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Causes of Mortality in the Black-necked Stork *Ephippiorhynchus asiaticus australis* in New South Wales

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Summary

Starvation of nestlings and juveniles was the only natural cause of mortality recorded in the Black-necked Stork *Ephippiorhynchus asiaticus australis* in New South Wales, and collision with powerlines constituted the main cause of anthropogenic mortality. Despite this mortality, the population apparently remained stable between 2003 and 2006, because of the recruitment of young birds from successful breeding seasons.

Introduction

The Black-necked Stork *Ephippiorhynchus asiaticus australis* is rare in New South Wales, with an estimated population of 70–80 breeding pairs and additional non-breeding immature and juvenile birds (Clancy 2008). It is listed as Endangered in Schedule 1 of the New South Wales *Threatened Species Conservation Act 1995*. Mortality is a vital life-history parameter requiring careful documentation to help determine if the population of a species is viable or is declining, and to understand how to reduce mortality to help manage threatened species. Mortality of Storks is known largely from anecdotal observations (Marchant & Higgins 1990; Dorfman *et al.* 2001; Dorfman 2002), which suggest that a combination of natural (starvation and predation) and anthropogenic (collisions with powerlines and barbed-wire fences, motor vehicles and shooting) factors are causing Stork mortalities. Poisoning by the introduced Cane Toad *Bufo marinus* has been identified as an additional potential threat. Ascertaining the relative contribution of natural versus human-related causes is therefore an important first step to determining the nature of conservation intervention required to reduce mortality in the species, if it is deemed necessary.

The aims of this paper are to catalogue and quantify the known causes of anthropogenic mortality, to consider whether these may contribute to a population decline in New South Wales, and to recommend how mortality from anthropogenic causes could be reduced.

Methods

Records were collated of Stork mortality in New South Wales from 1839 to 2006 from all available sources [published papers, newspaper articles, Australian Museum specimens, records of wildlife carer groups (Wildlife Information Rescue and Education Service—WIRES), local ecologists and naturalists, and my observations]. The date, location, age and sex of each Stork, cause of mortality and source of information were recorded where possible. Details of injuries sustained were known for only a few specimens. Data on injured birds were also included, as most Storks died following their injury or probably would have done so. Recent data on potential predation and the death or disappearance of nestlings were gathered during fieldwork in 2003–06 on breeding biology, feeding behaviour and diet of the species (Clancy 2008). The cause of mortality was sometimes difficult to determine but was based on the available evidence.

The data were separated by age and sex of the Storks where possible. Juveniles were defined as birds in brown plumage in their first year post-fledging; immatures were similar to adults but had brown legs and traces of brown juvenile plumage, particularly on the nape; and adults were birds in full adult plumage unless an autopsy identified them as immature birds (as determined by the condition of the gonads) that had recently assumed adult plumage (for details of plumage, see Marchant & Higgins 1990). The sex of adults was determined by iris colour (black in male, yellow in female), where obvious, or by internal dissection for all specimens lodged with the Australian Museum.

Results

Records for 69 dead Storks were collated for New South Wales for the period 1839–2006: three from before 1900, 41 from 1900 to 2002, and 25 during the period of my fieldwork (2003–06) (Appendix 1). Thirty-four of the deaths were probably because of collision with powerlines, 11 were from natural causes (such as starvation), eight Storks had been shot, four had flown into fences, and one was hit by a motor vehicle (sand-mining truck). Cause of mortality could not be determined with certainty for the remaining 11 (Table 1, Figure 1).

Natural causes

Predation No cases of natural predation were observed during my 2003–06 fieldwork, but there were signs that Dingoes *Canis lupus dingo* may prey on Storks. On 22 July 2004, a pair of adult Storks was loafing with a juvenile at Tullymorgan, on the Clarence Broadwater, when a Dingo approached. The three Storks took off in alarm and landed in the water. The female and the juvenile took off and swooped over the Dingo, which waded into the water. The Dingo retreated from the water and continued hunting. The Storks returned to the water and watched the Dingo depart.

In contrast, on 2 May 2004 at a wetland at Coutts Crossing, a pair of loafing Storks was disturbed by a foraging Red Fox *Vulpes vulpes*. The male spread his wings and moved confidently towards the Fox and held his head and neck stretched out in the direction of the predator. The Fox moved away and continued foraging.

On 27 December 2003, an adult White-bellied Sea-Eagle *Haliaeetus leucogaster* swooped low over a Storks' nest (which contained a large nestling) at Bunyip Creek. As the raptor flew near the nest, the nestling stood up, and the adult male Stork flew swiftly to the nest and stood next to the nestling.

Possible starvation All documented cases of putative starvation during the 2003–06 study period involved young birds (73% of which were nestlings), except for one of unknown age. Five nestlings disappeared from three nests between observation visits, and were presumed to have starved because of the lack of observations of predation or attempted predation of nestlings. Also, siblicide is virtually unknown in this species and parental infanticide is rare (Maheswaran 2003). Another nestling died in a nest, and a juvenile died shortly after fledging (diagnosed as starvation by a veterinarian shortly before death). A second juvenile, banded at Bulahdelah in November 2003, was found dead and emaciated near Casino in April 2004; its stomach contained a Black Cricket Gryllidae, a locust Acridoidea, three carab beetles Caraboidea and five dung beetles Scarabaeinae and cattle dung. An immature Stork found exhausted following a bushfire died shortly afterwards, possibly from starvation as its stomach contained only a small crayfish and 17 insects (a Mole Cricket *Gryllotalpa* sp., two water beetles *Homeodytes scutellaris,*

Table 1: Causes of death and injury in Black-necked Storks in New South Wales, 1839–2006. See text and Appendix 1 for sources. Juv. = juvenile, Imm. = immature, U = unknown, M = male, F = female, and T = total.

	Nestling	*Juv.*			*Juv.-Imm.*	*Imm.*			*Adult*			*Unknown*	*T*
Cause	*U*	*M*	*F*	*U*	*U*	*M*	*F*	*U*	*M*	*F*	*U*	*U*	
Powerline	0	0	0	1	1	0	2	2	10	6	4	8	34
Natural causes	8	0	1	1	0	0	0	0	0	0	0	1	11
Shot	0	0	0	0	0	0	0	2	0	0	2	4	8
Fence	0	0	1	1	0	0	0	0	1	0	0	1	4
Motor vehicle	0	0	0	1	0	0	0	0	0	0	0	0	1
Unknown	1	0	1	1	0	0	2	0	2	2	0	2	11
Total	9	0	3	5	1	0	4	4	13	8	6	16	69

three weevils Curculionidae, a longicorn beetle Cerambycidae, a carab beetle *Pamborus alternans*, two scarab beetles Scarabaeidae, three pie-dish beetles Tenebrionidae—Helaeinae, two other beetles and two water bugs Heteroptera). The Stork of unknown age was found dead in a natural area away from powerlines and fences, suggesting natural causes, probably starvation. Starvation may be a symptom of another problem, such as disease, rather than the ultimate cause of death.

Unnatural causes At least 74% of all known deaths of adult Storks were caused by collision with powerlines, with another 15% possibly so (Appendix 1). Taking only deaths from known causes, 87% of adults were killed by collision with powerlines, and the majority (59%) of Storks killed by collision with powerlines were adults. The sex of nearly half (47%) of the Storks killed by collision with powerlines was not known; males comprised at least 29% and females at least 24%. At least two of these deaths occurred during inclement weather, one involving hail. Hail may have injured one Stork but it more likely prevented the bird avoiding the powerline, as a veterinarian found that the injuries were more consistent with the

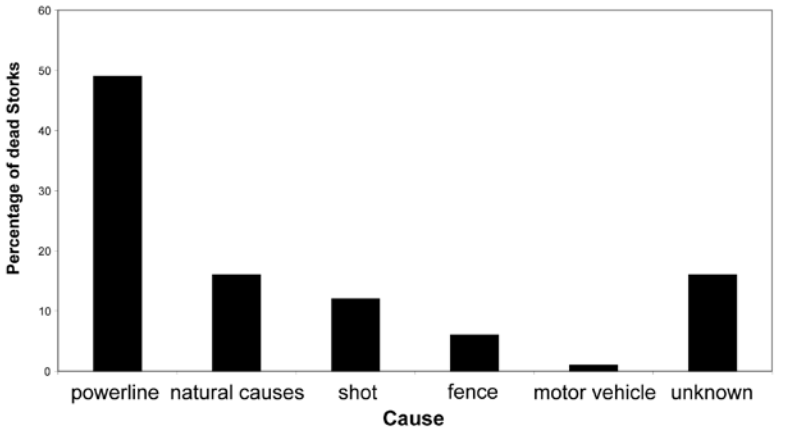

Figure 1. Causes of mortality of 69 Black-necked Storks in New South Wales, 1839–2006.

bird having had a collision. Four Storks were killed or injured after colliding with a fence (Appendix 1). At least one of these was probably an adult male and two were juveniles; one died at the fence and two were euthanased later. The injuries to the right wing of one of the Storks, later euthanased, were extensive. The age of one victim and the type of fence were not known. Another Stork was hit by a sand-mining truck within the Myall Lakes National Park in the 1970s (Mike Dodkin pers. comm.). Of the eight Storks shot, or probably shot, two were adult, two were immature and four were of unknown age. Five (62.5%) of these 'shot' records were before 1960 (1839, 1857, 1866, 2 in 1959) and three since then (1990, 2002, 2006) (Appendix 1). Nineteen free-flying Storks were known to have been killed during the period 2003–06.

Discussion

Collision with powerlines

Collision with powerlines was the greatest cause of mortality identified in the Black-necked Stork in New South Wales (49% of all deaths). Electrocution was rare, and collision usually involved severe damage to legs, wings and/or 'shoulders'. Most injured birds had to be euthanased, although two with injuries to the wings were kept alive, but died later. Young birds might be expected to be more likely to be killed because of inexperience, although only 20% of the Storks of known age killed in this study were juvenile or immature. Possibly the adult Storks killed were non-territorial or young birds that had recently assumed adult plumage (at ~2.5 years of age: Marchant & Higgins 1990). In India, only one Black-necked Stork has been recorded to collide with a powerline, during a period of morning and evening fog, although other storks died infrequently from collisions with powerlines (Sundar 2005).

Death and injury to birds from collision with powerlines is a worldwide phenomenon involving many orders of birds, with large waterbirds and raptors particularly susceptible (Bevanger 1990, 1994; Goldstraw & Du Guesclin 1991; Morkill & Anderson 1991; Negro & Ferrer 1995; Hess 1996). In India, more Sarus Cranes *Grus antigone* died from collision with powerlines than did Black-necked Storks (Sundar & Choudhury 2005). In Germany, the most frequent cause of death (60%) of European White Storks *Ciconia ciconia* was collision with medium-voltage pylons, mostly (85%) caused by electric shock, with 15% during the landing (National Semiconductor Environment 2007). Similarly, over half (59%) of the dead White Storks along a migration route in Israel had hit wires (BirdLife International 2005). Death from collision with powerlines may be more common in migratory species, which are unfamiliar with the location of powerlines, and are thus vulnerable when descending to feed or roost along the migration route. A study in Spain found that migratory and juvenile birds accounted for most of the deaths of White Storks caused by collision with powerlines (Garrido & Fernandez-Cruz 2003).

The causes of collision with powerlines can be grouped into biological (morphology, aerodynamic capability, physiology, behavioural and life-history strategies of birds), topographical, meteorological and technical (Bevanger 1994). These four variables probably all operate in New South Wales. The large size and limited manoeuvrability of the Stork may make it vulnerable to hitting powerlines. Topographical and meteorological factors include the siting of powerlines across or adjacent to wetlands and hail or heavy rain storms.

The impact of deaths from collision with powerlines on the state population of the Black-necked Stork is not known, but the population appears to be self-sustaining. There was a recruitment of at least 61 fledged young into the population and a death rate of 19 free-flying birds (11 from collision with powerlines) during the period 2003–06, indicating that the known death rate is significantly lower than the known recruitment rate (Clancy 2008). Unreported deaths are likely to be limited, as the death of a member of a territorial pair is likely to be noticed and reported to the Department of Environment, Climate Change & Water or wildlife rescue groups; indeed, some of the deaths recorded here were reported to the Department, WIRES or to me by members of the public.

Minimising powerline impacts

The usual standard flat-top configuration of powerlines involves three-phase conductors that are spaced from 0.6 to 1.2 m apart, providing insufficient clearance for large birds such as Storks with wingspans greater than 2 m (Hess 1996). Electricity-supply companies throughout the world have attempted to minimise the impact of bird collisions with powerlines and other structures with engineering methods (Hess 1996). A delta-top configuration, where the middle conductor is raised above the height of the other two conductors, can increase the distance between conductors and reduce the chance of large birds contacting two lines at once. One drawback is that birds may see the two lower conductors and adjust their flight-path to rise over them, only to collide with the third raised conductor (Hess 1996). Another ameliorative method is to place discs or coloured tape on the conductors to make them more visible. Discs have been installed in areas of frequent waterbird strike on the New South Wales North Coast, including Jerseyville. No Storks have been killed at Jerseyville since the installation of discs in 2000, despite three deaths between 1988 and 2000 (Ken Shingleton pers. comm.). In 2007 an Australian Pelican *Pelecanus conspicillatus* was killed at a section of line without discs, the first recorded waterbird death since 2000 (Ken Shingleton pers. comm.). An effective method to reduce deaths from collision with powerlines would be to design the pathways of powerlines to avoid wetlands wherever possible by rerouting or placing cables underground.

Other impacts

Other anthropogenic causes of mortality include fences and motor vehicles. Black-necked Storks, especially young birds, occasionally collide with fences, resulting in severe injury or death. They may feed in wetlands alongside roads, but the only Stork known to have been killed by a motor vehicle in New South Wales was killed by a sand-mining truck on a mining road. However, a banded Stork has been killed by a motor vehicle in the Northern Territory (David Drynan, Australian Bird & Bat Banding Scheme, pers. comm.).

Mortality of the Stork from hunting is negligible in New South Wales, although it was possibly hunted for food by Aborigines in the past. It was eaten in the 1980s in Queensland, and leg sinews of Storks were used to bind barbs to Aboriginal spears (Garnett & Bredl 1985). Early European settlers probably hunted Storks for food, but Storks may not have been commonly encountered until settlement spread north of the Hunter River. Records of Stork deaths before 1900 were generally of Storks shot for museum collections. There is no evidence to suggest that Storks are targetted by shooters today, although occasionally one may be shot.

Designing roads to avoid wetlands, erecting fences with plain wire where

possible, and enforcing the laws that protect the species should minimise Stork mortality.

The Stork's large size and sharp bill probably protect it from attacks by most natural predators. However, a Wedge-tailed Eagle *Aquila audax* attacked, and probably killed, a Brolga *Grus rubicunda* in flight (Rob Drummond pers. comm. 2006), so Storks may also be vulnerable. Small Stork nestlings at risk of predation from large aerial predators—Wedge-tailed Eagle and White-bellied Sea-Eagle—are not left alone in the nest until large enough to defend themselves, from ~30 days of age (Marchant & Higgins 1990; Clancy 2008). The behaviour of the adult and nestling Storks at Bunyip Creek in response to a Sea-Eagle flying over indicates that this was considered a threat to the nestling. In addition, Dingoes and Red Foxes may prey on sleeping Storks at night, and a crocodile, probably an Estuarine Crocodile *Crocodylus porosus*, killed and ate a Stork in Kakadu National Park, Northern Territory (Gopi Sundar pers. comm.).

From the data here, starvation was implicated in the deaths of seven nestling and juvenile Storks, although predation may have occurred in a few cases (Appendix 1). Another dead juvenile had only small invertebrates in its stomach and was probably starving.

The Cane Toad could threaten the Black-necked Stork, which consumes amphibians at all stages from tadpole to adult, and the toad is expanding throughout the core-range of the Stork in northern Australia (Dorfman *et al.* 2001) and spreading south in coastal north-eastern New South Wales. However, the Stork persists in areas, such as north Queensland, which have had toads since 1936 (Garnett 2003). Many toads *Bufo* spp. occur sympatrically with storks in other countries, but despite their poisonous parotoid glands they are consumed by storks, and two species of toads are fed to nestling Abdim's Storks *Ciconia abdimii* in Niger (Falk *et al.* 2006).

Conclusions

Anthropogenic factors cause a few deaths of the Black-necked Stork, with powerline collisions the most significant factor, but such mortality is unlikely to adversely affect the current Stork population in New South Wales. However, measures to reduce powerline collisions, such as the installation of discs on lines, and designing routes of new lines to avoid wetland areas, would be worthwhile as Storks are rare in this state and the number of powerlines is increasing. There would also be benefits for other waterbird species. Starvation is likely to be more significant during drought years.

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Macquarie and Griffith before lodgement with the Australian Museum. Specimens were processed at the Australian Museum by Walter Boles, who forwarded the stomach contents to Tony Rose, of Forster, for examination. All are thanked.

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Appendix 1

Cause of mortality/injury in Black-necked Storks, NSW, from records from the literature, Wildlife Information Rescue and Education Service and museum specimens, and personal communications to and unpublished records of the author (GPC). Location: Ck = Creek, Is. = Island, L = Lake, NP = National Park, R = River, Rd = Road; Age: A = adult, I = immature, J = juvenile, N = nestling; Sex: F = female, M = male; Cause of mortality/injury: B = barbed-wire fence, D = found dead, I = found injured, N = natural causes, P = powerline, Pr = predation, S = shot, St = starvation, U = unknown; Source and notes: AM = Australian Museum, Clause 64 = The Electricity Commission of New South Wales (1988), CSIRO = Commonwealth Scientific and Industrial Research Organisation, D = Dead, FAWNA = For Australian Wildlife Needing Aid, I = injured, NPWS = National Parks & Wildlife Service, NR = Nature Reserve, St = starvation, WIRES = Wildlife Information Rescue and Education Service, and * = museum specimen.

Date	*Location*	*Age*	*Sex*	*Cause of mortality/injury*	*Source*	*Notes*
1839	Hunter R			S	Bennett (1860)	Sent to AM
1857	Narrabeen L			S	Bennett (1860)	Sent to AM
June 1866	Grafton			S	Iredale (1937)	*, shot by J. McGillivray
1959	Myall R	I		S	Salmon (1965)	
1959	Myall R	I		S	Salmon (1965)	
14/12/1963	Forster	J	F	I	J. DeGent	AM*
26/9/1971	Red Rock (Yuraygir) NP			U	AM	Bones in AM
Jan.–Feb. 1973	Wee Waa	I	F	U, side bruised, ?poison	E. Coombs	AM*
1975	Bulahdelah	J		P	M. Dodkin	
1975	Myall Ls NP	J		Hit by sand-mining truck	B. Moffatt	
1978	McGraths Hill			P	Clause 64	
1978	McGraths Hill			P	Clause 64	
Aug. 1978	Kimbriki, Taree	A	F	P	M. Dodkin	AM*
Late 1970s	Coffs Harbour Zoo			P	B. Holder	
1979–1983	Mongogarie	N		D under nest, ?N	L. McNamara	

Appendix 1 continued

Date	*Location*	*Age*	*Sex*	*Cause of mortality/injury*	*Source*	*Notes*
1982–1983	Seelands	A	M	P	L. Cole	
1982–1983	Seelands	A	F	P	L. Cole	
1984–1993	Mongogarie	N		D hanging in nest-tree, ?N	L. McNamara	
09/10/1986	Lower Kangaroo Ck	N		D under nest, ?N	GPC	
Late Oct. 1986	Lower Kangaroo Ck	J		B	GPC	
Sept.–Nov. 1988	Bundjalung NP			D, ?N	B. Moffatt	
1988	Waterview Heights			P	Local radio	
1988	Friars Lane, Waterview			P	L. Brown	
1988	Jerseyville			P	J. Perkins	Taxidermed, now at Roto, Macquarie NR
1988–1989	Jerseyville area	J-I		P	J. Perkins	I, fate unknown
30/5/1990	Waterview Heights	I	F	P	WIRES	AM*
30/5/1990	W of Grafton	A	M	P	NPWS	AM*
June 1990	Micalo Is.	A		?S	J. Richards	WIRES
09/08/1990	Micalo Is.			D on fence	J. Richards	WIRES
14/9/1990	Woodford Dale, Woodford Is.	A		P	A. Grose	
1990–2000	Boyters Lane, Jerseyville			P	K. Shingleton	
08/01/1991	Sextonville Rd, W of Casino	A	M	P	*Northern Star*/NPWS	AM*
15/03/1993	Braunstone			P	D. Jennings	D under powerline
25/05/1994	Junction Hill	A		P	WIRES	I. Injured leg, flew away
28/11/1994	Grover, Meriwagga	A	M	U	NPWS, Griffith	AM*

Appendix 1 continued

Date	*Location*	*Age*	*Sex*	*Cause of mortality/injury*	*Source*	*Notes*
14/03/1995	Middle Boambee	A	M	Collapsed in paddock	WIRES	AM*
Mid 1995	Evans Head	A	F	U	CSIRO collection	
22/07/2000	Palmers Is.	I		P	J. Richards	WIRES
26/07/2000	Upper Horseshoe Ck	I	F	P	State Forests	AM*
Aug. 2000	Mongogarie	A	M	P	L. McNamara	
16/04/2001	Austral Eden	I		P	A. Lamont	
02/05/2002	Shannon Brook, SW of Casino	A	M	?P	S. Higgins	AM*
09/05/2002	Seelands Fish Farm			?S	J. Gumbleton	
15/11/2002	Wellingrove Rd, near Glen Innes	I	F	Found exhausted after bushfire	NPWS	Died of smoke inhalation or St. AM*
08–09/04/2003	Arndilly, Tullymorgan	A	F	P, ?hailstorm	WIRES/NPWS	AM*
17/06/2003	Seelands Fish Farm	A	F	U, left leg broken	GPC	? Tangled in wirenetting
17/09/2003	Arndilly, Tullymorgan	A	M	P	WIRES/NPWS	AM*
Oct. 2003	Nana Glen			D	M. Bruggisser	
28/10/2003	Coraki	A	M	P	H. Bodley	AM*. Had not bred
06/11/2003	Bunyip Ck, nest	N		?N	GPC	1 of 2 nestlings disappeared 6–18/11/04
18/11/2003	Woodford Dale, Woodford Is.	J	F	B	WIRES	Recently fledged. AM*
03/03/2004	Coraki	J		D, ? killed or scavenged by eagle	T. Bodley	Feathers found on ground with Wedge-tailed Eagle feather
29/04/2004	Yorklea Rd, S of Casino	J	F	D, ?St	N. Warne	Banded Bulahdelah. AM*
27/05/2004	Mooneba, W of Kempsey	A		P, electrocuted	NPWS	
03/11/2004	Coraki, nest	N		St	GPC	Weak, flapping about 03/11/04; remains found 16/01/05

Appendix 1 continued

Date	*Location*	*Age*	*Sex*	*Cause of mortality/injury*	*Source*	*Notes*
17–26/11/2004	Main Camp, nest	N		U	GPC	1 of 2 nestlings disappeared from nest
26/05/2005	Mantons Rd, Lawrence	A	M	P	WIRES	AM*
09/06/2005	Bunnor, Moree, nest	N		N (St, Pr)	J. & B. Southeron	1 of 3 nestlings disappeared 09–13/06/05
09/06/2005	Bunnor, Moree, nest	N		N (St, Pr)	J. & B. Southeron	1 of 3 nestlings disappeared 09–13/06/05
09/06/2005	Bunnor, Moree, nest	N		N (St, Pr)	J. & B. Southeron	1 of 3 nestlings disappeared 09–13/06/05
28/06/2005	2955 Summerland Way	A		P	WIRES	I. Wing hanging down, limping, disappeared
08/07/2005	Boothbys Ck, Southgate	A	F	P	WIRES	AM*
31/08/2005	Near Seelands Fish Farm	A	F	?P, dislocated shoulder	WIRES	Sent to AM
18/10/2005	Swan Ck, nest	J		St	GPC	Newly fledged. On ground 18/10/05, died at vet's 19/10/05
22/05/2006	Gum Scrub, near Rollands Plains	A	M	P	T. Galloway	FAWNA, died in care, 28/05/06
30/07/2006	Calliope	A	M	P, damaged right wing	WIRES	Taken into care, died, sent to AM
02/09/2006	Barretts Ck	A		?S	T. Kerr	D. Partly decayed. Shooting recently in area
30/11/2006	Tyndale, nest	A	F	P	GPC	D. Had been dead for some weeks
29/12/2006	Mountain View	A	?M	B	WIRES	I. At least one leg broken

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