Institution: University of the Highlands and Islands (UHI)		
Unit of Assessment: 7		
Title of case study: Protecting vultures across Asia and Europe		
Period when the underpinning research was undertaken: 2011-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Mark Taggart	**Role(s) (e.g. job title):** Senior Research Fellow	**Period(s) employed by submitting HEI:** Since 2011
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Vultures are nature's carrion disposal system, preventing the proliferation and spread of lethal pathogens in the environment. Yet today, 'Old World' vultures are the most threatened group of terrestrial migratory birds on Earth. In the last 25 years, ~99.9% of *Gyps* vultures across South Asia – once numbering many tens of millions – have died, most thanks to unintentional poisoning by a veterinary drug (NSAID) called diclofenac. University of the Highlands and Islands research into the impacts and risks posed by NSAIDs to vultures has been crucial in establishing a clear picture of evolving risks in South Asia and beyond. It has introduced robust new analytical techniques, shed light on new NSAID threats, and influenced new regulations to restrict or ban vulture-toxic medicines. It has also informed drug safety guidelines and national/international vulture recovery plans, all of which is underpinning conservation efforts that are now seeing positive early signs of vulture recovery in South Asian countries.

2. Underpinning research

The research detailed here outlines the development and application by Taggart of robust analytical chemistry tools to answer key questions about the threat posed to vultures by certain veterinary drugs: specifically, non-steroidal anti-inflammatory drugs (NSAIDs). These drugs are from the well-known drug 'family' which includes aspirin and ibuprofen.

In 2006, India, Pakistan and Nepal all banned the veterinary use of an NSAID called diclofenac, as it was causing widespread poisoning of vultures who fed on carcasses of treated farm animals. These countries were then followed by Bangladesh in 2010. To make this decision politically acceptable, Taggart and other scientists worked closely with conservationists (led by the RSPB) to demonstrate the safety of, and then promote the use of, an alternative 'vulture-safe' NSAID called meloxicam. However, since 2006, there have been doubts about whether farmers would actually stop using diclofenac and switch to (more expensive) meloxicam, and whether illegal diclofenac use would simply continue. Ensuring this switch happened was critical if plans for vulture population recovery were to be effective.

In 2014, Taggart provided primary data to address these questions [3.1]. Using liquid chromatography with triple quadrupole mass spectrometry (LC-MS/MS), he analysed drug residues in livers from animal carcasses available to vultures across India, screening more than 6,000 dead animals (cattle, water buffalo, sheep, goats) for multiple-NSAIDs. This clearly demonstrated that diclofenac use had indeed declined, with the prevalence of diclofenac positive carcasses dropping by half since the 2006 ban. Also, meloxicam was being used instead, with its prevalence increasing by 44%. As such, the risk to vulture populations had reduced by two-thirds. Although encouraging, this research still showed that significant amounts of diclofenac remained in illegal use in India, as did the threat to remaining vulture populations and to any captive bred birds due to be released back into the wild.

These analytical tests were also applied forensically by Taggart to determine if vultures were being killed by diclofenac or other NSAIDs. In 2015, he collaborated with colleagues in Spain to confirm an unexpected and disturbing case: the first documented report of a wild vulture being killed by an NSAID in Europe [3.2]. A Eurasian griffon vulture had died in Spain from exposure to flunixin, another widely used veterinary NSAID. This raised important red flags, as it provided the

first evidence that wild vultures in Europe (beyond South Asia) were being impacted, and, indicated that bans on diclofenac alone would not protect them. Building on this, Taggart also analysed samples from 48 vulture deaths from India occurring from 2000-2012 and presented the first evidence of wild vultures dying due to an NSAID other than diclofenac in Asia [3.3]. This study found evidence that nimesulide was killing vultures in the same way that diclofenac was, causing severe visceral gout and kidney failure. As well as forensic testing, Taggart also worked with colleagues in South Africa to provide critical analytical data as part of NSAID safety testing on captive birds. This work added aceclofenac [3.4] and carprofen [3.5] to a growing list of potentially lethal veterinary drugs that vultures could be exposed to globally, in their food.

This research has also been instrumental in building capacity in India, Nepal, Pakistan, and Bangladesh. Taggart has trained researchers involved in vulture conservation to sample, extract, and reliably test animal tissues for NSAIDs. Advanced laboratory equipment (LC-MS/MS) to test for NSAIDs can cost up to £1M, putting such testing beyond the reach of almost all scientists in India and other neighboring countries. As one part of this effort, in 2012, Taggart and colleagues published a study that showed that a low-cost alternative – with certain limitations – could be used in South Asia instead [3.6]. This simple biochemical technique – an enzyme-linked immunosorbent assay (ELISA) – could be used quickly and relatively cheaply, at ~£5 per sample. The technique can check whether tissues, including both cattle carcasses and dead vultures, contain diclofenac. This test enables scientists to screen samples in-country and reduces the need for costly shipping and analysis abroad.

3. References to the research

3.1 Cuthbert, R.J., **Taggart, M.A.,** Prakash, V., Chakraborty, S.S., Deori, P., Galligan, T., Kulkarni, M., Ranade, S., Saini, M., Sharma, A.K., Shringarpure, R., Green, R.E., 2014. Avian scavengers and the threat from veterinary pharmaceuticals. *Royal Society Philosophical Transactions B* 369, 20130574.

3.2 Zorrilla, I., Martinez, R., **Taggart, M.A.,** Richards, N., 2015. Suspected flunixin poisoning of a wild Eurasian griffon vulture from Spain. *Conservation Biology* 29, 587-592.

3.3 Cuthbert, R.J., **Taggart, M.A.,** Saini, M., Sharma, A., Das, A., Kulkarni, M.D., Deori, P., Ranade, S., Shringarpure, R.N., Galligan, T., Green, R.E., 2016. Continuing mortality of vultures in India associated with illegal veterinary use of diclofenac and a potential threat from nimesulide. *Oryx* 50, 104-112.

3.4 Galligan, T.H., **Taggart, M.A.,** Cuthbert, R.J., Svobodova, D., Chipangura, J., Alderson, D., Prakash, V., Naidoo, V., 2016. Metabolism of aceclofenac in cattle to vulture-killing diclofenac. *Conservation Biology* 30, 1122-1127.

3.5 Naidoo, V., **Taggart, M.A.,** Duncan, N., Wolter, K., Chipangura, J., Green, R.E., Galligan, T.H., 2018. The use of toxicokinetics and exposure studies to show that carprofen in cattle tissue could lead to secondary toxicity and death in wild vultures. *Chemosphere* 190, 80-89.

3.6 Saini, M., **Taggart, M.A.,** Knopp, D., Upreti, S., Swarup, D., Das, A., Gupta, P.K., Niessner, R., Prakash, V., Mateo, R., Cuthbert, R.J., 2012. Detecting diclofenac in livestock carcasses in India with an ELISA: A tool to prevent widespread vulture poisoning. *Environmental Pollution* 160, 11-16.

Taggart's principal contribution to these was to provide primary underpinning LC-MS/MS NSAID data. He led on the analytical chemistry method development, validation, sample processing/extraction/testing/data handling, as well as making a significant contribution to data analysis and writing for all articles. For [3.2] he was also corresponding author.

4. Details of the impact

The precipitous decline and near extinction of South Asia's three *Gyps* vulture species in the past 25 years, from many tens of millions to just a few tens of thousands of individuals, is not purely a conservation issue. Vultures provide multiple essential ecosystem services, not least by rapidly removing carrion and associated zoonotic risks to human health. The 'cost' of vulture

losses in South Asia will be felt for many decades to come, from a human health, waste management (cost), cultural and biodiversity loss perspective. One article (Markandya et al., 2008, Ecological Economics, 67, 194) regarding impacts in India alone, has placed the 'cost' to human health from vulture declines (between 1992-2006), principally due to increased scavenging dogs and resulting rabies transmission to humans, at ~$34 billion (US$).

The research highlighted here, in seeking to halt this biodiversity loss, has: armed NGOs with the primary data they need to persuade governments to (4.1) strengthen laws that ban or restrict NSAIDs in India, specifically to protect vultures; (4.2) supported action regarding veterinary NSAIDs across Europe to protect vultures and other avian scavengers; (4.3) informed and influenced international multi-species action plans aimed at securing global vulture population recovery; and, (4.4) built robust NSAID monitoring and analytical capacity in multiple countries within South Asia. As a result, there are now positive early signs of vulture population recovery, and release programmes have been stepped up as a safer environment for these species re-emerges.

4.1 Strengthening laws in India to eliminate illegal veterinary diclofenac use
Comprehensive carcass survey data for India published in 2014 – critical to protect vultures and allow population recovery – proved that existing bans on veterinary diclofenac had not stamped out its use [3.1]. It allowed the collaborative partnership SAVE – 'Saving Asia's Vultures from Extinction', within which UHI is a research partner – to exert pressure on the Indian government to tighten laws. Within ~6 months of publication, this study's findings were a central piece of evidence used by SAVE to lobby Indian authorities to ban large, 30ml, multi-dose injectable vials of diclofenac [5.1a]. Millions of these were being sold each year, labelled 'for human use only', but farmers were widely using them illegally on livestock. In July 2015, the Indian Health Ministry banned these vials across India, restricting all diclofenac vials to just 3ml, rendering them impractical for use on large animals. Dr Chris Bowden, RSPB Globally Threatened Species Officer and SAVE Programme Manager who led the call to ban these large vials, said: "the data provided by carcass surveys was absolutely critical to help drive this legislative change, and without this robust research data, the ban would not have occurred" [5.2]. Further, he noted that a subsequent unsuccessful appeal against this ban to the Madras High Court, brought in 2016 by certain drug companies [5.1b] "would undoubtedly have succeeded in over-turning this ban, had this very clear research evidence base not been in place" [5.2].

4.2 Informing European policy to mitigate NSAID risks to European avian scavengers
In late-2014, the European Commission (EC) expressed its concern about the potential impact that diclofenac and other NSAIDs could have on vultures and scavenging birds in Europe. This followed the widely criticised emergence of veterinary diclofenac onto the EU market in 2013, particularly in Spain, which is Europe's primary vulture stronghold. The EC asked the European Medicines Agency (EMA) to consult, consider risks, and report back. The subsequent assessment drew heavily on the research carried out and published by Taggart and colleagues [5.3]. Specifically, it highlighted [3.2], which reported the first (and then only) European wild vulture NSAID poisoning case, stating that it directly supported "the hypothesis that the exposure routes described are realistic" within the EU [p21 and p24; 5.3]. Also, in commenting on the relevance of Taggart's research to the EMA process, the Vulture Conservation Foundation (VCF) stated that it provided "clear and indisputable evidence that medicated carcasses are available to and being consumed by scavenging birds in Europe" [5.1c]. The EMA concluded that "diclofenac use in animals posed a risk to European vultures" and recommended that various "measures are put in place to better protect the birds" [5.4]. Hence, in 2015, the EC asked all relevant EU member states to draw up National Action Plans to mitigate against these risks. This has now been undertaken in 12 EU countries [5.5; p12 and 13]. Mitigation measures adopted vary by country, and include: providing better risk guidance/information to vets, adding specific warnings regarding risks to wildlife/vultures to product packaging/literature; enforcing strict controls regarding fallen livestock on farms; and, instigating new monitoring schemes to test carcasses available to scavenging birds. The current guidance enforced in Spain, for instance, requires clear labelling and provides guidance about limiting NSAID exposure to wildlife [5.6].

4.3 Influencing internationally adopted, multi-species action plans to conserve vultures
Taggart's research has also informed and influenced a major international action plan aimed at conserving vultures. A "Multi-Species Action Plan (MsAP) to Conserve African-Eurasian Vultures" was adopted in 2017 by the UN Global Convention on Migratory Species (CMS). The MsAP sets out to reverse population declines of 15 vulture species, the most threatened group of terrestrial migratory birds on Earth [5.7]. In the plan, [3.1, 3.2, 3.3 and 3.4] are cited in support of one of twelve core global objectives: "To recognise and minimise mortality of vultures by non-steroidal anti-inflammatory drugs (NSAIDs) and occurrence and threat of toxic NSAIDs throughout the range covered by the Vulture MsAP". Most specifically, the MsAP [5.7, p59] highlighted the research noted here on flunixin [3.2], nimesulide [3.3], and aceclofenac [3.4], as these studies represented the most concrete evidence that these NSAIDs also posed risks similar to that of diclofenac. NSAIDs were then ultimately listed in the MsAP as the only 'critical' and primary threat to vulture species in South Asia, and, an additional 'high' threat across Europe, Central and East Asia (Global Threat Priority Map [5.7, p57]). Regarding the relevance of Taggart's research to the final MsAP objectives, Dr Roger Safford - Senior Programme Manager for Preventing Extinctions at BirdLife International - the primary author of the NSAID sections within the MsAP, said it: "…directly informed…and thus shaped the proposed conservation actions to counter this threat, not only in South Asia but across the Old World. Without it, there would have been insufficient evidence to include NSAIDs other than diclofenac as threats, and so the MsAP actions in relation to these drugs would have been flawed" [5.8].

The impact of the MsAP in relation to NSAIDs will be measured every six years, in 2023 and again in 2029. This will be assessed in part by the "number of CMS Parties and Range States to have banned or voluntarily withdrawn potentially harmful NSAIDs for veterinary use and introduced safe alternatives" [5.7, p95, Objective 2]. Since the MsAP was first mandated by the CMS in 2014: India banned multi-dose vials of human-use diclofenac in 2015 [5.1a]; Iran banned veterinary diclofenac, also in 2015 [5.1d]; Cambodia followed suit in 2019 [5.1e]; and, Bangladesh has entirely banned the diclofenac 'pro-drug' aceclofenac [3.4; 5.1f] and partially banned ketoprofen, another vulture-toxic NSAID, within its "Vulture Safe Zones" that encompass ~25% of the country [5.1f]. On the ground in South Asia, such action is now also starting to result in encouraging early signs of vulture population recovery in parts of both India and Nepal [5.9], i.e., "for the white-rumped vulture there is now strong evidence….that a decline up to about 2013 has given way to a rapid increase from about 2013 to 2018" [5.9, paper 1, p97]. Further, it has now been deemed safe enough to begin to release precious captive and captive-bred *Gyps* vultures back into the wild to assist population recovery, with releases starting in Nepal in 2017 [5.1g] and in India in 2019 [5.1h].

4.4 Capacity building to support robust NSAID monitoring within South Asia
In 2012, Taggart demonstrated that a sensitive, low-cost ELISA could be used to screen carcasses of vultures or their food for diclofenac [3.6]. The test was validated in India by Taggart and colleagues at the Indian Veterinary Research Institute (IVRI; India's premier Government veterinary research establishment). Staff at IVRI and at the Bombay Natural History Society (BNHS; one of India's largest conservation NGO's) were trained by Taggart to undertake this test. Training is supported by a freely available manual compiled by Taggart and colleagues [5.10]. In 2014, this new capacity allowed IVRI to make a discovery with potentially global implications. They published the first evidence that diclofenac may also be deadly to other raptors, identifying clinical signs of diclofenac poisoning alongside diclofenac residues (detected by ELISA) in steppe eagles found dead in Rajasthan [5.11]. In a press release regarding this finding, Birdlife International said: "With fourteen species of *Aquila* Eagle distributed across Asia, Africa, Australia, Europe and North America, this means that diclofenac poisoning should now be considered largely a global problem" [5.1i].

Taggart has also been working with multiple SAVE partners in South Asia to transfer knowledge regarding NSAID monitoring and analysis, ensuring that techniques used in [3.1-3.6] are applied in-country to gather data consistently and reliably. This is critical if the research evidence generated in South Asia is to be used by NGOs to persuade governments to change laws and

ban or restrict NSAIDs. Taggart has trained staff at: IVRI (5 staff) and BNHS (>10) in India; the International Union for Conservation of Nature (IUCN) in Bangladesh (>10); Bird Conservation Nepal and the National Trust for Nature Conservation in Nepal (8); and, provided training resources – both written guidance and equipment - to the World Wildlife Fund for Nature in Pakistan. Collectively, this work is enabling more and improved data gathering, and helping to create a clearer picture of the NSAID risks present in each country. This work has been funded by the RSPB and more recently through SFC-GCRF funding to UHI. Such activity is also agreed within and guided by the SAVE 24-partner consortium, within which Taggart sits on the Technical Advisory Committee. Prof. Rhys Green – Professor of Conservation Science at University of Cambridge, and SAVE Chairman said that Taggart's research "has played a vital part in the conservation of these species and continues to do so", and that his engagement in capacity building has been "essential in ensuring that survey design and protocols for collecting, storing and processing samples were fit-for-purpose in the challenging physical and cultural environment of South Asia" [5.2].

5. Sources to corroborate the impact

5.1 PDF of nine (5.1a to 5.1i) online media articles covering and reporting on progress towards protecting vultures. Articles cover banning toxic drugs in Asia and Europe and the resulting release of captive-bred birds into the safer environment. These articles recognise the research contributions listed, particularly [3.1], [3.2] and [3.4].

5.2 Testimonial letters by Dr Chris Bowden (RSPB and SAVE Programme Manager) and Prof. Rhys Green (SAVE Chairman and Professor of Conservation Science at University of Cambridge) commenting on the impacts [3.1-3.6] have had since 2014.

5.3 CVMP (Committee for Medicinal Products for Veterinary Use) report (published 11/12/14; accessed 15/7/20) on the "Risk to vultures and other necrophagous bird populations in the EU in connection with the use of veterinary medicinal products containing the substance diclofenac". Most relevant sections (as highlighted in PDF) are page 21, 24; [3.1-3.2] cited in references.

5.4 PDF copy of European Medicines Agency press release (published 12/12/14; accessed 15/7/20) regarding "Diclofenac use in animals poses a risk to European vultures - EMA recommends that measures are put in place to better protect the birds".

5.5 PDF by Vulture Conservation Foundation reporting on progress in Europe to restrict diclofenac. National Mitigation Action Plan information (by country) on pages 12/13.

5.6 Spanish Agency for Medicines and Health Products; Ministry of Agriculture and Fisheries, Food and Environment; "Precautions regarding the prescription and administration of veterinary medicines containing diclofenac authorized in Spain". Original PDF in Spanish, English translation provided. Published 18/6/15, accessed 15/7/20.

5.7 Botha et al., 2017. Multi-species Action Plan to Conserve African-Eurasian Vultures. ISBN 978-3-937429-23-6. Pages 59-60 regarding NSAIDs (highlighted) are most relevant.

5.8 Testimonial letter from Dr Roger Safford - Senior Programme Manager for Preventing Extinctions at BirdLife International.

5.9 Two recent references indicating vulture population recovery: (1) Galligan et al., 2020. Partial recovery of Critically Endangered *Gyps* vulture populations in Nepal. Bird Cons. Int., 30, 87-102; (2) Prakash et al., 2019. Recent changes in populations of Critically Endangered *Gyps* vultures in India. Bird Cons. Int., 29, 55-70.

5.10 Training document (PDF; freely available online) written by Taggart et al., "Procedures for extracting and analysing tissue samples for diclofenac using ELISA".

5.11 Sharma et al., 2014. Diclofenac is toxic to the Steppe Eagle: widening the diversity of raptors threatened by NSAID misuse in South Asia. Bird Cons. Int. 24, 282-286.