophosphorus pesticides (El-Sherif, El-Danasoury and El-Nwishy 2009). The risk of poisoning for raptors and other soaring birds is increased as a result of their ecology, such as insectivory, opportunistic taking of debilitated prey, scavenging, presence in agricultural areas and bioaccumulation of some types of insecticides.

Birds that forage in agricultural areas are more likely to be exposed. For example, the Bonelli's eagle (*Aquila fasciata*) hunts on farmland due to the high concentrations of their preferred prey (eg, the rock dove *Columba livia*), which feed in this habitat (Evans, Amr and Al-Oran 2005). The same process led to the extinction of this eagle in some Middle Eastern countries during 1940-1976 (Frumkin 1986).

A study that simulated foraging in insecticide-treated fields in Texas, USA, found foraging location is more likely to influence exposure than diet preferences or daily intake rate (Corson, Mora and Grant 1998). Exposure is therefore, the result of a temporal and spatial overlap between species occurrence and principle areas and timings of insecticide application. For example, birds that forage

more frequently in grassland areas are less likely to be exposed to insecticides because no insecticide applications occur there. In some areas, exposure risk decreases as crops grow because certain species generally spend less time in crop fields (Corson, Mora and Grant 1998). Therefore, pesticides applied at the time of planting may pose the highest risk of exposure to birds.

Figure 2: Foraging behaviour and diet can increase exposure to pesticides

Pesticide poisoning is potentially a threat to Bonelli's eagle (*Aquila fasciata*) and other raptors which hunt on farmland due to the high concentrations of their preferred prey (eg, rock dove) which feed in this habitat (Evans, Amr and Al-Oran 2005).

1.1.2. Pest types

Species that rely on particular types of insect pests may be more likely to be exposed to insecticides because of, for example, (1) the insect's behavioural reaction to particular substances making it more likely to be preyed upon; (2); insects that are the target of particular pesticides make up a large proportion of a bird's diet; and (3) the insect occurs in relative abundance at particular times (eg, pest outbreaks) making it more likely that a large quantity of that pest will be ingested by birds.

Outbreaks of pests attract birds and so may increase the likelihood of exposure of birds to pesticides. Many species of raptor can be killed through consumption of contaminated invertebrates. For example, European species such as black kites (*Milvus migrans*) feed on locusts in the Sahel. Additionally, outbreaks of pests may be treated with large concentrations of pesticides in a short period of time, potentially increasing the occurrence of exposure.

Migrant pests (eg, locusts and African armyworm)

Locusts

Major desert locust outbreaks occur repeatedly along the Red Sea coastal plains threatening lowland agricultural regions, including in Eritrea, Sudan and even spreading to the rich agricultural areas of the Ethiopian highlands (Showler 2002).

Populations of locusts and grasshoppers are monitored by the Locust Control Centre/FAO and treated as soon as outbreaks threaten (Cressman and FAO 1996). When pests cross national borders, internationally coordinated operations are necessary. Plagues develop only when control efforts break down, or political or natural disasters prevent access to breeding areas, and interventions do not start early enough. Control failures and plague development have occurred with the desert locust in the Red Sea basin in 1986 and 1992. Once plagues develop, curative insecticide applications become necessary over wide areas, with associated financial and environmental costs that are far in excess of the cost of preventive control (Lomer, et al. 2001). One severe desert locust outbreak in Ethiopia resulted in destruction of enough grain to feed 1 million people (Steedman 1988).

Outbreaks are generally treated by intensive application of chemical pesticides, a technique whose efficacy has been widely debated and has considerable environmental drawbacks (Fashing, Nguyen and Fashing 2010). Whereas efforts have been made in recent decades to reduce negative environmental effects of treatments used to manage locust outbreaks (Lomer, et al. 2001), insecticides are still the primary means of combating them (Peveling 2005) despite the mixed record of success (Wiktelius, Ardö and Fransson 2003).

Chemical control of desert locust is carried out over large areas of land, covering a range of different landscapes and ecosystems. There are no real restrictions for spraying in or close to environmentally sensitive areas and awareness of sensitivity is not always obvious to the people involved in control. Indeed, control operations can include protected areas and areas with numerous migratory birds (Wiktelius, Ardö and Fransson 2003).

Application of insecticides, such as organophosphates, some of which are toxic to birds, are the most common method used to control locusts, often with aerial application – putting birds at risk of exposure in both agricultural areas and outside agricultural areas as aerial spraying can be widespread (Eriksson and Wiktelius 2010; Abou Ali and Belhaj 2008; Story, et al. 2005). Organophosphorus pesticides may not only have a direct effect on individuals within a species but also populations as a whole, disrupting population dynamics and changing species composition, with the most sensitive species becoming extinct in areas of highest contamination (Story and Cox 2001). Effects of organophosphate and carbamate pesticides can be recognized by various responses, including impaired thermoregulatory functions, changes in levels of activity and aggression, or reduced food and water intake. Hence, sublethal effects have the potential to inhibit reproduction and survival (Story and Cox 2001).

The last major desert locust outbreak in the Sahel region (2003-2005) was treated with organophosphate insecticides – notably chlorpyrifos and malathion and to a lesser extent fenitrothion – putting birds at risk. In one study on the Red Sea coast of Sudan, the number of hoopoe larks (*Alaemon alaudipes*) decreased after an insecticide application for locust control (Eriksson 2008).

Locusts sprayed in coastal regions may survive – indeed, locust resistance to pesticides is increasing (Yang, et al. 2009) – and reach neighbouring highlands where they could be consumed in large quantities by wildlife (Fashing, Nguyen and Fashing 2010; Peveling 2001). Locust plagues can attract birds as potential food sources. Movements of birds, such as white storks (*Ciconia ciconia*), are influenced by the presence of locusts and are known to feed on poisoned locusts (Milstein 1966; Vesey-FitzGerald 1959).

During an outbreak in Australia in which locusts were sprayed with organophosphorus insecticides, locusts in weakened or dying states were the primary food item for several bird species (Story and Cox 2001). Roosts and concentrations of birds feeding on locusts may be extremely vulnerable to pesticide aerial spraying (Mineau 2002). To date, results have demonstrated that the level of exposure of species feeding in sprayed areas can be quite high, even for birds not consuming locusts (eg, zebra finches). Laboratory studies show that fenitrothion can have effects on locomotion (and, therefore, predator-escape capability) for much longer periods (days to weeks) than predicted from biomarker persistence in the blood (Szabo et al. 2003).

Two organophosphates regularly applied in locust control are toxic to birds (Ostrowski and Shobrak 2001). The recommended rate of fenitrothion application (250 to 300 g/ha) was near that shown to cause mortality in birds (Steedman 1988). Chlorpyrifos, at a rate of 250 g/ha, might also pose a hazard to migrating birds (Smith 1987).

Stable isotope analyses revealed that little trophic overlap exists between desert locusts that feed on trees and shrubs and nomadic livestock that feed on grasses in the Sahelian savanna grasslands (Sánchez-Zapata, et al. 2007). These results suggest low resource competition with the main human resources in regions with little agricultural development. In addition, during an outbreak that occurred in winter, desert locusts were consumed by resident and long-distance migrant birds. This accounted for significant changes in the diet and foraging strategies of wintering generalist predators such as the black kite (*Milvus migrans*). This raises questions about the need for spraying locust swarms in areas where economic losses are scant and wintering populations of European trans-Saharan migrant birds are high (Sánchez-Zapata, et al. 2007).

There is little resource competition between locust swarms and domestic livestock but an important role for the locust as a food resource for predators that may play a key role in semi-arid community structure and ecosystem functioning in the Sahel. In spite of this, more than 70 million US\$ were invested mainly to stop the 2004 sub-Saharan desert locust crisis. These efforts included spraying 3 million L of contact insecticides with known negative environmental effects over 12 million ha. Although locusts did not compete with domestic animals belonging to Sahelian nomads, locusts may invade subsistence and cash crops (Van Der Werf, et al. 2005). The use of chemical pesticides against locusts is increasingly being re-evaluated because of its high environmental and monetary costs (Neueschwander 2004; Krall 1997).

African armyworms

The African armyworm (*Spodoptera exempta*) is a migratory outbreak pest of cereal crops and grasslands in eastern and southern Africa, devastating small-scale subsistence farms and commercial production alike. Crops most frequently affected are maize, sorghum, millet, wheat and rice, and to a lesser extent teff, barley and sugarcane.

The first armyworm outbreaks appear in Tanzania and Kenya and are serious in nine out of ten years; in 2001 they covered 157 000 hectares of crops and pasture (affecting about 80 000 smallholder farms in 54 districts). In major outbreak years, the adult moth stage of the pest migrates to cause extensive damage in Uganda, Ethiopia and Eritrea and may travel as far as Yemen. Indirect losses to livestock due to armyworm outbreaks in pastures are sometimes severe, due to a combination of starvation and poisoning.

Outbreaks of African armyworms have been reported in virtually every country in sub-Saharan Africa, though their biggest impact is generally felt in the eastern half of the continent, in countries such as Yemen and Ethiopia. Treatment costs using insecticides have been estimated at US\$10 per hectare (Iles and Dewhurst 2002).

Insecticides containing methoxyfenozide (relatively non-toxic to birds) can be an effective control measure, although insecticide resistance is well-documented among these caterpillars. This is where botanical insecticides such as neem oil, pyrethrum and pongam can be effective, as many of these insecticides also contain mixtures of biologically-active regulators that inhibit the onset of pest resistance.

Insect growth regulators and slow-release pheromone formulations that disrupt the mating cycle have also been used successfully. But it was the discovery of a nucleopolyhedrovirus (SpexNPV), *Spodoptera exempta*, in 2009 that proved to be one of the most effective control measures.

Rodents

Rodents are responsible for approximately 5 per cent of crop losses on average, but loss varies and can be up to 25 per cent, in the Near East region (Greaves 1989). In Ethiopia, a survey of farmers found that rodents are the main pests in crop fields (92.1 per cent) and storage (88.5 per cent) (Meheretu, et al. 2010). The farmers (64.2 per cent) reported they experienced 8.9–44.7 per cent loss in annual production from rodents (Meheretu, et al. 2010). Crops targeted by rodents often include cereals, root crops, and stored crops (United States Agency for International Development 2001).

Breeding cycles of rodents are synchronised to the wet season. Field rodents often reach plague numbers toward the end of the wet season and this is when field crops are nearing harvest, which necessitates rodent control to protect harvests (Leirs, Sluydts and Makundi 2010; Fiedler 1994). If this overlaps with migratory periods, then birds could face an increased risk of exposure to rodenticides.

Broad-scale management of rodent irruptions in Africa, eg, Sudan, tends to rely on rodenticides (Leirs, Sluydts and Makundi 2010). Control of rodents in agricultural crops is often recommended to be treated with second generation anticoagulant rodenticides because different species endemic to the region vary considerably in their susceptibility to anticoagulants (Greaves 1989; Gill and Redfern 1983). Rodents are also carriers of disease in the region and control may be associated with public health management (Khanjani, et al. 2009).

In a survey of Ethiopian farmers, rodenticide application was the most commonly practiced management strategy in crop fields (51.8 per cent) (Meheretu, et al. 2010). Farmers are responsible for rodent control activities in their individual fields (rarely done collectively) and generally do not treat fields when there are no crops present (Makundi, et al. 2005). In Syria, rodenticides are often used in agricultural fields (Hassoun and Al-Hayek 2012).

Many raptor species are especially likely to be exposed to rodenticides due to a regular diet of rodents. Scavenging species may be especially at risk because they feed on carcasses that could be contaminated with rodenticides.

Rodents make up a large proportion of some birds diets, including the imperial eagle (*Aquila heliaca*) in Jordan (Al Hasani, et al. 2012), thereby increasing the possibility of secondary poisoning where rodenticides are used in open areas. For example, rodenticides used around chicken farms, which may attract certain bird species, could increase the risk of poisoning of scavenger and predator bird species (Al Hasani, et al. 2012). In 2008, three critically endangered bald ibis (*Geronticus eremite*) were found poisoned in Jordan believed to be related to poison laid by chicken farmers for rodents (BirdLife 2008).

Insectivorous species may be susceptible to exposure through the ingestion of contaminated insects. Invertebrates can become contaminated through consumption of rodent carcasses and faeces, ingestion of soil residues, eg, earthworms, and direct consumption of poison baits, including those placed in bait stations (Eason, et al. 2002). Two unpublished studies indicated that in insects exposed to ARs, residue levels take in excess of four weeks to return to background levels, and trace levels are detectable up to ten weeks following brodifacoum baiting operations, which poses a risk to insectivorous bird species (Craddock 2003; Booth, et al. 2003). Insects may not bio-accumulate ARs after repeated exposures (Craddock 2003), thereby lowering the likelihood of increased toxicity to insectivorous birds. However, as insectivorous species will feed on many invertebrates, the potential exists for bioaccumulation to occur. One study suggested that a granivorous species, the crested partridge (*Rollulus roulroul*), may have died by consuming cockroaches exposed to the SGAR brodifacoum (Borst and Counotte 2002). Therefore, migratory soaring birds that target insects in rodent treatment areas could be at risk of exposure.

Rates of bird exposure to rodenticides in the Middle East and North Africa are largely unknown and need further research. However, widespread exposure in birds to rodenticides has been detected through wildlife monitoring programmes in Europe and North America, with exposure rates as high as 90 per cent in some birds of prey (Walker, et al. 2013; Christensen, Lassen and Elmeros 2012). If rodenticide use rates and application types are similar in the Rift Valley/Red Sea region, widespread exposure is also likely to exist in birds there.

The relationship between anticoagulant rodenticide (AR) levels and physiological effects is poorly understood and there is a large inter-species variation in the toxicity of rodenticides (World Health Organization 1995), but residues found in red kites were at levels potentially lethal to barn owls and rodenticide-induced mortalities have been recorded in this species (Walker, et al. 2013).

Practices such as the lack of protection of bait stations, broadcast baiting, permanent baiting, and failure to remove bait at the end of baiting campaigns are likely to increase the risk of primary and secondary poisoning (Shore, et al. 2013). Indeed, how the rodenticide is applied may have more of an effect than how often it is applied. For example, during the Foot and Mouth outbreaks in the United Kingdom, large amounts of ARs were used on farms without increasing exposure in buzzards and barn owls (Shore, et al. 2006). Therefore, the way rodenticides are used in agriculture is particularly important in determining whether poisoning of birds occurs.

A broadcast method of rodenticide dispersal, commonly employed in France to tackle vole outbreaks is associated with a particularly high risk to non-target wildlife. This untargeted approach is believed to be the primary reason why secondary poisoning by rodenticides is an issue of conservation concern in France, but generally not in other countries of the species' range, where deliberate illegal poisoning is a more significant factor (Knott, Newbery and Barov 2009). If outbreaks are treated similarly, e.g., broadcast method, in the Rift Valley/Red Sea region, then secondary poisoning of birds is likely to occur.

Quelea

The red-billed quelea (*Quelea quelea*) is a granivorous bird occurring throughout the semi-arid zones of sub-Saharan Africa. Arguably the most abundant land-bird in the world, quelea can occur in huge

flocks (breeding colonies may harbour 60,000 adults per hectare) that are capable of devastating small-grain crops such as millet, sorghum, wheat and rice (but avoid maize), usually when their natural food sources are depleted. Roosts and breeding colonies attract a wide variety of predators and scavengers in large numbers, including herons, storks, and raptors.

Often given a pest status throughout its range, millions of queleas are destroyed annually by most countries that have this species within their borders. Estimates of cereal losses in Sudan alone are \$6.3 million annually (Ibrahim, et al. 2013). Despite the culling of 65-180 million birds per annum in the region, it has had no effect on populations, other than temporary local relief from crop damage.

Ground and aerial spraying of the organophosphate fenthion has been the predominant means to control the red-billed quelea for more than forty years. Fenthion control costs in Zimbabwe for a single year is approximately US\$38,000 (Pelham 1998). Birds of prey, owls and passerines have been commonly reported casualties of spraying with fenthion over land. Non-target species may be affected directly by spraying, but predatory birds, scavenging birds and even mammals can be contaminated by secondary poisoning when they eat quelea carcasses found up to 20 km or more from the primary control site (Cheke, McWilliam, et al. 2012; McWilliam and Cheke 2004).

Results of monitoring effects of spraying organophosphate fenthion in Botswana and Tanzania showed that although few non-target mortalities were noted, indirect effects in terms of depressed cholinesterase in birds and small mammals were marked and pesticides persisted at unacceptable levels and for long periods (between 47-188 days) (Cheke, et al. 2012; Cheke, et al. 2011).

Management of quelea in the region of interest in this study is carried out in Sudan, Eritrea and Ethiopia, often done by the government at no cost to the farmers, which could lead to over-use of pesticide control as a precautionary mechanism (Elliott 2000). One of the manufacturers of fenthion, Bayer, announced in 2003 that they would cease production of the pesticide. However, alternative suppliers exist and other chemicals are likely to be developed for quelea control (Elliott 2000).

1.1.3. Cultivation practices and crop types

Particular types of crops may increase likelihood of exposure to birds. Some crops are associated with use of pesticides that are more acutely toxic to birds and/or particular forms of pesticides that are more likely to result in exposure. Additionally, some crops may be associated with cultivation practices of more frequent applications or quantities of pesticides than others. Other types of crops are more attractive to birds as foraging areas, either due to the direct palatability of the crop as a food source, or because of other resources likely to be present within that particular crop.

The timing of pest control operations is significant for avoiding secondary poisoning of birds. A study in the Middle East found that to avoid poisoning of birds that consume insects, it was necessary to coordinate the application of pesticides with birds' annual cycles to avoid secondary poisoning (Yom-Tov 1980). Imposing time constraints when spraying organophosphates and carbamates onto crops, as they only stay active in the food chain for a number of days or weeks, could be imposed to correspond with the presence of migratory birds. This will limit the temporal and spatial overlap between species and pesticide use (Mitra, Chatterjee and Mandal 2011).

Secondary poisoning leading to mortality of raptors, which resulted from consumption of contaminated songbirds, occurred at the time of insecticide application (often at seeding) (Mineau, Fletcher, et al. 1999). The time of insecticide application could be the highest risk of exposure for birds.

Figure 3: Example of pesticide intensive cultivation practices

Cotton growing regions in Sudan and Egypt are pesticide intensive, with Egypt being one of the heaviest users of pesticides (approximately 70 per cent are insecticides) in Africa (Mansour 2004).

Egypt's pesticide registration scheme meets the FAO Guidelines on the Registration and Control of Pesticides; however illegal use of banned pesticides may be occurring given high rates of insecticides found in livestock carcasses (Sallam and Morshedy 2008).

1.1.4. Form of pesticide

The form of the pesticide itself, granular, liquid or treated seed, may affect the likelihood of exposure. The most common form of secondary poisoning in raptors is associated with the use of granular insecticides (Mineau, Fletcher, et al. 1999) (Elliott, Birmingham, et al. 2008). If granular carbamates are used in the Rift Valley/Red Sea region, birds may be at risk of exposure.

Seed treatments can also poison birds in particular circumstances. Whether poisoning from treated seeds will occur is dependent on the area sown, toxicity and concentration of the pesticide, availability of other foods, and ability of the birds to selectively avoid treated seed. For example, a United Kingdom study found that fonofos-treated wheat (now withdrawn by manufacturer in the UK) will poison birds, but only when both rapid feeding is possible and there is a high concentration of residues on the seeds. This is most likely to occur when seed is split before sowing, as this produces dense patches of seed which enable rapid feeding (Hart, et al. 1999). Another study estimated the rate of poisoning by insecticide-treated seeds in a bird population resulting in mortality from exposure was likely to lie in the range 0-5 per cent (Prosser, et al. 2006). Birds in the Rift Valley/Red Sea region may be at risk of exposure if treated seeds with high concentrations of particular insecticides toxic to birds are spilled during periods of migration.

The effect of spray-form insecticides on mortality of birds is dependent on its toxicity (addressed in the next section) and its rate of application (Mineau 2002). A study on the effects of repeated liquid sprays of methiocarb (a carbamate) found only sublethal effects on the dozens of bird species monitored in a UK orchard (Hardy, et al. 1993). However, the extent of sublethal effects on overall population health was not assessed in that study. In a US study, ingestion of caterpillars taken from a cotton field sprayed with parathion (an organophosphate) killed 16-18 Mississippi kites (*Ictinia mississippiensis*) (Franson 1994). Liquid sprays of some insecticides may place migratory soaring birds at risk of poisoning in the Rift Valley/Red Sea flyway.

1.2. Toxicity and persistence

The toxicity of pesticides and their persistence in the environment are key to determining whether exposure will have any effects on birds. Two categories of agricultural pesticides have the potential to contribute to primary or secondary poisoning: insecticides and rodenticides.

Within the large category of insecticides, carbamates and organophosphates show the highest toxicity and ability to increase risk of poisoning. Rodenticides of particular risk to migratory birds are the widely used anticoagulant rodenticides (ARs). Each of these categories are discussed below in more detail.

1.2.1. Insecticides

If exposure to insecticides is likely to occur, the toxicity level of the insecticide will greatly influence the corresponding effect on birds. Some substances are acutely toxic to birds generally; other substances are more likely to affect particular bird species because of their unique physiology.

Sublethal effects on birds exposed to insecticides are more common than lethal effects, although they are generally more difficult to document and quantify. Many studies have shown that sublethal doses of organophosphates can cause behavioural effects in birds. Effects are variable and can include reductions in food consumption that leads to weight loss, lack of aggressive behaviour, memory impairment that can compromise survival, immobility on the ground that increases predation risk, apathy in incubation, nest defence and care for nestlings leading to fewer nestlings and hence reduced productivity (Grue, Powell and McChesney 1982), and fertility (Sánchez-Bayo 2011). Sublethal toxicity associated with exposure to organophosphates and carbamates can also lead to alteration in migratory behaviour, such as a lack of migratory orientation (Vyas, Hill, et al. 1995).

Many of these effects are transient, but those affecting, for example, reproduction, can impact on the long-term viability of a species, even if there might not be apparent short-term population declines (Fluetsch and Sparling 1994). However, behavioural effects are difficult to quantify and there is limited evidence linking them to population declines (Walker 2003; Peakall 1985).

The likelihood of sublethal or lethal effects occurring is strongly influenced by the toxicity of the insecticide, which varies between first generation and second generation insecticides, with the latter often showing significantly greater toxicity. There is also significant variation between the compounds in each of these groups, which is discussed below.

First generation insecticides: regular agricultural use causes both sublethal and lethal effects leading to population declines

Organochlorines (eg, DDT, aldrin and dieldrin) were one of the earliest generations of synthetic pesticides. A number of elements make organochlorines highly risky to birds and ecosystems. DDT and other organochlorines are characterised by their environmental persistence (remain in the environment for a long period of time), toxicity to organisms and their ability to accumulate in the tissues of birds and other wildlife resulting in an increased concentration with each step up the food chain (Newton 1984). Raptors are particularly vulnerable because of their position in the food chain and diet preferences, which makes them vulnerable to bioaccumulation of the substance.

Organochlorines are widely documented as causing population-level effects in birds as a result of their use in agriculture (Newton 1998).

Bans of organochlorines for agricultural purposes exist in the region of interest (Salem, Ahmad and Estaitieh 2009). However, DDT, which has been banned for decades and caused devastating declines and local extinctions in many MSB species, can still be found in some countries in the Rift Valley/Red Sea flyway such as Ethiopia and Sudan where several hundred tonnes are used annually. Heavy contamination from prior use is also an issue in some areas.

Second generation insecticides: the effects depend on toxicity level of insecticide, sublethal effects more common than lethal effects, may affect population levels but harder to detect

After banning of the persistent organochlorine pesticides, second generation and less persistent pesticides were introduced: organophosphates and carbamates, also known as cholinesterase-inhibiting insecticides. Unlike organochlorines, they only stay active in the environment for days or weeks at a time and do not bioaccumulate in the food chain (Mitra, Chatterjee and Mandal 2011). Although these insecticides have limited persistence, decreasing risk of exposure, in the environment, they have an elevated toxicity – particularly to birds (Pisani, Grant and Mora 2008). Both sets of compounds are acutely toxic (neurotoxic) to birds, often at very low doses (Donovan, Taggart and Richards 2012) (C. Cox 1991).

Second generation pesticides often present less obvious effects, such as transitory behavioural disturbances, which could be of ecological significance (Rattner and McGowan 2007; Fleischli, et al. 2004; Elliott, Wilson, et al. 1997; Lee 1972). Some of the second generation insecticides have been shown to be very toxic to birds and are linked with population declines. For example, granular carbofuran applied at seeding in canola fields resulted in reduced abundance and declining population trends of common agricultural species such as the horned lark, house sparrow, western meadowlark (*Stumella neglecta*), American robin, and mourning dove in the Canadian prairies (Mineau and Whiteside 2006). If similar conditions are present, this risk could extend to birds in agricultural fields in the Rift Valley/Red Sea.

Organophosphates have been implicated in 335 separate mortality events causing the deaths of approximately 9,000 birds between 1980 and 2000 in the United States (Fleischli, et al. 2004). Secondary poisoning by carbamate and organophosphate insecticides have been attributed as the cause of mortality in barn owls (*Tyto alba*), American kestrels (*Falco sparverius*), red-tailed hawks (*Buteo jamaicensis*), great horned owls (*Bubo virginianus*) and bald eagles (*Haliaeetus leucocephalus*) (Fleischli, et al. 2004). Although studies have not yet been done in the Rift Valley/Red Sea flyway, secondary poisoning is likely to be a risk to similar bird species in areas where certain organophosphates and carbamates are used.

Many of these highly toxic substances have been removed from the agricultural pesticide market or are regulated to some extent in most developed countries. For example, carbofuran and monocrotophos are no longer legally used as agricultural pesticides in many countries. Much of the evidence of poisoning of birds in agricultural areas is related to these compounds. In less developed regions, these compounds are often still used in agriculture. For example, the last major desert locust outbreak in the Sahel region (2003-2005) was treated with organophosphate insecticides –

notably chlorpyrifos and malathion and to a lesser extent fenitrothion – potentially putting birds at risk. The use of carbofuran (highly toxic to birds) (Osten, Soares and Guilhermino 2005) has now been restricted or banned for agricultural purposes in Europe, Canada and USA, but it is still used widely throughout Africa (Otieno, Lalah, et al. 2010) and Asia (Park 2009).

1.2.2. Rodenticides

Anticoagulant rodenticides are the key type of rodenticides of risk to birds. If exposure to anticoagulant rodenticides is likely to occur, the toxicity level of the anticoagulant rodenticide (AR) will greatly influence the corresponding effect – whether lethal or sub-lethal. Additionally, certain bird species are more likely to be affected by ARs because of their unique physiology. Rodenticide toxicity and species at risk of experiencing adverse effects as a result of exposure are discussed below.

Anticoagulant rodenticides are distinguished by first or second generation: first-generation anticoagulants (FGARs), developed after World War II, typically require multiple feedings to result in mortality; and second-generation anticoagulants (SGARs) are more recently developed and have a greater toxicity, such that typically only a single feed is required to result in mortality (Endepols, Klemann and Buckle 2007). FGARs have, in many areas, been superseded to a large extent by second-generation anticoagulant rodenticides which were developed in response to the emergence of genetic resistance to warfarin in rats and mice (Tosh, et al. 2011).

First-generation anticoagulant rodenticides

First-generation anticoagulants, including warfarin, diphacinone, and chlorophacinone, require multiple exposures over a short period of time (days) to cause mortality (Hadler and Buckle 1992). Generally, the first generation anticoagulants have relatively low persistence. For example, warfarin has a half-life of between 5-28 hours in animal tissue. Due to their low toxicity and more limited persistence, the likelihood of toxicity from FGARS is lower than that from second generation anticoagulants (Hadler and Buckle 1992; Hosea 2000). For example, one study of tawny owls found a low probability of secondary poisoning from first generation compounds (Townsend, et al. 1981).

Many commensal rodents have developed resistance to FGARs, which means they can ingest large amounts of rodenticides yet survive (Baert, et al. 2012). This increases the risk of secondary poisoning if rodents are taken as food by birds. However, there have been few documented non-target wildlife poisoning incidents involving first-generation anticoagulants and limited studies on their potential risks to birds in the field. However, due to the lower toxicity and persistence, it is generally accepted that FGARs represent a significantly lower risk to non-target wildlife than equivalent use of SGARs.

As a result of FGARs being largely replaced by SGARs, this review focuses on the toxicity of SGARs, which is discussed below.

Second generation anticoagulant rodenticides

Commonly used SGARs, such as brodifacoum, bromadiolone, flocoumafen, and difenacoum, are classified as second-generation anticoagulant rodenticides (SGARs). SGARs were introduced in the 1970s following widespread development of rodent resistance to first-generation anticoagulant

rodenticides. SGARs are the primary means of controlling rodents in many developed countries and are used worldwide (Tosh, et al. 2011).

This class of rodenticides are much more acutely toxic than first-generation anticoagulant rodenticides, generally providing a lethal dose to rodents after a single feeding. They also tend to be more persistent in animal tissues and have a higher affinity for liver tissue, which is often an attractive food source for predators/scavengers. Based on brodifacoum and bromadiolone, it was predicted the likely persistence of residues after a sub-lethal dose in target and non-target animals could be up to 24 months (Eason, et al. 2011).

Brodifacoum is licensed in Ethiopia, and most likely in other countries in the Flyway, to treat rodent outbreaks in the field (Ministry of Agriculture, Animal and Plant Regulatory Directorate 2013). As a result, second generation anticoagulant rodenticides represent a greater risk of secondary poisoning than FGARs to migratory birds because of their toxicity and biophysical persistence.

Figure 4: Relative toxicity to birds of second-generation anticoagulant rodenticides

A number of studies have indicated that brodifacoum appears to have the greatest potential for non-target wildlife mortality due to its physiological persistence in body tissues and acute toxicity (Stone, Okoniewski and Stedelin 2003).

Several of the most highly toxic SGARs are restricted to particular uses, eg, use limited to indoors or around buildings in certain countries. For example, a risk assessment conducted by the United States Environmental Protection Agency in 2002 identified several rodenticides that pose significant risk to birds and non-target mammals, in part because of their toxicity and persistence. As a result, in 2008, the US imposed restrictions on the sale, distribution and packaging of brodifacoum, difethialone, bromadiolone and difenacoum (Rattner, Horak, et al. 2011).

For similar reasons, legislation in the UK currently draws a distinction between brodifacoum, flocoumafen and difethialone (only licensed for indoor use), and difenacoum and bromadiolone (licensed for outdoor use) (Chartered Institute of Environmental Health 2011) (Dawson, Bankes and Garthwaite 2001) (Tosh, et al. 2011).

With the use of SGARs, rodents survive for several days after consuming a lethal dose and often will continue feeding on the bait (Cox and Smith 1992). This increases the likelihood that the body burden in poisoned rodents may significantly exceed the lethal dose needed to kill them (and so present a greater poisoning risk to predators), and poisoned animals may remain active and available for capture by predators for some period after ingestion of the rodenticide (Thomas, et al. 2011). Therefore, predatory or scavenging birds may be more likely to ingest a high dose of SGARs from feeding on contaminated rodents, which, in-turn, may increase the likelihood of lethal or sub-lethal effects in birds. For example, the barn owl (*Tyto alba*) population in oil palm plantations on the Malaysian peninsula declined dramatically following the replacement of a first generation rodenticide (warfarin) with baits containing SGARs (brodifacoum) (Duckett 1984). This suggests that SGAR use in open field agriculture could cause bird declines.

Exposure to anticoagulant rodenticides may be occurring more frequently than are detected (Albert, et al. 2010). It has been suggested that birds suffering from adverse exposure to anticoagulant rodenticides may be likely to die undiscovered in their roosts, as a period of lethargy may precede death. Therefore, while long-running monitoring schemes may assess changes in exposure rates over time, it is difficult to accurately estimate effects on bird populations.

One model estimates the use of SGARs may result in a mortality rate of 11 per cent for great horned owls (based upon a 65 per cent likelihood of being exposed to SGARs and 17 per cent likelihood of exhibiting toxic effects as a result of the exposure) (Thomas, et al. 2011). However, this is the first estimate of population effects for a wild raptor population and its estimate may be too low (or too high) as an unknown number of birds die out of sight as a result of SGAR exposure (as a period of lethargy may precede death) (Newton, Wyllie and Freestone 1990), which is not reflected in the model. It also does not include consideration of sub-lethal effects of SGAR exposure, which are largely unknown. But since a high proportion of birds are exposed to sub-lethal amounts of SGARs, any effects could be widespread. However, this is only a preliminary study and the uncertainties around it are unquantified to some extent. Therefore, the true level of mortality may be greater or lesser, but it is the only estimate that we have to date. It is unknown whether this level of individual mortality would result in population effects.

There is a lack of published information on the effects of sub-lethal doses of second generation anticoagulant rodenticides, which are largely unknown (Burn, Carter and Shore 2002). Sub-lethal effects could include haemorrhages which interfere with locomotion, predisposing animals to predation; accidental trauma; toxic injury to the liver and reduced food intake. Inadequate nutrition may then predispose birds to infectious and parasitic disease, hypothermia, or poisoning with pesticides stored in fat (Albert, et al. 2010).

Sub-lethal exposure to SGARs may hinder the recovery of birds from non-fatal collisions or accidents if they lead to sub-lethal but prolonged clotting times. They may also impair hunting ability through behavioural changes, such as lethargy, potentially increasing the probability of starvation. In laboratory rats, sub-lethal exposure to rodenticides resulted in increased abortion rates, but these types of reproductive effects have not been studied in birds (Burn, Carter and Shore 2002).

However, there is limited evidence of sub-lethal effects occurring in the field, and those attributed to anticoagulants may be due to other correlative factors (Thomas, et al. 2011).

1.2.3. Illegal pesticide use

Overall, there has been a net reduction in the average avian acute toxicity of insecticides over time and most current problems stem from a failure to remove “old dangerous products” from the market (Mineau and Whiteside 2006). Stocks of obsolete (ie, banned) pesticides, often products of risk to birds, are a common occurrence in many countries in the region.

Within the framework of the Africa Stockpiles Program, huge quantities of persistent pesticides have been completely or partially destroyed in a number of African countries (e.g. Egypt, Namibia, Niger, Senegal, Seychelles, South Africa, Sudan, Tanzania, Uganda, Zambia) (Mansour 2009).

The United Nations Food and Agriculture Organization (FAO) reports that Ethiopia holds one of the largest stockpiles of obsolete pesticides in Africa. In Yemen, there have been reports that up to 70 per cent of pesticides used on fruit and vegetable crops, particularly the qat tree, are illegally imported substances (UN Office for the Coordination of Humanitarian Affairs 2007). Indeed, qat crops have the highest pesticide use placing birds at a higher risk of poisoning in qat cropping areas. Also, the country suffers from illegal accumulation and stock piles of old substances, with the current legal system making it difficult to prevent imports of illegal substances and eradicate existing stores

(Yemen News Agency 2009). In a 2010 government-led campaign, 61 out of 139 inspected pesticide stores were closed as a result of selling illegal pesticides.

Egypt is a hotspot of illegal pesticide use, but illegal use is prevalent and growing in most countries in Africa and the Middle East (Guyer 2012). Access to illegal pesticides is often through ineffective import procedures and regulation (eg, false declarations) (Guyer 2012).

2. Protection of livestock from predators using poison-baits and effects on birds

Poison baiting is probably the most widely used predator eradication method worldwide (C. Márquez, J. M. Vargas, et al. 2012). It is also illegal to use poison-baits in many countries. The use of poison baits is usually generated by conflicts with human interests associated with livestock rearing or game management for hunting, and indiscriminately affects birds or mammals that occasionally or regularly feed on carcasses, or other poison-laced baits (Whitfield, et al. 2003; González, et al. 2007).

Poison-baits are used to target predators in areas where livestock are reared, putting scavenger bird species at risk of poisoning (Evans, Amr and Al-Oran 2005). The use of poison baits for the control of predators such as red fox (*Vulpes vulpes*), wolf (*Canis lupus*), jackals (*Canis spp.*) and feral dogs (eg, around rubbish tips) is a widespread activity over much of the Rift Valley / Red Sea flyway region that often results in the accidental death of scavenging raptors, such as eagles, kites and vultures (Tucker 2005).

Poisoning is used to protect livestock from predators. Small-stock (sheep and goats) farmers may use more poison than large-stock (cattle) farmers (Ledger 1985). For example, most farmers in Kenya consider birds of prey nuisance birds because some species prey on domestic fowl (Ogada and Kibuthu 2008). These attitudes could contribute to an increased use of poison-baits affecting birds.

Figure 5: Artificial predator population rise contributes to increased predation of livestock and poison-bait use

In some areas in the Middle East, predation by jackals contributes to the loss of between 1.5-2 per cent of calves per year. Jackal populations, which frequently forage in farmland areas, for example in Ethiopia (Admasu, et al. 2004), are thought to be inflated because of access to artificial food sources, such as rubbish dumps. Farmers attempt to reduce costs to livestock by carrying-out illegal poisoning, thus affecting wildlife (Yom-Tov, Ashkenazi and Viner 1995).

The pesticides most frequently involved in animal poisonings are insecticides and rodenticides (Martínez-Haro, María-Mojica and García-Fernández 2008). The use of specific types of pesticides for poison-baits varies according to several factors, including, the type of agriculture in the region, the popular knowledge of the toxicity of a specific product, and its availability in the local market (Vyas, Spann, et al. 2002). The proportion of the active ingredient in the formulations available, greatly determines the risk of lethal or sublethal effects, if exposure occurs (Martínez-Haro, María-Mojica and García-Fernández 2008).

Declines of bird species in some Middle Eastern countries have been associated with the use of poison-baits (Yom-Tov, Hatzofe and Geffen 2012). For example, in one region between 2004-2007, 38 per cent of all poisoning cases that involved wildlife were caused by illegal use of pesticides, and 22 per cent were caused by cattle ranchers who quarrel over grazing areas and poison each other's herds, whose carcasses are then consumed by raptors (Leader, et al. 2009). Indeed, during a three-year survey (2006–2008) a poisoning event was detected on average every third day (Leader, et al. 2009). Also, poisoning is a major cause of lethality of the greater spotted eagle in the Middle East (Perlman and Granit 2012).

The use of poison-baits may dramatically affect populations of many species. For example, poison baiting in southern Spain has been linked with severe raptor declines, such as the red kite (C. Márquez, et al. 2013). Particularly, the black vulture (*Aegypius monachus*), Egyptian vulture (*Neophron percnopterus*), bearded vulture, and Spanish imperial eagle (*Aquila adalberti*) have been severely affected by poisoning (Hernández and Margalida 2008; Hernández and Margalida 2009; Mariano González, et al. 2008). Indeed, vultures and red kites have been suggested as having the highest propensity of being poisoned among any wildlife (C. Márquez, et al. 2012). Therefore, migratory soaring birds in the Rift Valley/Red Sea flyway may be particularly susceptible to poisoning from poison-baits compared to other wildlife in the region.

In a study of red kites in Spain, modelling indicated mortalities caused by illegal poisoning suppressed the population by 20 per cent. However, despite this, the population was likely to increase slowly, maybe as a result of supplementary feeding. In a study of radio-tracked red kites, 53 per cent of the tagged birds died as a result of illegal poisoning. The effect of this mortality on the population was unable to be determined (Tavecchia, et al. 2012).

Modelling has indicated an estimated 3-5 per cent annual adult mortality from persecution in golden eagles, and has suggested the population would likely grow in the absence of persecution (Whitfield, et al. 2004). In parts of Scotland, it has been indicated that persecution may reduce breeding productivity of golden eagles (*Aquila chrysaetos*) by up to 20 per cent (Whitfield, et al. 2004).

The number of raptors, primarily scavenger species, declined more than 40 per cent per year over a three-year period in central Kenya (Ogada and Keesing 2010). During the study, the overall population of large wild herbivores showed little change, which may suggest that food shortages were not the cause of the decline. Possible causes of raptor decline include the consumption of poison-baits, which are placed by pastoralists to kill large predators that attack livestock. Further research was recommended to determine whether the declines are having a population-level effect (Ogada and Keesing 2010). Whether poisoning explains the rapid decline in abundance of scavenging birds is yet to be determined.

Therefore, the risks to migratory soaring birds from poison-baits include potential population declines.

3. Treatment of livestock with veterinary pharmaceuticals

Non-steroidal anti-inflammatories (NSAIDs) are used to treat domestic livestock for inflammation and pain relief. Didofenac, a popular NSAID for veterinary care of livestock, is toxic to a number of vulture species. It has resulted in the poisoning of scavenging vultures throughout India, Pakistan and Nepal by contaminating domestic livestock carcasses traditionally fed on by vultures. Prior to the ban of diclofenac in these regions, it was prevalent in livestock carcasses and caused substantial population declines of three species of *Gyps* vultures in South Asia (Shultz, et al. 2004).

After ingestion of livestock carcasses treated with diclofenac near to their death (eg, before it has been metabolised by the animal), birds die as a result of visceral gout due to kidney failure. Death of the bird usually occurs within a few days of exposure (Green, et al. 2004).

Small quantities of didofenac may kill an individual or group of vultures. Population modelling shows that just 0.1–0.8 per cent of carcasses need to contain lethal levels of didofenac to have caused the observed decline in vulture numbers (Green, et al. 2004). Therefore, very few carcasses need to be contaminated to result in a population decline in vultures. This may also be partly related to the tendency of vultures to feed in flocks.

There are a number of NSAIDs that may be toxic to scavenging bird species, including ketoprofen, aceclofenac, carprofen, flunixin and acetaminophen. Ketoprofen was found to be toxic to *Gyps* vultures, and perhaps a wider range of avian species (Naidoo, et al. 2010). At least two species of *Gyps* vultures are likely to experience toxic effects from ketoprofen at doses that birds could encounter in the wild (Naidoo, et al. 2010). Mortality in male eider ducks has also been associated with ketoprofen (Mulcahy, Tuomi and Larsen 2003). Aceclofenac is converted to diclofenac and its metabolites found in all mammal species tested to date raise concern that these same pathways will be followed in livestock. Carprofen and flunixin appear to carry a high risk of renal damage in birds. One study found mortality associated with the use of carprofen and flunixin in 30 per cent of cases of over 870 birds from 79 species (Cuthbert, et al. 2007).

Acetaminophen, a NSAID recently introduced to veterinary use for the treatment of domestic animals, did not have toxic effects in a study on chickens (Jayakumar, et al. 2010). The same study found toxic effects from didofenac. Therefore, acetaminophen may be an option to further explore for the treatment of livestock without risk of toxic effects on birds. Meloxicam is of low toxicity to *Gyps* vultures and a wide range of other raptors and scavenging birds. Meloxicam is out of patent, licensed for veterinary use in India, and considered a very effective NSAID to treat a variety of livestock ailments. The treatment of meloxicam on 60 different bird species with a sample size of 739 birds resulted in no mortalities (Cuthbert, et al. 2007).

The results of one study show that certain NSAIDs are toxic to raptors, storks, cranes and owls. Mortality was found following treatment with didofenac, carprofen, flunixin, ibuprofen and phenylbutazone (Cuthbert, et al. 2007). Of particular concern is the mortality of a Marabou stork (*Leptoptilos crumeniferus*) following treatment with flunixin. The extent to whether NSAIDs are posing a risk to birds in the Rift Valley/Red Sea flyway is unknown (Tucker 2005). However, with the

potential to cause devastating declines, further research is urgently needed to identify whether there is a risk in this region to scavenging bird species.

Part two: guidelines to prevent poisoning of birds

The recommendations, below, are proposed to minimise the effects of agricultural chemicals on migratory soaring birds. As a whole, the guidance includes both non-legislative and legislative recommendations involving communities, industry, conservationists, and government working to limit impacts of agricultural chemicals on biodiversity. Where possible, priority is given to supplementing existing projects and initiatives to benefit birds and ecosystems generally.

1. Recommendations for crop protection from insect pests

1.1 Substitute (remove and replace) substances of high risk to birds

An effective pesticide regulatory system limiting effects on birds includes both preventative and evaluative factors to: (1) ensure substances of high risk to migratory birds are not permitted for use in activities that could result in exposure of migratory bird populations – preventative; and (2) allow for removal of substances if evidence indicates risks to migratory birds from their use – evaluative. These Guidelines focus on the latter, although the risk assessment process for new products also needs further development in both developed and less-developed regions (Forbes and Calow 2013; Murfitt 2012; Kramer, et al. 2011; Sala, Cavalli and Vighi 2010), including a focus on implementation and enforcement of the existing framework, which could be done using, for example, farming cooperatives.

National pesticide regulatory systems' should include an evaluation mechanism, which incorporates a mandatory review/evaluation process of approved pesticides with criteria to adjust labelled/approved uses to minimise effects on birds, if new evidence surfaces. To ensure a re-evaluation process is triggered when risks to migratory birds may occur (Mineau 2003), a monitoring system needs to be put in place to regularly assess risks of pesticides and will provide an information platform for participatory research. Monitoring of insecticide use and recording of effects on migratory birds should be part of the required mitigation plan at the stage of the original product use approval. This should include expansion of capacity building, education and collaboration at the policy and end-user levels.

Better education, particularly, in schools, universities and rural communities, including the development and integration of bird and biodiversity protection and conservation studies into curriculums, will allow for effective monitoring of pesticide effects on birds by communities and pesticide users.

Additionally, legislation should be introduced to make possession of obsolete pesticides illegal. This would incentivise farmers to voluntarily return obsolete pesticides to authorities, which, in turn, would limit the likelihood that these would be available for crop protection and predator control. A national strategy, building on the legislation, with action plans at different levels (eg, local, community, grassroots initiatives) could be used to define the key stakeholders and set long and short term objectives.

A regional memorandum of understanding (MoU) between neighbouring countries should be encouraged for better assessment, cross-border movements, management and control of pesticides, as many countries face similar and interconnected issues associated with pesticides, particularly with obsolete stocks. This MoU could also define a focal point in each country for effective coordination and communication and encourage investment in research for safe alternatives.

1.1.1 Include criteria on birds when prioritising areas for obsolete pesticide removal programmes

Many developing countries import pesticides to increase agricultural production and control vector-borne diseases such as malaria. Over time, unused pesticides become obsolete and unsafe for use. Today, across Sub-Saharan Africa, more than 50,000 tons of obsolete pesticides litter the landscape.

Often, the most harmful substances for birds are older compounds. Many of the now highly regulated stocks of pesticides exist in stockpiles throughout the Rift Valley/Red Sea (El-Shahawy and Simeonov 2013). These obsolete stocks are owned by national governments (eg, locust control insecticides) and by farmers. Over the last 10-15 years, various projects have been made to clear up stockpiles (mostly by the FAO), and in 2005 a continent-scale initiative started in Africa. In 2005, the Global Environment Facility (GEF) committed US\$25 million along with substantial funding from other sources, including industry, to clean up stocks in Ethiopia, Mali, Tanzania, Tunisia, and South Africa. As of today, 3,310 tons have been removed from 897 sites under the Africa Stockpiles Programme (ASP), involving African countries, international organisations, NGOs, the private sector through CropLife International, and regional bodies. A key element of success of these programmes has been ensuring stocks are centralised with concurrent awareness campaigns for farmers, technical officers and policy-makers on the need to develop and promote alternatives.

In the Middle East, as well as Africa and other developing countries, the FAO programme on the Prevention and Disposal of Obsolete Pesticides can assist states with removing existing products and preventing re-accumulation (FAO 2013). The Programme makes developing countries aware of the hazards associated with obsolete pesticides stockpiles and what they can do about them. One of the ways it does this is by organising national and regional workshops on the issue, involving government, NGOs, industry partners and growers.

International assistance is usually needed to dispose of obsolete pesticide stockpiles. However, there is a lot that individual countries can do to prevent the accumulation of obsolete pesticides and minimise the environmental and public health hazards posed by these stockpiles. By taking a leadership role in the disposal process, eg, creating an inventory of obsolete pesticide stockpiles, developing countries can reduce costs and significantly increase their prospects for international financial assistance.

An extensive training programme has been developed to assist developing countries take a detailed inventory of their obsolete pesticide stocks; see Figure 6 focusing on the removal of obsolete pesticides in Ethiopia. The FAO Programme has also published guidelines on preventing the accumulation of stocks, as well as pesticide storage and stock control, and inventory taking.

Figure 6: Case study of obsolete pesticides in Ethiopia

Ethiopia has accumulated obsolete pesticide stocks since pesticides were first imported in the 1960s due to prolonged storage of pesticides, inappropriate storage conditions/poor storage facilities, untrained staff, and a lack of national legislation for pesticide registration and monitoring system of pesticide use in the country.

Approximately 1,000 tonnes of accumulated obsolete pesticides have been destroyed under the FAO programme, including organochlorines (258.3 tonnes), organophosphates (155.4 tonnes), carbamates (58.5 tonnes), and others. The remaining stocks in the country are due to be destroyed.

Along with the disposal process, a number of activities are being implemented to prevent future pesticide accumulation. These activities include the development and enforcement of pesticide policy, the implementation of integrated pest management, capacity building in terms of providing professional trainings, creating awareness among stakeholders on the environmental and human health hazard posed by obsolete pesticides, as well as other actions to prevent their accumulation, and enforcement of national legislations and policies related to pesticide use.

1.1.2 Install pesticide container management scheme

The management of pesticide containers is a significant factor in preventing risks of bird poisoning. Containers need sufficient labelling requirements so that their contents are used correctly; and when they are finished or no longer needed, adequate disposal to limit likelihood of containers being re-used for counterfeit products or contributing to stockpiles of old and/or obsolete products.

Pesticide container management schemes should be made mandatory, run by industry or government, and supported by, for example, levies on container suppliers and/or users or pesticide sales tax.

Labelling requirements on containers

The container label plays a vital role in communicating information about the pesticide, its hazards, safety information and its use, and should include bird toxicity information in local languages and in symbols to be effective in low-literacy areas.

Containers should also have labels with information about how they should be cleaned and disposed of following their use. As part of a country's pesticide registration process, the standard of containers allowed to enter the market can be strictly controlled to ensure that these design and labelling requirements are met.

Stakeholder involvement

For a successful container management scheme it is important to engage and involve all stakeholders, particularly in the development of the scheme. These include:

- governments and their agencies whose responsibility it is to set up and to regulate the legal framework for pesticide registration, pesticide use and disposal of waste materials, and to determine the mechanisms for funding the scheme;
- manufacturers, importers and suppliers who are responsible for compliance with pesticide and waste regulations, good practice in product and container design, product stewardship throughout the supply chain and who, in many cases, fund and manage the container management scheme;
- users, whose responsibility it is to manage and use pesticide products in a safe, legal and responsible way, including the return of the empty containers for appropriate recycling/disposal;
- NGOs, agricultural colleges and schools, extension services, farmer cooperatives and associations who are well placed to raise awareness of good practice in pesticide use, and in some cases to run container management schemes; and
- waste management and recycling organisations.

Establishing a steering committee and stakeholder forum early in the process should be a priority. Further guidance can be found in FAO's Code of Conduct and FAO's Country Guidelines, as well as the European Crop Protection Association (ECPA) Container Management Guidelines.

1.1.3 Incorporate effects on birds into Integrated Pest Management principles

Integrated pest management (IPM) is a strategy that encourages the reduced use of pesticides by employing a variety of pest control options in combination to control and manage pests (Shojaei, et al. 2013). IPM protects crops from yield losses while offering the least amount of disturbance to ecosystems (FAO 2013). Studies have shown a 20 per cent reduction in pesticides using IPM; furthermore, it yields greater biodiversity than conventional farming methods (Freier and Boller 2009). Effective IPM reduces pesticide use, thereby reducing likelihood of exposure of migratory birds to pesticides, and should be the first course of action for fighting crop pests.

IPM is not a 'one size fits all' solution, but is location specific and combines all suitable pest control techniques with the needs and situation of the farmer, including economic factors. Understanding how a crop grows and interacts with the local environment is necessary to the successful implementation of the scheme (CropLife 2011). Farmer Field Schools (FFS) are used to provide a knowledge base to growers about a specific crop. A skilled person meets regularly with a group of farmers where they observe, record and discuss what is happening within their own fields.

During the 1980s-90s national IPM programmes were launched throughout the developing world. The Food and Agriculture Organisation (FAO) run the most successful of these projects, including implementing the Regional Integrated Pest Management Programme in the Near East using Farmer Field School (FFS) techniques. This programme was put into action by non-governmental organisations with the support of industry, such as CropLife, a membership organisation representing agricultural and chemical companies, and have trained 3 million people from government bodies, retailers, distributors and end users on IPM techniques. Both the FAO and CropLife have guidance available to implement IPM within countries in the Middle East North Africa region.

Education is a key method of reducing pesticide usage, regarding particular harmful chemicals, cultivation practices, forms of pesticides, exposure times and impact on ecology will minimise the risk. Additionally, existing alternatives to pesticides should be implemented, such as soft pesticides and push-pull cropping strategies (planting both attractive and repellent crops in close proximity to the high-value crop).

CropLife and the FAO have implemented IPM programmes, with varying degrees of success, throughout the countries in the Flyway. Egypt, Jordan, Lebanon, Palestine, and Syria are part of the FAO IPM programme in the Near East. This programme began in 2004, and focuses on local adoption of IPM strategies (FAO 2013). FFS are the core activity in promoting IPM and farmers are encouraged to participate to gain knowledge of local ecosystems using this approach (FAO 2013).

As many countries within the Red Sea/ Rift Valley Flyway already have IPM strategies in place, the primary focus should be to ensure these are successfully implemented within the agricultural sectors and to re-evaluate these strategies and include methods to reduce poisoning risks to migratory bird

species (particularly in high risk areas, such as bottleneck sites). Focus could then move to those countries without any IPM guidelines in place. Using lessons learnt from successful IPM projects in the region, governments should draw up guidelines to include IPM in national legislation.

CropLife Africa Middle East implemented programmes in 2002 across Sudan, Ethiopia, Saudi Arabia, Yemen, Egypt, Jordan, Lebanon, and Syria. Eritrea and Djibouti don't yet have IPM programmes. Programmes focus on local application, using FFS to promote local knowledge, understanding of ecosystems, and training on correct procedures used to reduce pesticide usage and reliance. However there is limited evaluation of what works, opportunities to improve IPM, and how these improvements could be applied to developing countries.

Neither of the programmes currently in practice in the Flyway takes special consideration for migratory bird populations. The IPM programmes administered by various organizations, such as CropLife and FAO, could be tailored to take into account specifications for migratory bird populations, this could be achieved by modifying the use of highly toxic chemicals and spray times and quantities for pesticide use to coincide with migratory or breeding times with a focus on bottleneck sites and high risk areas within the flyway. For example, CropLife has established a project in Zambia, which has been replicated in other countries, to improve the application of pesticides by training people as spray service providers; see Figure 7. The Spray Service Provider training materials could be adapted to include consideration of migratory birds. With such inclusions, the training would have added value especially when applied throughout the Flyway.

These considerations will minimise the risk of poisoning of migratory birds by pesticides. Furthermore, for IPM to be successfully enacted, a high level of advocacy targeting various players within the programmes must be adopted by governments.

Figure 7: Recommendation to improve Spray Service Provider Programme

The Spray Service Provider Programme's main objective is to establish a network of Spray Service Providers (SSPs) for the safe and effective application of pesticides. An SSP is a lead farmer who receives specialised training in the application of pesticides and then hires out his services to fellow farmers to spray their lands.

Establishing an SSP network attempts to prevent untrained farmers from handling pesticides, only allowing those who are properly trained and certified to do so. The advantages of SSPs include better application of pesticides with less likelihood of use inconsistent with label requirements, avoiding over- or under-application, less risk to people and the environment, better management of empty containers and less accumulation of obsolete pesticides.

The SSP training programme focuses on understanding pesticide labels, the different classifications of pesticides, transportation and storage methods, and best practice for preparation and environmentally responsible use in the field. Once they have received the training, these farmers become official Spray Service Providers (SSPs), and are now servicing the rest of their farming communities.

In Zambia, the programme has trained a total of 115 SSPs from member companies and in turn, they trained farmers to become SSPs. As of October 2012, a total of 1,250 SSPs service almost 10,000 farmers. As such, the programme has provided a successful model for passing on knowledge and skills to small-scale farmers.

The education programme also reached out to pesticide dealers to ensure that shops are managed responsibly and stockists can give accurate advice to farmers buying pesticides.

The SSP scheme addresses the growing number of counterfeit pesticides are entering the Zambian market. Without proper guidance, small-scale farmers are vulnerable to mistaking counterfeit pesticides for industry-certified products. The SSP scheme trains participating farmers on how to avoid using harmful counterfeit products, and at the same time relieves other farmers from the responsibility of purchasing and storing pesticides, as SSPs take on that role within villages.

Benefits to birds from this programme include less use of older and more toxic obsolete pesticides that are likely to be risky to birds through training on which products to use, effective applications of pesticides that are less likely to result in exposure of birds, and a tighter supply chain by giving responsibility of purchasing and storage of pesticides to certified SSPs and thereby limiting access to obsolete/illegal insecticides.

Improvements to the scheme could provide further benefits to birds. Training on how to mitigate potential exposure routes to birds through appropriate insecticide application methods and timing, as well as the use of substances that are less likely to be toxic to birds, should be incorporated into the scheme.

Uptake of IPM, so far, has been slow in both the developed and developing world (Ohmart 2009). A number of methods could be employed to encourage the implementation of IPM.

The transitional period, moving from traditional high pesticide use, to IPM involves learning how to use new technologies and improving farmer's decision-making abilities to suit their needs (Brewer, et al. 2009). This transitional period is considered to be a difficult process, and may take time to adjust to. Support or consulting services could be made readily available to aid in this process, offering advice for farmers who need it, this could be achieved through online or telephone consultancy services, or through an expert consultant readily available within the area (Brewer, et al. 2009). As previously mentioned some farmers lack assurance in alternative pest control processes (Shojaei, et al. 2013), though with education and social learning environments this could be addressed. Economic barriers, whether real or perceived, can be a barrier against implementing IPM (Skevas 2012). Methods to overcome these barriers are discussed below.

Studies have shown consumers prefer foods with sustainable labels (Durham, Roheim and Pardoe 2012). Methods, such as eco-labelling or certification will therefore increase the attractiveness of products against their market competitors, ie, non-IPM products.

Figure 8: Examples of current incentives employed in the Red Sea Flyway

Egypt is currently using an IPM certification method; once trainees have completed their IPM training course they are issued with an official certificate and a license to operate using IPM techniques from the Ministry of Agriculture and Land Reclamation (CropLife 2011).

Jordan is eco-labelling the crops that have been grown using IPM systems to make them more attractive to consumers (FAO 2013). However, this initiative was prevented from being successful because of the lengthy method used to authenticate products. Re-establishment is recommended of this programme with revised product authentication methodology, and if successful applied on a wider basis within the Flyway.

Economic incentives could be used to persuade farmers to implement IPM. Governments subsidising certain products promote pest management alternatives (Skevas 2012). For example, Lebanon is currently providing free traps, encouraging pest prevention methods, and discouraging pesticide usage (FAO 2013). Subsidies are particularly relevant in campaigns to control outbreaks of locusts and rodents, often led by government, which should be done in a manner consistent with IPM principles and avoiding aerial application of substances likely to affect birds (for example, certain carbamates and organophosphates).

Spreading awareness of the effects of pesticides not only on human health but on the health of local wildlife could improve decision-making on pesticide use. Therefore, integrating information regarding the importance of migratory birds, and the impacts pesticides have, during the FFS will raise insight into the impacts. Furthermore the ecosystem services provided by migratory birds should be included in these sessions. Ecosystem services illustrate the social, economic and environmental benefits received by our natural environment, in this case migratory birds (DEFRA 2010). Highlighting benefits to the agricultural environment provides an economic and social value to the birds that aid their protection.

A combination of pest control strategies is recommended to manage pests and promoting use of traditional knowledge about natural solutions, with limited use of substances of risk to birds, and therefore less impact on migratory birds. When pesticide use is necessary, employ methods that are less likely to expose to migratory birds and/or products which are less toxic to migratory birds; for example, spraying pesticides outside of migration periods when birds are using agricultural habitats as wintering areas or stopover sites. IPM techniques should incorporate bird friendly pesticide practices and cropping strategies and be included in programmes as they are evaluated.

1.2 Create restricted pesticide zones in high risk areas

In high-risk areas, such as bottleneck sites, insecticides of risk to birds can be limited by creating restricted pesticide zones. These zones would restrict the use of pesticides of high risk to birds and could include existing protected areas and public areas (European Parliament and Council 2009). A network of restricted pesticide zones throughout the Red Sea Flyway may be an effective way of ensuring a reduction in exposure to pesticides within high-risk sites.

Key areas of the Rift Valley/Red Sea flyway, eg, bottleneck sites and Important Bird Areas (IBAs), should be made into restricted pesticide zones. Reducing pesticide usage within these zones will likely minimise exposure of birds. The primary focus should be on limiting the use of organophosphates and carbamates of risk to birds for crop protection in these areas. These should be replaced with pesticides of a lower toxicity to birds, or through alternative pest control techniques.

Restricted pesticide zones can be implemented using a number of methods, both legislative and non-legislative. Legislation, either in national or local government, may control the use of hazardous substances, ie, pesticides, replacing them with safer alternatives, or require agreement from an authority prior to the application of pesticides in a protected area (Department for Environment, Food and Rural Affairs 2012).

Figure 9, below, illustrates how conservation zoning plan can control the use of pesticides, and other harmful activities, on the Yemen islands of the Socotra Archipelago.

Figure 9: Case study of a pesticide free zone on Socotra Archipelago, Yemen

The pesticide-free Socotra archipelago located 380 km off the Yemen Coast is one of the most biodiversity rich and highly endemic islands in the world. They are also home to over 160 migratory bird species.

Due to the four islands' isolation, the population is self-sustaining with strong traditional rules and practices have been set place to protect the natural environment (Scholte, Al-Okaishi and Suleyman 2011). For example, the population currently carries out monthly fishing rest periods. The main agricultural practices on the island include livestock and date plantations. Currently no persistent pesticides are used on the island (Porter and Suleiman 2013).

Conservation efforts, for birds and other wildlife, started prior to any major development. This allowed for regulation and guides to infrastructure building and commercialism to minimise any environmental damage (Socotra Governance and Biodiversity Project, UNDP 2013).The island was divided into four zones in 2000, known as the Conservation Zoning Plan (Hakim 2002).

The Resource Use Zone, ensures the long term protection of unique bird life, as well as a sustainable flow of products and services to meet community needs (The Environment Protection Council 2000). The practices of this are to be enforced by the community. The General Use Zone contains sites of significant level of habitat modification and/or resource exploitation that has already occurred. The National Park, which contains natural areas of land or sea designated to protect, and exclude any exploitation. Lastly, the Nature Sanctuaries, which are unmodified or slightly modified land or sea areas that retain their natural character and influence (The Environment Protection Council 2000). The protected areas are managed through the Environmental Protection Authority and the local community.

There are a number of IBAs throughout the Flyway, they have been identified as significant sites for the long-term viability of naturally occurring bird populations. However designating a site as an IBA, does not mean the site is protected under any formal mechanism (Asmar 2009). These are distinct areas of land available for practical conservation, legal protection, management and monitoring. The IBA programme aims to guide the implementation of national conservation strategies, through the promotion and development of national protected-area programmes (Birdlife International 2014). The flyway currently has 328 sites designated as IBAs, and protection of these areas is considered to be an essential minimum. It is therefore recommended that additional restricted pesticide zones are introduced to ensure there is a sufficient network of restricted pesticide zones to prevent impacts across migratory range are established within the Flyway.

Training local communities and farmers about the benefits of protected areas may also help reduce pesticide use in restricted areas. Furthermore, allowing the area to be managed by local peoples serves as an alternative to prevailing top-heavy state declared management (Makhzoumi, et al. 2012). Local peoples have an increased knowledge on biodiversity issues specific to the area, which in turn leads to effective management and better enforcement through a sense of stewardship of the local site (Aziz No Date). Top-heavy state management can lead to a loss of stewardship and therefore a loss of interest in the area and its biodiversity (Makhzoumi, et al. 2012). Motivation for community management can be derived from a number of places, economic, cultural, religious, recreational, or livelihood supporting values (SPNL 2013).

Community engagement and involvement in protected area conservation is vital, this is increasing achieved through Local Conservation Groups (LGCs) (Birdlife International 2014). Figure 10 provides an example of local conservation management in a protected area in Lebanon. Furthermore, much

of the promotion and education on the protection area often comes from non-governmental organisations, endorsements and encouragement.

Figure 10: Case Study from Hima, reduced pesticide usage in Lebanon

Hima refers to an ancient natural resource conservation system, the traditional forest protection and management scheme (Asmar 2009). In 2003, the area Ebel Es-Saqi, in the South East of Lebanon was designated as a Hima. The area witnesses the passage of 2 billion birds per year; agriculture is the major land use within the Hima (Birdlife International 2013). The protected area is under the jurisdiction of the Ministry of Agriculture and the Ministry of Environment (SPNL 2013).

Local community groups (Site Support Groups) are used to manage the in-situ biodiversity, the groups are networked together to provide an exchange of experience and skills. The Hima has historical and deep rooted meaning for local peoples as a form of human wellbeing not just of conservation, therefore with higher incentive to protect the area (IUCN; SPNL 2007).

Continuous awareness of practices, threats to birds and other wildlife, and importance of the Hima, is taught through activities in local schools. Ebel Es-Saqi is a newly established Hima, work is being undertaken with farmers to reduce and eventually eliminate the amount of agro-chemicals used on their lands. Laws are set which ban wood felling, hunting, and construction of large infrastructure. Livestock grazing is also restricted and the Site Support Group has drawn up a strict management plan to oversee and enforce the laws (SPNL 2013).

The Hima encourages eco-tourism, bird-watching and hiking activities, all of which bring economic benefits to the local area (Asmar 2009). This economic benefit may aid in the protection of migratory birds.

Within and outside Pesticide Restricted Zones, incentives will be necessary to change farmers' behaviour towards pesticide use. Monetary incentives are often short-term, ending with the completion of the subsidies. In contrast, non-monetary incentives, such as social influence, personal satisfaction derived from being environmentally responsible, attachment to a cause (eg, declining bird populations), and locally-developed policies can be an effective and long-lasting motivation to change farming practices (De Young, et al. 1993; Pieters 1991). Precise information on how, where and what to do is essential for uptake of new techniques (Jacobson, et al. 2003). Therefore, education programmes with local stakeholders (building on influencing strategies produced by the Convention on Biological Diversity/IUCN²), which include non-monetary incentives, should be a key focus for implementation of these Guidelines.

Restricted pesticide zones are particularly important for migratory birds, as farmland is important habitat for birds to live, feed and reproduce (Voluntary Initiative 2009). Based on this, it is advised that all conservation zones and farmland in high-risk areas use pesticides that have a reduced toxicity for bird life, especially during migration periods.

The IUCN has published a Protected Areas Programme for North Africa-Middle East Region called 'PARKS', this is designed to strengthen international collaboration between area management teams and to enhance their role, status and activities. The Programme analyses efforts to protect areas of

² Convention on Biological Diversity/IUCN resource on influencing stakeholders: <http://bch.cbd.int/protocol/outreach/CBD-Toolkit.pdf>.

important environmental significance and details important lessons to be learned from their protection. This includes a number of examples of the establishment and operation of protected areas within the Red Sea Flyway. Restricting pesticide use should be incorporated into the programme's action plan, by including it in the objectives. This can be incorporated in the effective management, by restricting the use of pesticides in protected areas, and increasing awareness of the effects of high-risk pesticides at all levels within the region.

2. Recommendations for crop protection from quelea

Quelea have the potential to cause significant agricultural crop losses and management is often needed to minimise those losses. The two most popular control mechanisms, chemical spraying of fenthion and the explosion technique, result in risks to non-target wildlife, particularly putting predator and scavenging birds at risk of primary and secondary poisoning. Consequently, two alternative quelea management techniques are recommended below and they would work well together.

2.1 Apply integrated pest management to change cropping strategies and reduce pesticide use

Small-grain-crop damage by quelea is largely caused by a lack of alternative natural food sources, such as wild grass seeds, which they prefer.

Crop protection strategies should be developed for each particular damage situation. The FAO currently encourages the use of integrated pest management (IPM) approaches, such as working with farmers in examining all aspects of farming practices in relation to quelea damage, and seeking to minimise pesticides. It includes modifying crop husbandry, planting time, weed reduction, crop substitution (eg, maize, which quelea do not consume), bird scaring, exclusion netting, and only uses chemical control for birds directly threatening crops when other methods have failed.

Damage from quelea is related to agronomic factors, such as time of planting and ripening of wheat in relation to quelea migration. Hence, timely operations of some of the agronomic practices related to wheat production, on their own, will reduce crop damage and also result in reduced pesticide usage.

Where damage is caused to irrigated crops in the dry season or to wet season crops grown along bird migration routes, alteration of crop phenology is appropriate. Movement away from winter wheat and barley may be an effective way to limit quelea damage. However, if there are substantial irrigation costs (if a change of seasons), this option may be unviable (Mundy 2000). Where control cannot be avoided by earlier planting of crops, it has to be timed to occur before young birds fledge and increase the population size (Elliott and Allan 1989). Control operations should also be limited to where crops are at risk, taking into account maximum quelea movement and crop growth stages, eg, the soft milk stage of the wheat is more vulnerable to quelea damage compared to the hard grain stage, reduces damage.

Non-target mortality, resulting from direct poisoning in sprayed roosts or colonies, and secondary poisoning through consumption of contaminated pretty items, can be much reduced by restricting

control only to those sites where economic damage to crops actually occurs. Large breeding colonies or roosts are unlikely to threaten vulnerable crops further than 10km and 40km away, respectively.

Where damage is caused by newly independent young, which is often the case when juvenile quelea emerge out of local breeding colonies nearest to the cultivated lands, destruction of nearby breeding colonies may be needed, through, for example, harvesting of chicks.

Another solution to reduce pesticide use and crop damage due to quelea is to grow winter cereals with bigger grains or those with sharp awns to deter the birds from eating the grain.

If control using chemicals, such as fenthion, cannot be avoided, it should be applied using best practice. Measures such as deterring non-target birds from the area before application and to remove quelea carcasses immediately after chemical application should be included in any control campaign. Aerial sprays should be avoided whenever possible.

2.2 Harvesting quelea as a food source

Studies have found mass trapping and chick harvesting to be more environmentally-friendly control methods than spraying or use of explosives, with the added benefit of providing high quality protein, uncontaminated food, and income generation for the trappers (Mtobesya 2012). The nutritional content of quelea is high, with a greater calorie content than mammalian meat and around five times the protein found in staple cereals.

Trapping and selling quelea for food is an important economic activity in some areas, eg rural Chad, and has been estimated to have an annual income from the sale of approximately 7 million quelea would cover 40 per cent of agricultural crop losses (Mullière 2000). If trapping was targeted at roosts responsible for crop depredations, then the value of quelea as a natural bush product could at least match grain losses.

The most widespread and easiest method of harvesting quelea is the collection of nestlings from breeding colonies just before they fledge.

Birds that have been sprayed should not be harvested for human consumption as they present a human health risk of poisoning. In other areas, the consumption of birds by people may be undesirable culturally. It is therefore recommended that harvesting for human consumption occur in areas where birds are a traditional food source.

3. Recommendations for crop protection from rodent pests

3.1 Use best practice to prevent and manage rodent irruptions

Rodent irruptions, as can occur in regular cycles or irregularly following events such as abundant rainfall, attract raptors (Pavey and Nano 2013). Many different landscapes and habitat types are subject to rodent irruptions (Luque-Larena, et al. 2013). Rodenticides are sometimes used, and when used, they can be deployed over large areas (Jacob and Tkadlec 2010). Rodenticides can be a risk for non-target species, and can impact large numbers of raptors in grassland areas, when used on a large-scale during rodent outbreaks (Olea, et al. 2009). Second generation anticoagulant rodenticides (SGARs) should not be used for rodent outbreaks, as they have a higher toxicity to birds than first generation anticoagulant rodenticides (FGARs). If resistance to first generation products has been identified, use instead preventative rodent damage measures. Preventative measures could include eg, synchronous planting of crops and good field sanitation to limit resource availability/length of planting season (Htwe, Singleton and Nelson 2012; Davis, et al. 2004). If SGARs are used, then they should be deployed in a manner to minimise harm.

Unavoidable treatment of rodent irruptions with second generation rodenticides should be completed using best practice guidelines to limit risks to migratory birds, particularly birds of prey, from rodenticide use. Best practice guidelines should be developed on a regional basis by users, regulators, and other stakeholders, and encompass:

- treatment options, eg, timing of rodent management – if done at tillering stage it can have better results than if done later in crop growth (Phung, et al. 2012; Buckle and Smith 1994),
- alternative mitigation techniques to minimise risk when SGARs are used (Singleton 2010),
- monitoring and evaluation of outcomes, and
- information shared/education with agricultural community (Palis, et al. 2011).

The best practice guidelines should also be followed when using any substances, not limited to anticoagulant rodenticides, of risk to birds to treat rodent outbreaks. The governments in the Rift Valley/Red Sea Flyway should monitor rodent irruption treatments to ensure SGAR use is minimised and best practice is complied with. These recommendations are designed to reduce both the toxicity and exposure of pesticides to migratory soaring birds.

3.2 Restrict/ban SGAR use in open field agriculture

The likelihood of exposure to SGARs used in open-field agriculture is high for migratory birds where these substances are applied. In many areas rodents are not resistant to the first generation anticoagulant rodenticides (although, in certain places in the region, rodents may display some natural resistance), which may be a reflection of a lack of historical use of anticoagulant rodenticides in the Rift Valley/Red Sea area. Therefore, the less toxic and persistent first-generation anticoagulant rodenticides (FGARs) can be effective in these areas, while minimising the risk to migratory birds.

To identify whether FGARs would be an effective alternative to the more toxic SGARs, new tools are available to test for FGAR resistance making it easier to switch to first-generation ARs in areas lacking resistance (Endepols, et al. 2012; Prescott, et al. 2007).

In resistant open-agriculture areas, exploration and introduction of alternatives to SGARs should be done where appropriate, including trapping of pests, integrated pest management strategies, and crop rotation (Eason, et al. 2011; Sudarmaji, et al. 2010; Laxminarayan 2003). Alternatives to anticoagulant rodenticides will not only limit risks to non-target wildlife, but will also reduce the spread of resistant rat populations (Lambert 2003); see Figure 11 for examples of alternatives to rodenticides.

Figure 11: Case study of alternative rodent control technique: use of barn owls to control rodents

Within the Middle East, a large number of nest boxes, which are used to attract barn owls and other potential raptor species, have been constructed in farmland areas (implemented in many regions of the world). These are typically placed about 200-400 m apart, and are used to decrease the use of rodenticides. The birds prey on agricultural pests species and overall over 1000 nest boxes have been constructed over seven regions within the country (Charter 2013). Preliminary studies of the diet of barn owls showed that Jordanian barn owls preyed on 91% rodents. Barn owl presence has also been shown to have a positive effect on crop yields (Motro 2011). The installation of nest boxes is much less costly than regular rodenticide control campaigns (Paz, et al. 2012).

In many countries in the Rift Valley/Red Sea, SGAR rodenticides are provided by the government to farmers. Adoption of these guidelines could initially focus on the countries where a change in government supplied SGARs to alternatives is possible, and then move on to countries where legislative changes are necessary to prevent SGAR use in open field agriculture.

3.3 Prohibit permanent baiting

Permanent baiting, where baits are placed year-round and, often, infrequently monitored, is a source for risk of exposure for non-target species, such as birds. If rodenticides are used only when rodent infestations are present, it will limit non-target wildlife exposure to rodenticides, particularly to SGARs, which are widely applied in a permanent baiting way (Laakso, Suomalainen and Koivisto 2010). Many professional pest controllers use permanent baiting with anticoagulant rodenticides as standard procedure (Cefic 2013). Permanent baiting may also be a factor associated with anticoagulant bait-resistance in rodents (Klemann, Esther and Endepols 2011).

Best practice guidelines on rodenticides:

- discourage the use of rodenticides as monitoring tools,³ and
- encourage programme baiting, in which rodenticides are applied only when infestations are present, followed by bait removal.

However, there are issues with user awareness and implementation of best practice (Tosh, et al. 2011). This indicates that efforts need to be made to raise user awareness of best practice guidelines.

Regulatory changes in the eleven target countries in the Rift Valley/Red Sea Flyway may also be necessary to prevent permanent baiting being used as a routine practice. This could include changes to label requirements and monitoring users' compliance with label requirements.

³ Rodenticides are sometimes used as a monitoring tool to detect the presence of rodents, eg, if bait is taken then rodents may be present.

4. Recommendations for protection of livestock from predators

Livestock predation is the most common source of human wildlife conflict (Mateo-Toma, et al. 2012). Poison baits are the most widely used predator eradication method (Marquez, Villafuerte Vargas and Fa 2012). Addressing conflict is important for both migratory bird conservation and the livelihood of people living in the affected areas (Dickman 2006). Within the Rift Valley Flyway, farmers and landowners set baits for a number of predators, including wolves, jackals, leopards, foxes, feral dogs, baboons, hyenas, caracal, sand cats and wild cats (Bunaan, et al. 2001). This method is not species-specific and often results in inadvertent killing of non-target animals; for example, poison baits are used indiscriminately in Saudi Arabia; (Gasperetti, Harrison and Buttiker 1985), and poisoning carcasses for mass killing of wild carnivores is prevalent in Jordan (Bunaan, et al. 2001). Non-target species, including many migratory bird species, have experienced widespread declines, even local extinctions, due to the illegal use of poisoned bait (Márquez, et al. 2013).

Figure 12: Egyptian Vulture population decline in Spain due to poison baiting

Egyptian vulture (*Neophron percnopterus*) populations have been declining over the past few decades. Vultures are particularly susceptible to poison-baits due to their scavenging nature. A study illustrated that poison is the most likely reason for Egyptian vulture population decline in Spain (Hernández and Margalida 2009). Poisoning mostly affects the breeding adult population which causes population declines. Eliminating poison bait usage and offering supplementary feeding stations are two methods proposed to counteract this decline (Hernández and Margalida 2009).

4.1 Apply alternative predator control methods

To prevent the use of poison-baits in predator control, the drivers for poisoning must be identified. Predator control using poison-baits is often a human-wildlife conflict issue, eg, people fear livestock are at risk from predators. Both legislative and non-legislative techniques can be used to bring about a resolution to the conflict, which may be through, education of communities together with the use of effective enforcement techniques. The first step to any conflict resolution is to identify the reasons behind the problem and their drivers. These drivers are likely to vary significantly by region and industry in terms of what the key predators are, the livestock at risk of predation, and the economic value of the species being harvested using poison-baits.

An initial assessment of the problem can be gained by consulting with communities and those likely to encounter conflicts with predators, particularly the agricultural sector. Often the focus of the conflict is related to effective predation management and many resources are available on wildlife conflict resolution, see, for example, Decker et al's Practitioner's Guide to Human-Wildlife Conflict. The conflict should be resolved by working with community, industry and enforcement agencies (Decker, Lauber and Siemer 2002). Farmers must be offered practical alternative methods of livestock protection, such as, predator proof enclosures or guard dogs (Dickman 2008); see an example in Figure 13. This ensures their livestock is protected from predators and reduces the need for baiting.

Figure 13: Use of guard dogs to drive Baboons from agricultural land in Saudi Arabia

In the mountainous region of south-west Saudi Arabia, dogs are used to repel baboons (*Papio hamadryas*) from agricultural areas. The baboons quickly learn to avoid the dogs and therefore stay away from the crops or livestock in question (Biquand, et al. 1994).

A number of deterrents can also be used to stop predators accessing livestock or crops. Acoustic deterrents, such as beating drums, shouting, or cannon firing, could be used to discourage animals from entering the area (FAO 2009). This has found to be successful on a number of predators; however, this method also carries the risk of disturbing migratory or roosting birds. Olfactory deterrents can deter predators and other problem species from entering the agricultural area, for example, burning chilli plants is a known successful olfactory deterrent (FAO 2009). Intensifying human vigilance through guarding herds or taking active steps to defend their herds can stop animals from causing damage (FAO 2009). Animals also have a fear of humans and their presence can reduce the number of killings.

Educating individuals and raising awareness regarding law concerning the use of poison baits can help prevent usage (see Figure 14). Collaboration should be prioritised with the national governing bodies, the agro-chemical industry, farmers, the hunting community, and NGOs to publicise laws concerning poison-baits and the consequences for individuals, landowners, and wildlife. Promoting alternative methods of predator control, establishing ranger teams and environmental bodies who are specialised in poison-bait legislation and persecution will lead to improved enforcement and general public awareness. Furthermore, general public awareness to report any illegal poison baiting occurring should also be enhanced (Convention of Migratory Species 2013).

Figure 14: Raising awareness of the Arabian Leopard in the Rift Valley

Within Saudi Arabia, public awareness programs have been initiated in “leopard areas”, involving local people. Brochures regarding the conservation of the Arabian leopard, its CITES position, hunting laws currently in force and penalties, will be distributed in schools, police stations, and shops. The captive breeding programme is used to make the Saudi public aware of leopard conservation, and to generate funds (Judas, et al. 2006).

Campaigning and improving land use planning within the area are long-term solutions to discourage poisoning and other indiscriminate lethal methods of resolving wildlife conflict (FAO 2009). Furthermore improving the livestock protection within the area may reduce the number of deaths from predation. This, in turn, will reduce the amount of poison-baiting, and therefore minimise the risk that migratory birds, and other non-target wildlife, will be exposed to poison-baits.

4.2 Provide compensation and/or insurance for livestock predation

In addition to ensuring alternatives to poison-baiting are available for predator control, insurance and/or compensation schemes for farmers must be in place for instances when livestock are taken by predators. The use of compensation schemes run by government, NGOs and/or local community groups, are applied to alleviate the conflict caused by livestock predation. Compensation payments, upon livestock depredation and crop damage are given to the party reflecting their loss, reducing the motivation of property owners to kill wildlife illegally (Treves, et al. 2009). The compensation must reflect the actual value and replacement cost of the livestock lost to predators, as is demonstrated in the livestock compensation scheme in Figure 15 (European Commission 2013). The most effective compensation programmes are fast, fair and transparent. To be a success, an insurance scheme will need good collaboration between key government agencies and farmers involved in setting the standards of compensation, as this helps eliminate any existing policies that encourage human wildlife conflict (Bowen-Jones 2012).

Figure 15: Livestock compensation for Leopard predation

The World Wide Fund for Nature (WWF) developed a programme to compensate local people with in the Sumbar River Basin in Turkmenistan. The scheme compensates local ranchers with live animals, ie, directly replacing their taken livestock (Lukarevsky 2002). A flock of sheep were purchased using funds from WWF, which is managed by a local council. Ranchers were given a set period of time in which to report an attack to an expert. The expert then determines if a leopard killed the livestock and if the rancher properly managed his herd at the time of attack, if so, the livestock is then replaced. During a period for four months the council handed over 27 sheep as compensation for leopard attacks (Lukarevsky 2002).

Insurance schemes are a form of compensation payment, but require the participants to pay a premium for their involvement in the scheme, the premium then funds, at least in part the claim payments (Chen, et al. 2013). The insurance schemes can be set up and run by government, with collaboration from communities and other interested parties. The premiums paid in by participants can be set to the market rate, or subsidised by other organisations. Accurate assessment of damage to crops, livestock or human injury is required before payment is made. An assessment of the responsibility and care of farmers is also taken into account is shown below, in Figure 16. As local communities pay the premiums, they are less likely to submit false claims (Chen, et al. 2013).

Figure 16: Self-Insurance Scheme in Namibia

Developed in Namibia by Integrated Rural Development and Nature Conservation (IRDNC) and funded by the GEF Small grants Programme, the scheme aims to reduce the livestock losses of the conservancy members by offering payment for livestock mortalities, crop damage, and human mortalities or injuries (FAO 2009).

Incentives to use alternative predator control methods include lack of compensation for livestock killed within a protected area, if the livestock are outside of a secure enclosure at night, or if the farmers were pre-warned of predators in the area and took no action of bringing their livestock to safety. Conservancies paid out US\$14,300 for harm to livestock and people, as well as US\$1,012 for 43 crop damage claims (FAO 2009).

4.3 Effective monitoring and enforcement mechanisms

A key obstacle with legislative techniques is ineffective enforcement, from inadequate monitoring and surveillance (Wellsmith 2011). Wildlife conservation within crime agenda is generally given a low priority, and can lack political motion to prioritise this (Wellsmith 2011). Therefore, obtaining high-level political support for effective enforcement against wildlife crime across the entire Flyway, must be a primary objective.

A number of methods can be used to strengthen enforcement against poison baiting including:

- *Strengthening penalties*: a number of countries have reduced poisoning incidents within bird populations by introducing strong infringement penalties against those responsible (Ogada, Keesing and Virani 2012);
- *Consistent sentencing guidelines*: inconsistent legal outcomes undermine the credibility of the judicial system, and suggest a lack of seriousness towards wildlife crime (House of Commons, Environmental Audit Committee 2012);
- *Funding for the capacity of enforcement and monitoring*: insufficient funding is a key element of ineffective enforcement (Eliason 2011);

- *Vicarious liability*: imposes a criminal liability on a person whose employees/ agent/ contractor commits an offence (House of Commons, Environmental Audit Committee 2012);
- *Enforcement of supply chain*: restrict accessibility and use of highly toxic substances through product removal and certification policies.

Poison baiting issues vary between countries; therefore, legislation should be tailored to target both the drivers and usage of poison-baits with the region. This should be regularly reviewed, and include best practice recommendations (such as providing alternative predator control methods and insurance/compensation schemes), which are created with inputs from communities. The African Convention of Nature and Natural Resources, which prohibits the use of poison-baits, should be given priority for further adoption and implementation. Currently 40 countries have signed up, including Ethiopia and Sudan. However Egypt, Djibouti, and Eritrea are absent from the legislation. This existing Convention should be used to encourage the regulation of poison-baiting by supplementing, enhancing, or forming legislation. Memoranda of understanding can also be used between countries to encourage collaboration on implementation and enforcement.

Implementation strategies, coordinated by national governments, should be created with input from all stakeholder groups, local and regional authorities should be responsible for the implementation and administration of the enforcement and monitoring of the legislation (Giorgi and Mengozzi 2011), as well as regular reviews.

Increasing monitoring of poison bait will increase reported poison-baiting incidents, thereby, influence enforcement. Establishing monitoring teams within environmental bodies who are specialised in the investigation and prosecution of illegal poisoning will give ownership of these issues and drive increased enforcement. By educating the public to recognise wildlife-poisoning incidents as well as how to report suspected poisonings can lead to increased enforcement effectiveness. Additionally, veterinarians should report suspected illegal wildlife poisoning.

Restrictions must be imposed on accessibility to highly toxic substances. If a member of the public cannot obtain the substances readily, they may be disinclined to use them. Governments should communicate transparently with the agrochemical industry and growers to ensure that plans are endorsed and cover the key areas of concern to that region.

The flyway should establish consistent product removal policies, with the aid of the African Stockpiles Programme; this will limit the opportunity for farmers to access illegal pesticides. A further control would be to impose a restriction on the use of high-risk pesticides to only certified professionals. Without this certification, it should not be possible to purchase or use these high-risk pesticides. The restrictions establish traceability of pesticides, restrict their marketing and improve monitoring of substances used.

5. Recommendations for veterinary pharmaceuticals for livestock

5.1. Assess diclofenac use and monitor domestic livestock carcasses

The first step to understanding whether diclofenac poses a risk to scavenging bird species in the Rift Valley/Red Sea is to assess whether diclofenac is being used to treat domestic livestock. This assessment should be undertaken by governments, with input from the agricultural veterinary sector. If diclofenac is being used, it is also necessary to determine whether it is likely birds will be exposed to carcasses. For example, are livestock carcasses left in the open or are they unlikely to be disposed outside? Are domestic ungulate carcasses the primary food source for scavenging birds?

In areas where vultures are likely to be exposed to diclofenac-treated domestic ungulate carcasses, diclofenac should be removed from the veterinary pharmaceutical market and substituted with the safe alternative, meloxicam (see below). This will reduce the risk of future exposure of migratory birds to the high risk drug.

Once removed from the market, domestic ungulate carcasses should be monitored by government to ensure regulatory compliance. Priority for monitoring carcasses should be carried out in high-risk areas (eg, breeding sites of vultures). If continued use of diclofenac is present, vulture safe zones (see Convention on Migratory Species Minimising Poisoning Guidelines) can be created by working closely with communities, veterinary professionals and farmers to raise awareness and work collaboratively on solutions.

5.2. Immediately substitute (remove and replace) diclofenac for veterinary use in domestic livestock

Diclofenac, a previously popular NSAID for veterinary care of cattle in India, Pakistan, Bangladesh, and Nepal, is toxic to a number of vulture species. It resulted in the poisoning of scavenging vultures throughout India, Pakistan, Bangladesh, and Nepal by contaminating domestic livestock carcasses available to vultures. Prior to the ban of diclofenac in these countries, the drug was prevalent in livestock carcasses and caused substantial population declines of three Gyps vulture species in South Asia (Shultz, et al. 2004).

The use of diclofenac in regions outside South Asia may pose a risk of poisoning to other vultures. For example, the promotion of diclofenac on the African continent could pose a risk to vultures in this region, including the endangered African white-backed vulture (*Gyps africanus*) and Cape Griffon vulture (*Gyps coprotheres*) due to these species' sensitivity to diclofenac. Although, exposure levels may be different in areas outside South Asia, through, for example, the level of NSAID treatment of cattle (particularly, sickly and elderly cattle), removal of cattle carcasses from open areas and variation in bird diet.

To ensure diclofenac does not lead to declines of scavenging bird species in the Rift Valley/Red Sea, it should be removed from the market for the purposes of veterinary treatment of domestic livestock in areas where scavenging bird species could be exposed to contaminated domestic ungulate carcasses. Governments should place a ban on the trade and use of diclofenac within their country, this should be supported and adhered to by industry and farmers.

5.3. Mandatory safety-testing of NSAIDs of risk to scavenging birds

NSAIDs, including diclofenac, are widely used globally as veterinary pharmaceuticals to treat domestic livestock (Swan, et al. 2006). Determining the toxicity of diclofenac and other NSAIDs to scavenging birds (such as raptors and scavenging storks) is an urgent priority to ascertain the wider threat that these drugs may pose to birds.

Safety-testing of all veterinary NSAIDs that could be used to treat animals that may become food for scavenger bird species should be primarily introduced as mandatory. This includes safety testing of substances that are currently on the market as well new substances. Mandatory safety-testing of risks to these species will reduce the likelihood of exposure to substances that are highly toxic to birds. Mandatory safety-testing should be introduced in all areas where birds of prey, especially vultures, are concentrated and rely on domestic ungulate food sources. Many Gyps vulture species worldwide rely on domestic livestock as their traditional wild ungulate food sources have disappeared (Pain, et al. 2008).

The regulatory approval given by the governments in South Asia of diclofenac was a result of an assessment error – arising from the fact that the assessments relied on acute, single species testing (Enick and Moore 2007). In this case, single species testing is not appropriate given the effects of certain NSAIDs on vultures, and other species. Safety testing of new and existing NSAIDs for veterinary treatment of cattle should be revised to include multiple species testing by the applicant using in-vitro and read-across testing methods. This could be carried out by industry themselves, International Cooperation on Harmonisation of Technical Requirements for Registration of Veterinary Medicinal Products (VICH) and/or the Organisation for Economic Co-Operation and Development (OECD).

The burden of proof can be changed to rest with the applicant or manufacturer to show that an NSAID is safe for scavenging birds through independent safety testing. Only NSAIDs that have been shown to be safe should be approved for veterinary treatment of domestic livestock, such as meloxicam (Mahmood, Ashraf and Ahmad 2010), in areas of (1) high vultures and other scavenger birds concentration; and (2) where domestic livestock are the principle food source of scavenging birds. This approach has been used in the European Union for antibiotic growth promoters in livestock, which takes a precautionary approach to veterinary chemical approval (compared to the US, which uses a conservative burden of proof) (Sanderson, et al. 2004).

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