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ASSESSMENT OF THE RATES OF INJURY AND MORTALITY IN WATERFOWL CAPTURED WITH FIVE METHODS OF CAPTURE AND TECHNIQUES FOR MINIMIZING RISKS

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ABSTRACT: Swan pipes, duck decoys, cage traps, cannon netting, and roundups are widely used to capture waterfowl in order to monitor populations. These methods are often regulated in countries with national ringing or banding programs and are considered to be safe, and thus justifiable given the benefits to conservation. However, few published studies have addressed how frequently injuries and mortalities occur, or the nature of any injuries. In the present study, rates of mortality and injury during captures with the use of these methods carried out by the Wildfowl & Wetlands Trust as part of conservation programs were assessed. The total rate of injury (including mild dermal abrasions) was 0.42% across all species groups, whereas total mortality was 0.1% across all capture methods. Incidence of injury varied among species groups (ducks, geese, swans, and rails), with some, for example, dabbling ducks, at greater risk than others. We also describe techniques used before, during, and after a capture to reduce stress and injury in captured waterfowl. Projects using these or other capture methods should monitor and publish their performance to allow sharing of experience and to reduce risks further.
Key words: Animal welfare, banding, catching, injury, mortality rate, ringing, trapping, waterfowl, wildlife capture.

INTRODUCTION

Wild birds have been captured for a variety of reasons, by various techniques, over many centuries (Bub 1995), for food, clothing, domestication, removal of pest species, and scientific study (Whitworth et al. 2007a). For the latter, such studies include ringing (=banding) waterfowl to allow estimates of survival, productivity, emigration, and immigration (Day et al. 1980), and are therefore central to the development of population models on which sound conservation management can be based. The assumption that capture for ringing does not significantly affect the birds is essential, because it is the basis for generalizing the data to unmarked birds (Murray and Fuller 2000). Wild birds in the United Kingdom (UK) are legally protected, and the British Trust for Ornithology (BTO), under license from country government agencies, issues ringing permits to individuals to capture wild birds for purposes that include scientific research, ringing, and marking.

The Wildfowl & Wetlands Trust (WWT) has been capturing waterfowl for scientific study since its inception in 1946 (Mitchell and Ogilvie 1997), and has changed and refined capture methods used, to improve their effectiveness and reduce the risks of injury and stress to birds captured. This is important both ethically and to ensure high-quality data.

As a consequence of highly pathogenic avian influenza (HPAI) H5N1 outbreaks in Asia and Eastern Europe in 2005, European Union (EU) Member States increased levels of surveillance for avian influenza (AI) viruses in wild birds. Between autumn 2005 and December 2010, WWT increased capture efforts and sampled large numbers of live captured birds for AI under contract to the Department of Environment, Food and Rural Affairs (DEFRA), at three WWT sites in England, one in Scotland, one in Northern Ireland, and one in Wales. Birds were captured with the use of cage traps, duck decoys, swan pipes, cannon netting, and roundups (Bub 1995). Buccal and cloacal swab samples were taken, and screened for AI viruses at the European Reference Laboratory, Weybridge, UK.

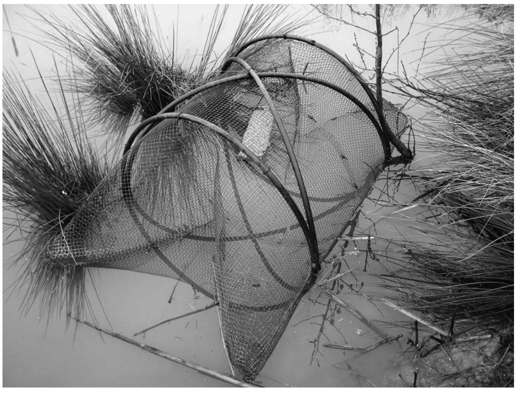

FIGURE 1. Example of a cage trap used to capture Teal (2 m long, 1.3 m wide, and 1 m high) (photo by T. Mundkur).

Studies have reported mortality rates for numerous capture methods, including ≤2.1% in rocket-netting shorebirds (Jurek 1974), 1.14% in pelicans (King et al. 1998), and 2.3% in net-gunning egrets and ibises (Herring et al. 2008). Combined injury and mortality rates fell below 1% for 18 of 22 organizations carrying out mist netting (Spotswood et al. 2012). Some of these methods (e.g., rocket netting) are no longer licensed in the UK. Other capture methods, for example, modified mist nets in ducks (Brodeur et al. 2008) and flip traps (Herring et al. 2008) reported no fatalities. For mist netting, it has been suggested that mortality rates should not exceed 1% (Ralph et al. 1993).

Previously reported injury and fatality rates for cannon netting varied between 0% (Southern and Southern 1983) and 1% (Cox et al. 1994). For cage traps, mortality levels in ducks of 0.17–1.16% (Dieter et al. 2009) and 4% (Evrard and Bacon 1998) have been reported.

Reasons for injury and mortality have included design of traps (Dieter et al. 2009), and holding facilities. Experience of the capture team and methods of handling are likely to be important factors. Muscle damage and capture myopathy is also a serious risk (Young 1967; Minton 1980; Brannian et al. 1981). Bird injuries and conditions that might occur during captures include fractures, sprains, bruising, dislocations, lacerations, eye trauma, crushing, excessive feather loss, capture myopathy, shock, brachial paralysis, hyperthermia, and hypothermia (Whitworth et al. 2007a). Thus a great deal of preparation is required to minimize these risks.

Each species can be prone to particular risks during capture, for example, bill trauma in Shelduck and foot trauma in diving ducks. Some species may also present risks to handlers. Large swan and goose species can cause contusions with their wings and scrapes with their toenails (Fowler 1995). Individualized handling techniques are used for each species to reduce stress and injury, for example, jackets for swan species (Swan Study Group 2005).

This article reports the incidence of injury and mortality in waterfowl captured with the use of five common capture methods. We also describe precautions taken to minimize risks of injury or death to birds during this process. Additional factors used to assess capture method, for example, specificity, cost, performance, age, and sex selectivity (Lopez-Olvera et al. 2009) are not assessed here.

MATERIALS AND METHODS

All captures were conducted by WWT staff and volunteers. Protocols used throughout the capturing were those provided in the WWT capture manual (WWT, unpublished) together with the BTO Ringers Manual (Redfern and Clark 2001). The objectives of these protocols were to ensure that all personnel used best practices to reduce stress and injury to birds.

Capture methods

Cage traps rely on the basic principle of a bird entering a trap and not being able to find its way out, and are often baited with grain (Bub 1995). Traps used were varied in size, mainly used for ducks, and designed to suit the target species and capture site (Fig. 1). Traps were placed carefully in relation to surrounding vegetation to reduce the risk of predation, and some were placed within fox-proof fences.

Duck decoys consist of netted, curving pipes running off an area of open water. Birds were encouraged inside either by feeding with grain or using a dog as a lure (Fig. 2). Once within

FIGURE 2. Use of a Nova Scotia duck tolling retriever as a lure in the duck decoy at Wildfowl & Wetlands Trust Slimbridge (each of four pipes is ~70 m long, 8 m wide, and 3 m high at the mouth) (photo by P. Marshall).

the netted pipe the decoy operator appeared at the mouth to flush the birds up the pipe, and into holding nets at the end.

Swan pipes consist of large netted tunnel-like structures (Fig. 3). Birds were baited in with the use of grain, and captured when the open end of the pipe was closed with a drop net or gate. Birds were then driven, by people walking or wading behind them, into a holding area at the other end. The heavy weld mesh used to construct the pipe was covered by windbreak netting along the sides to reduce risks of injury from collisions. Long baffles and thinner strips of material were hung from the roof of the pipe to encourage any birds taking flight within the structure to remain low, thus reducing the chances of hitting the roof. The sides of the holding pens were padded, and provided space underneath the sides for ducks to escape from swans. Hand nets were used by experienced personnel as a supplementary capturing technique, and long nets (elongated nets stretched across areas of water) were occasionally used, for example, to capture diving ducks that

FIGURE 3. Birds entering the swan pipe at Wildfowl & Wetlands Trust Caerlaverock (60 m long with 21 hoops at 3-m spacing going from 11 m wide at the mouth to just less than 3 m wide by the holding pens. Three meters high at the mouth and 2 m high in the pens) (photo by R. Lee).

escaped during the main drive. Extracting birds from hand nets and long nets required skill, manual dexterity, and patience.

Cannon netting is a method for capturing large numbers of birds using nets pulled by explosively powered projectiles to cover a predetermined area of ground and capture any birds before they have time to escape. They were used in areas (often baited) where wildfowl feed (Heath and Frederick 2003). A specific permit endorsement from BTO is required to use a cannon net, as it is a specialized and potentially dangerous activity with risks to both humans and birds if not correctly carried out (Appleton 1991; Bub 1995).

Roundups are used for capturing large numbers of birds that have been rendered flightless as a result of wing feather molt. It is also used for large birds that cannot take to the air easily and require a long takeoff, for example, Mute Swans (*Cygnus olor*) (Fig. 4). Corrals were made with soft material sides to reduce the chance of damage to blood feathers—a specific risk to birds during active molt. Birds were moved slowly to reduce risks of trampling (Whitworth et al. 2007a).

In all traps, any sharp edges were removed during construction and regular maintenance was carried out to reduce risks of injury to birds during capture.

Precapture preparation for large-scale captures

At every large-scale capture, organization of the team and logistics were vital. Each capture was supervised by a ringer-in-charge—a member of staff with experience conducting

FIGURE 4. Mute Swans in a corral having been captured in a roundup. The corral is shaped like a figure eight, with the size of the two circular corrals determined by the number of birds expected (~3.5 m in diameter each circle for 100 swans) (photo by C. Grant).

large-scale bird captures and holding an appropriate BTO permit. Planning included estimation of the number of birds acceptable to capture, which was determined by weather, size of holding areas, number of holding crates or sacks available, size and experience of the team, and the amount of time required for processing. The aim was to release all birds within a maximum of 3 h of capture, ideally sooner (WWT, unpublished). Handlers experienced in specific techniques, such as extraction from cannon nets, were also used when required. Appropriate staff were designated as animal welfare officer, bird treatment officer, health and safety officer (and sometimes a public relations officer and a designated releaser) at each capture. Anticipation of the presence of particularly vulnerable species (e.g., diving ducks, because of their lack of adaptation for walking [Delacour 1959]) at each site allowed for prioritization of birds most likely to be prone to injury and stress. A precapture briefing explained the roles and responsibilities of all capture personnel and health and safety and contingency plans for dealing with issues, for example, greater numbers of birds being captured than anticipated, and deterioration of weather conditions. Species of birds targeted for capture included Mute Swan, Whooper Swan (*Cygnus cygnus*) and Bewick's Swan (*Cygnus columbianus*); Greylag Goose (*Anser anser*) and Barnacle Goose (*Branta leucopsis*); and Shelduck (*Tadorna tadorna*), Mallard (*Anas platyrhynchos*), Pintail (*Anas acuta*), Wigeon (*Anas penelope*), Teal (*Anas crecca*), Pochard (*Aythya ferina*), and Tufted Duck (*Aythya fuligula*).

Handling wild birds can expose the handler to zoonotic risks, and the appropriate level of personal protective equipment required was assessed. In all cases, waterproof outer clothing and boots were worn to protect from fecal contamination and to provide easy disinfection postcapture. Sturdy gloves protected the handler from the claws of some species and also reduced fecal contamination. If a potentially serious pathogen could be present (e.g., HPAI H5N1) face masks were worn to prevent inhalation of aerosol particles.

Processing for all capture methods

After birds were captured, they were separated depending on species and size, and placed in open-topped holding pens, corrals, holding sacks, or crates. Crates were lined, for example, with soft plastic wind break where appropriate, and with soft floor mats to reduce injury. Corners of holding pens and corrals were also reduced, for example, with hessian (burlap) to reduce risks of trampling. Sufficient space was provided for birds to preen themselves dry and reduce the likelihood of hypothermia, and holding crates were tall enough to ensure birds could stand, to help prevent capture myopathy. All holding facilities were inspected regularly to ensure birds were not becoming distressed or suffering any environmental problems, for example, hypothermia. To reduce stress, birds were kept in dark and quiet conditions where possible, holding areas were screened, and personnel entering them kept to a minimum. Sacks for holding birds were made of lightly woven hessian that was absorbent but fairly opaque, allowing air flow when tied shut.

After birds were sorted and placed in the appropriate holding facility, the ringer-in-charge assessed species composition and overall numbers, and decided on the order of processing. Any physically injured or distressed birds were brought to the attention of the bird treatment officer, and either fast-tracked through the processing line or treated as appropriate and released immediately. Birds with old injuries sustained in the wild were assessed. If they appeared to have good weight and feather condition, and healing (or fully healed) injuries, they were ringed and released as normal. When injuries were considered to be too severe the birds were euthanized.

Processing normally included ringing, aging, sexing, taking biometrics, and sample collection. There were occasionally additional steps for special research projects, for example, radiography. The majority of recording of bird injuries took place during sample collection.

TABLE 1. Total numbers captured, injuries sustained, and fatalities of ducks, geese, swans, and rails captured by Wildfowl & Wetlands Trust in the UK for avian influenza surveillance (2005–2010) and in additional swan pipe and swan cannon-net captures (2011–2014).[a]

	Duck					Goose					Swan					Rail		
Year	No. captured	Mild injuries	Moderate injuries	Severe injuries	Fatalities	No. captured	Mild injuries	Moderate injuries	Severe injuries	Fatalities	No. captured	Mild injuries	Moderate injuries	Severe injuries	Fatalities	No. captured	Injuries	Fatalities
2005	2119	0	0	1	2	138	0	1	0	0	474	0	0	0	2	9	0	0
2006	2267	5	0	4	2	142	0	0	0	0	816	10	1	0	1	15	0	0
2007	2644	12	4	3	2	379	1	0	1	0	1035	6	3	1	0	73	0	0
2008	2073	4	1	1	0	356	0	0	0	0	735	4	2	1	0	19	0	0
2009	1312	0	2	0	1	159	0	0	0	0	437	0	1	0	0	15	0	0
2010	1431	0	1	0	2	29	0	0	0	0	352	0	2	0	0	13	0	0
2011	220	0	0	0	1	10	0	0	0	0	322	0	1	1	0	8	0	0
2012	48	1	1	0	1	0	0	0	0	0	220	2	1	0	0	0	0	0
2013	484	0	0	0	0	29	0	0	0	0	285	0	1	0	0	4	0	0
2014	40	0	0	0	0	1	0	0	0	0	223	0	0	0	0	0	0	0
Total	**12,638**	**22**	**9**	**9**	**11**	**1,243**	**1**	**1**	**1**	**0**	**4,899**	**22**	**12**	**3**	**3**	**156**	**0**	**0**
% of total		**0.17**	**0.07**	**0.07**	**0.09**		**0.08**	**0.08**	**0.08**	**0**		**0.45**	**0.25**	**0.06**	**0.06**		**0**	**0**
Overall %	**0.40**					**0.24**					**0.82**					**0**		
Total overall %	**0.50**																	

[a] Data were not included from the small duck captures from 2011 to 2014, as a comparable and standardized system of recording injuries was not in place.

Postcapture processing for all capture methods

An experienced person ensured that birds were fit for release, because postrelease veterinary intervention is generally impossible. Waterfowl were released onto a suitable water body as close to the capture site as possible, but not in view of birds still in the holding areas, and allowed to walk or swim from the hand. Any birds that showed difficulty moving were assessed for possible capture myopathy by the bird treatment officer. If possible, family groups and mated pairs were released together. Highly social species that may disperse a long distance from the capture site, for example, Barnacle Goose, were released together or in large groups to reduce risks of disorientation and predation.

For health and safety and biosecurity reasons, after each capture all equipment was disinfected, for example, with a solution of 1:50 Virkon S (DuPont, Hertfordshire, UK). Given that equipment and personnel may move between sites to undertake fieldwork, this is particularly important to avoid the possibility of spreading disease (Cromie et al. 2012).

For large-scale captures, a postcapture debriefing was conducted to discuss what had worked well and what could be improved upon, and a capture report was compiled.

Data collection

Data were obtained from waterfowl captures carried out from October 2005 to December 2010 and included swan pipe and cannon-net captures through December 2014. All capture locations were WWT nature reserves: England (51.741006°, −2.403744°; 53.62268°, −2.865203°; 52.52589°, 0.2778282°), Wales (51.66336°, −4.123932°), Scotland (54.976543°, −3.496783°), and Northern Ireland (54.529348°, −5.695174°).

Records from captures, capture summaries, and postmortem records were used to ensure that as many data were collected as possible. The total number of birds captured, together with the number and type of visible injuries and any fatalities, were noted (Tables 1 and 2). Data were not included from small duck captures from 2011 to 2014 because a comparable and standardized system of recording injuries was not in place.

Injuries were classified as mild, superficial injuries, for example, toenail damage; moderate, for example, wounds not requiring suture; or severe, for example, wounds requiring suture, fractures, and capture myopathy (Table 3).

RESULTS

During the study period (2005–2014), 18,936 birds were captured and examined. The maximum number of birds captured in one event was 472 in a swan pipe capture. The total rate of injury (including mild dermal abrasions) was 0.42% (80 birds) across all species (Table 1). Swans showed a significantly higher number of mild and moderate injuries than ducks $X^2=19.66$ (df=3, $N=17{,}537$), $P=0.0001$, but

TABLE 2. Injuries and fatalities for ducks, geese, and swans by capture method during avian influenza surveillance (2005–2010) and additional swan pipe and swan cannon-net captures (2011–2014).[a]

	Catch method																			
	Duck Decoy/Small Swan Pipe catches				Swan Pipe				Cannon-net				Cage Trap				Round Up			
	Injury severity				Injury severity				Injury severity				Injury severity				Injury severity			
Species group	Total No. Captured	Mild and moderate injuries (%)	Severe (%)	Fatalities (%)	Total No. Captured	Mild and moderate injuries (%)	Severe (%)	Fatalities (%)	Total No. Captured	Mild and moderate injuries (%)	Severe (%)	Fatalities (%)	Total No. Captured	Mild and moderate injuries (%)	Severe (%)	Fatalities (%)	Total No. Captured	Mild and moderate injuries (%)	Severe (%)	Fatalities (%)
Duck	4855	2 (0.04)	1 (0.02)	5 (0.1)	6080	27 (0.44)	5 (0.08)	6 (0.1)	271	0	0	0	702	0	0	0	730	2 (0.27)	3 (0.41)	0
Goose	2	0	0	0	834	2 (0.24)	1 (0.12)	0	305	0	0	0	88	0	0	0	14	0	0	0
Swan	12	0	0	0	4422	34 (0.77)	3 (0.07)	2 (0.05)	49	0	0	0	41	0	0	0	375	0	0	1 (0.27)

[a] Data were not included from the small duck captures from 2011 to 2014, as a comparable and standardized system of recording injuries was not in place.

had similar rates of severe injuries. There were insufficient injuries in geese for analysis (Table 1). All recorded swan and goose injuries occurred during swan pipe captures. Eighty percent of duck injuries also occurred during large swan pipe captures, with smaller numbers occurring during roundups and small duck captures in swan pipes (Table 1).

There were 14 fatalities (0.07% of total) during all capture events, 11 ducks and three swans (Table 1). Two swan fatalities occurred during swan pipe captures and one during a roundup. For ducks, 55% of mortalities occurred during large swan-pipe captures, with the rest occurring during small duck captures with swan pipes and duck decoys. No significant difference was found between fatality rates for ducks in swan pipe captures and small captures in the swan pipe/duck decoy. Of the ducks, 91% were dabbling species (five Pintail, two Mallard, two Teal, and one Widgeon) and the other was a Shelduck. One Whooper Swan also died because of pre-existing aspergillosis infection during a swan pipe capture (not included in mortality data). In addition, six birds (0.03%) were euthanized (four ducks, one goose, and one swan) because of severe capture-related injuries (all had fractures) Euthanized birds were included in birds with severe injuries in Table 2. The total mortality due to capture was therefore 20 birds (0.1% of total). A further 32 (0.17%) birds were noted to be suffering from conditions sustained prior to the capture and four were euthanized due to their severity (e.g., severe lead poisoning, infected open fractures).

DISCUSSION

This study reports for the first time injury and mortality rates for five bird capture methods, which allows direct comparison

TABLE 3. Wound and injury classifications.

Mild	Moderate	Severe
Toenail loss or damage	Contusion to head	Wound requiring suture
Carpal bruise or scrape	Noticeable lameness	Fracture
Superficial eye injury	Wound not requiring suture	Capture myopathy (off legs)
Graze to bill	Injury to wing in pin	
Scratch to leg		
Nick in web of foot		

of the safety of the different methods for the birds captured. Results show that the five capture methods have a low level of associated injury and mortality, provided the protocols outlined above are followed.

The majority of injuries and fatalities occurred in the swan pipe or duck decoy for all species in this study. These traps, containing large netted pipes, allow birds, once captured, to still take flight until they have been driven into the holding areas, leading to risk of injury from collisions with the structure. This differs from cannon netting, where large numbers of birds may be captured but are less able to injure themselves before being extracted. In round ups the inability to fly (either due to molt or space restriction) makes trampling the greatest risk for the birds captured. Roundups are, however, usually single-species captures, thereby reducing the risk of larger birds causing injury to smaller species, compared to the risks of swan pipe captures.

The small number of goose injuries may be because of their adaptations for walking on land, allowing them to move swiftly to avoid injury during large captures. As swans are large birds, less agile on land than geese, and relatively aggressive in confined spaces, they are at greater risk of hitting their extremities and stepping on each other, leading to relatively minor injuries, as reflected in their higher mild and moderate injury rate. The lack of injuries in rails, for example, Moorhen (*Gallinula chloropus*) and Coot (*Fulica atra*), was also likely due to their agility. The majority (91%) of duck fatalities were of dabbling ducks, which are more likely to achieve flight than some other species (e.g., diving ducks) and therefore suffer increased chance of injury in traps containing netted pipes.

Published data on injury and mortality from the use of the capture methods described in this article is sparse. No injuries or fatalities were reported from cannon netting in this study and similar levels were reported in Ring-billed Gulls (*Larus delawarensis*) (Southern and Southern 1983) although the longer time the gulls spent under the net, the more likely they were to not be resighted. Cox et al. (1994) reported a 1% mortality rate (91.7% of those due to drowning) when capturing waterfowl with cannon nets. It appears that the use of cannon nets over water increases the risk to birds captured. Cage traps differ markedly in design, and although no injuries or fatalities were reported in these WWT capture events, Dieter et al. (2009) report mortality between 0.17% and 1.16% with the use of cage traps. Evrard and Bacon (1988) report 4% of ducks captured in small swim-in traps were killed (75% due to predation). Our cage trap design varied depending on the situation and some were sited within fox-proof fences, which helped reduce risks from predation.

It is extremely difficult to determine the health status of any wild bird until it has been captured. A number of birds carry old visible injuries (Bedrosian and St. Pierre 2007), but parasitic, viral, bacterial, fungal, and toxic conditions may not be visible, except as a bird in poor body condition. The severity of these underlying conditions may affect the ability of the birds to deal with the stress of capture and may increase the likelihood of further injury or mortality (Kelly and Kelly 2005) as shown in our results by the death of a Whooper Swan from aspergillosis during a swan pipe catch. The methods established to reduce stress in all captured birds, for example, appropriate holding facilities and reducing handling time and disturbance, should help reduce exacerbation of any underlying conditions. It is difficult, if not impossible, in certain situations to know the actual rate of mortality because some birds that die between the time of capture and release, or shortly afterwards, may die from causes unrelated to the capture and handling (Fair et al. 2010). However, where possible, postmortem examination should be used to determine cause of death.

Special precautions should be made when capturing birds during weather extremes or physiological stress, including reducing holding time, capturing at night if daytime temperature is high (Höfle et al. 2004), or ensuring sufficient space to preen dry in wet conditions. As WWT captures took place mostly during winter months, ensuring the weather was not too cold or the wind too strong was extremely important. Summer roundups were carried out either early or late in the day to ensure temperatures were not too high. Both high (Williams and Thorne 1996; Nicholson et al. 2000) and low ambient temperature (Spraker et al. 1987; Höfle et al. 2004) have been considered predisposing factors to development of capture myopathy. High relative humidity may also increase the risk (Höfle et al. 2004) and low relative humidity may increase the risk in high temperatures due to dehydration (Nicholson et al. 2000). Birds that are undergoing, or have just completed, migration may be weakened from long flights (Evans and Kear 1978). They may need to feed to build up fat reserves, so should be processed and released as quickly as possible, for example, Bewick's Swans.

Assessment of levels of injury in captured wild birds is almost certainly underestimated, as it is impossible to be sure that all injuries have been noticed and recorded. Surveillance depends on the level of observation skills in people and species of birds captured. Training is essential to ensure that all noted injuries are recorded in a standardized way, including age of injury and detail regarding severity. Spotswood et al. (2012) noted some ambiguity in how incidents were defined because of differences in classification. As with all research methods involving capture of wild animals, some injury or mortality will occur, no matter how skilled or experienced the researchers, and even when great care is taken to prevent harm. This study suggests that the greatest risks occur in netted pipe traps, and ensuring that ducks are captured and confined in holding areas as quickly as possible when these types of traps are used could help reduce risks of injuries and fatalities due to collisions. Padding of holding pens and ensuring birds are not overcrowded should also help to reduce injury levels in swans.

Further study to determine potential long-term impacts of capturing wild birds would be worthwhile to determine the effects further. Resightings could help to determine the proportion of birds that are alive postcapture and appear in a healthy state, for example, birds carrying engraved plastic leg rings or neck collars (although a small proportion of these marks may be lost over time [Rees et al. 1990]). For birds that do not carry rings that can be read in the field, recapture would be required to determine their health. Some species are rarely seen after release, except for a short period if captured on their breeding territories (Fair et al. 2010).

There is likely to be a bias in published reporting of capture-related injuries, as such data are not recorded in many cases or may be considered too sensitive to publish. Without the data of recorded incidents it cannot be determined whether data are biased by methods of capture or whether capture-related mortality affects mark-and-recapture studies (Spotswood et al. 2012). Given these difficulties, the best that can be reasonably undertaken is the thorough recording of obvious injuries and fatalities. These data can be used to underpin a gradual improvement, and sharing of best practice can help everyone capturing birds improve welfare and capture methods. Further study and publication of records is the only way this can be achieved. It is prudent to undertake periodic assessments of capture-related welfare issues, such as this, in order to ensure the highest possible standards are maintained.

Many organizations, such as WWT, have rightly developed a culture of undertaking regular harm/benefit analyses. The benefits of marking birds and monitoring diseases have brought significant benefits to conservation and health of wildlife, domestic animals, and even humans (Whitworth et al. 2007b). It is important to ensure the costs to the birds are continually reduced and evaluated wherever possible.

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