REPRODUCTIVE WASTAGE IN EXTENSIVELY-MANAGED BEEF CATTLE

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Summary

This paper complements a comprehensive review of reproductive wastage in northern Australia by Burns *et al*. (2010) by providing outcomes from recent research that has added considerably to our understanding of the risk factors. Recent research has involved a large number of cattle on a large number of extensive beef properties, where herd sizes usually exceed 1,000 breeding cows. High variability in foetal and calf loss in northern Australia has been demonstrated. A high incidence of elevated reproductive wastage occurs, especially in the tropical northern forest region where 40% or greater loss has been recorded. Loss associated with reproductive disease, primarily BVDV and *Campylobacter*, was confirmed. Animal factor effects previously associated with reproductive wastage were quantified. Of greatest significance was a range of nutritional, environmental and management risk factors having large impacts on calf survival, either directly or as a result of cow mortality. This research has provided the basis that will enable beef producers to attain achievable levels of reproductive wastage, thereby increasing business productivity and profitability.

Introduction

Foetal and calf loss between confirmed pregnancy and weaning is a major problem in northern Australia, with the average exceeding 15% in tropical forested areas (McGowan *et al*. 2014). A high proportion of loss occurs within a week of birth. Reasons for loss are multiple. Although the specific causes of the majority of loss remain unconfirmed, recent research indicates that the primary causes are not infectious diseases, but are nutritionally related.

Burns *et al*. (2010) conducted a comprehensive review of foetal and calf loss in north Australia. This paper provides additional information and perspective from more recent research and the business impact in extensively-grazed beef cattle in northern Australia. For the purposes of this review, terms are defined in Table 1.

Northern Australia and beef breeding cattle

Northern Australia is transected by the Tropic of Capricorn. Summer temperatures are high. Winters are warm in the north and cooler in the south. Frosts are common in inland areas south of the Tropic of Capricorn. Australia is relatively dry with 50% of the country having a median rainfall of less than 300 mm per year and 80% less than 600 mm (Anon 2014). A north Australian 'wet' season, when most rain falls and grass grows, generally occurs from December through March. The remainder of the year is called the 'dry' season. Annual average evaporation exceeds 2 metres and is double this in some situations.

Cropping in northern Australia is mostly restricted to the north-eastern seaboard of Queensland and the eastern half of sub-tropical Queensland (central and southern forest regions; Table 1). Outside the large areas of desert in WA and the NT, beef production predominates, with wool production occurring in some areas of Queensland. Of the ~26 million Australian beef cattle, over half are located in this northern region and 45% in Queensland (Anon 2012). Management systems for beef cattle herds in northern Australia are described as extensive. Cattle diets are almost exclusively pasture. Stocking rates are low and in some areas are as low as one cow per 150ha (Tothill and Gillies 1992). Management groups of 500 to 1,000 cattle are common. The majority of cows is continuously mated with peak calving occurring late in the calendar year. Seasonal mating is usually between 3 and 7 months where suitable cattle-control infrastructure is available. Cattle handling for husbandry is infrequent and is typically twice annually in April-July and August-September (Bortolussi *et al*. 2005).

Table 1. Definitions of terms used

Term	Definition
Northern Australia	Queensland, the Northern Territory and the northern half of Western Australia.
Beef CRC	A 2000-2011 genetics project in which >2,000 females, their steer siblings and bull progeny were monitored. Females were monitored at 4 sites in Queensland representing the main country types.
Cash Cow project	A north Australian project in which ~78,000 cows were monitored on 72 commercial beef businesses for between 2-4 years.
Northern Downs	Downs (naturally non-forested, black soil plains) areas of western Queensland, the Barkly Tableland, and the Kimberley region.
Northern Forest	Non-downs northern dry tropical areas, north of ~21^{O}S (Bowen to Karratha).
Central Forest	Forested areas associated with the Brigalow areas of Queensland.
Southern Forest	Non-downs areas outside the Brigalow country of central and southern Queensland.
Prenatal loss	Abortion, calculated as a percentage of pregnant cows.
Perinatal loss	Calf death within 48 hours of birth, calculated as a percentage of pregnant cows.
Postnatal loss	Calf death between 2 days after birth and programmed weaning, calculated as a percentage of pregnant cows.
Neonatal mortality	Calf death within one week of birth, calculated as a percentage of pregnant cows.
Cows missing	Annual incidence of cows experiencing mortality, tag loss and unrecorded relocation.
Cow mortality	Annual incidence of cow death, with most deaths associated with death of a foetus or suckling calf.
Reproductive wastage	Death of a foetus, calf or cow between confirmed pregnancy diagnosis and weaning, and calculated as a percentage of pregnant cows.
Lactation rate	Calves weaned as a percentage of cows retained after weaning the previous year.
Weaning rate	Percentage of pregnant cows * (1 – Reproductive wastage).

While median weaning rates for much of northern Australia are low, performance is higher in the eastern half of Queensland south from the Tropic of Capricorn where there more fertile soils predominate (Table 2. The high incidence of low weaning rate is primarily a consequence of low annual pregnancy rates. Instances of high combined foetal and calf loss occurs in all areas, but is almost always high in the northern forest.

Table 2. Annual performance of north Australian beef cows with 25 to 75 percentile range (McGowan *et al*. 2014)

Country type	Pregnant	Missing	Foetal/Calf loss	Weaning
Southern Forest	85% (77-92%)	9%	6% (2-10%)	76% (62-88%)
Central Forest	85% (78-92%)	10%	7% (4-10%)	77% (69-87%)
Northern Downs	83% (74-91%)	7%	10% (5-15%)	72% (57-78%)
Northern Forest	66% (55-74%)	15%	13% (10-19%)	53% (44-62%)

Incidence of reproductive wastage

The review of Burns *et al*. (2010) and reports from recent relatively-small projects show there is considerable variation in reproductive wastage in northern Australia and that there has been a paucity of specific information in this area (Table 3). Field work for two large projects has recently been completed and provides a much more detailed understanding of the variation in reproductive wastage (Table 4). In the Cash Cow project, the 25th percentile was taken as the practical achievable level for reproductive wastage. Large variation in loss was demonstrated above this level across the region. Schatz and Hearnden (2008) reported an average reproductive wastage of 22%, and up to 39% of first-lactation cows in large Northern Territory herds (>4,000 cows monitored) failing to lactate in the year after pregnancy diagnosis.

Table 3. Recent reports of foetal and calf wastage in north Australian beef cattle herds, excluding Beef CRC and Cash Cow projects

Measure	Level	Sth forest	Central forest	Nth downs	Nth forest	Data source #
Prenatal loss	Target				5%	a
Perinatal loss	Target				4%	a
Postnatal loss	Target				3%	a
Reproductive wastage	Target				12%	a
Prenatal loss	Range	0-9%	0-12%	8%	1-12%	b
Perinatal loss	Range		3-12%	2-12%	3-8%	b
Postnatal loss	Range		0-5%	9-10%	3-16%	b
Reproductive wastage	Range		7-10%	21%	3%	b
Reproductive wastage	Range			12-39%		c
Reproductive wastage	Average			13%	8%	d
Reproductive wastage	Range				0-29%	e
Cow mortality	Range				0-10%	e
Cow mortality	Range				1-28%	f

a: Holroyd 1987; b: Burns et al. 2010; c: Schatz and Hearnden 2008; d: Fordyce *et al*. 2013; e: Fordyce *et al*. 2009; f: Henderson *et al*. 2013

Variation in established pregnancy per oestrus cycle has rarely been reported for this region. Preliminary data analyses from 24 mating groups of tropically-adapted cattle at 4 sites across Queensland revealed a range of 40%-70% during 12-week mating periods (Fordyce *et al*. 2005). Given the low incidence of infectious disease in the study herds, the median rate of approximately 60% pregnant per oestrus cycle in this investigation is currently considered the achievable level for beef herds in north Australia.

Cow mortality has not been usually cited as a component of reproductive wastage. Fordyce *et al*. (1990) reported that mortality risk increased between conception and weaning, and that almost all pregnancies and calves were lost from cows that died following a prolonged dry period. The incidence of cow mortality (Tables 3 and 4) is highly variable and high in many situations, especially in the northern forest. Based on the incidence of missing cows, the incidence of mortality may be at least 3% higher in the northern forest than elsewhere (Table 4). A recent study of cow mortality in 45 large north Australian beef herds in northern forest and northern downs regions reported a median breeding cow mortality rate of 6% (Henderson *et al*. 2013).

Table 4. Raw data for reproductive wastage in the Beef CRC project (9,678 pregnancies in >2,000 cows) and the Cash Cow project (23,166 pregnancies)

Calves	Measure	#	Southern forest	Central forest	Northern downs	Northern forest
Brahmans - Beef CRC ##						
All	Repro wastage	Av		12.7%	27.8%	11.4%
	Cow mortality	Av		0.7%	0.4%	0.8%
	Prenatal loss	Av		2.7%	3.1%	3.4%
Singles	Perinatal loss	Av		3.7%	14.5%	2.5%
	Postnatal loss	Av		5.5%	9.7%	4.5%
	Wean	Av		87.0%	71.7%	88.5%
Twins	Peri & Peri	Av		0.1%	0.0%	0.1%
	Post & Post	Av		0.0%	0.0%	0.0%
	Peri & Wean	Av		0.2%	0.3%	0.0%
	Post & Wean	Av		0.1%	0.1%	0.1%
	Wean & Wean	Av		0.1%	0.0%	0.1%
Tropical composites - Beef CRC ##						
All	Repro wastage	Av	8.8%	9.2%	20.8%	
	Cow mortality	Av	0.6%	1.1%	1.0%	
	Prenatal loss	Av	4.0%	2.6%	3.5%	
Singles	Perinatal loss	Av	2.5%	2.9%	11.1%	
	Postnatal loss	Av	1.8%	2.6%	5.0%	
	Wean	Av	90.9%	90.4%	78.9%	
Twins	Peri & Peri	Av	0.0%	0.0%	0.1%	
	Post & Post	Av	0.0%	0.0%	0.1%	
	Peri & Wean	Av	0.1%	0.2%	0.1%	
	Post & Wean	Av	0.1%	0.2%	0.0%	
	Wean & Wean	Av	0.1%	0.1%	0.2%	
All breeds - Cash cow project						
First	Repro wastage	Med	8.9%	10.2%	14.9%	16.4%
			3.9-13.6%	3.7-17.7%	7.3-20.0%	10.8-19.1%
Second	Repro wastage	Med	4.6%	7.3%	4.7%	9.5%
			0.7-7.1%	3.5-11.3%	4.3-9.3%	5.4-13.6%
>Second	Repro wastage	Med	4.6%	6.2%	6.9%	13.5%
			2.2-8.5%	3.8-9.1%	3.3-14.7%	9.4-19.2%
All	Missing cows	Med	8.3%	7.9%	6.6%	10.6%
			3.3-12.5%	1.8-11.2%	3.8-9.8%	5.8-15.9%

A: Average; Med: Median with interquartile range
Excludes one year of data from the northern downs site where Vitamin A deficiency was associated with 41% calf loss

Infectious reproductive diseases and reproductive wastage

There are a limited number of recognised infectious diseases that contribute to calf loss in northern Australia. Foremost among these is BVD. McGowan *et al*. (2014) reported that the average percent cattle pregnant within 4 months of calving was 57%, 43% and 34% in north Australian herds with <20%, 20-80% and >80% of cows sero-positive to BVDV, respectively; about a third of herds were within each sero-prevalence category. This result confirms a large impact of the virus on fertilisation failure and or embryo loss in this region. High prevalence of recent BVDV infection in cows sampled in early-mid pregnancy was associated with almost 10% higher foetal and calf loss than in herds with a low prevalence of recent infection (P<0.001; Table 5). Both Kirkland *et al*. (2012) and Morton *et al*. (2013) also reported a low proportion of cattle herds having recent BVDV infection and confirmed the large impacts of foetal and calf loss associated with recent infection. Both groups reported that half the herds they studied had 0-30% sero-positive animals, indicating high susceptibility to the virus.

Table 5. Reproductive wastage (%) associated with herd exposure to common infectious reproductive diseases in the Cash Cow project (McGowan *et al*. 2014)

Disease	Herd prevalence		Herd distrib (%)		% reproductive wastage
	Level	Criterion	2009	2011	(confid interval)
BVD	Low	<10% AGID 3+ #	42	64	11.5 (6.5-16.4)
	Mod	10-30% AGID 3+	31	27	12.1 (7.0-17.2)
	High	>30% AGID 3+	28	9	20.8 (12.5-29.2)
C.fetus sp.	Low-Mod	<30% vaginal mucus Ab	98	89	12.9 (8.4-17.4)
veneralis	High	≥30% vaginal mucus Ab	2	11	19.9 (10.8-29.0)
Neospora	Nil	0% sero-positive	19	24	12.6 (3.5-12.2)
caninum	Low	0-20% sero-positive	55	53	12.0 (5.9-18.1)
	Mod-High	≥20% sero-positive	26	23	15.9 (7.0-24.9)

Agar gel immuno-diffusion

Recent data from >37,000 cattle that were mostly 1-2 years of age showed there is very little variation in >1% BVDV antigen prevalence across Australia (Dr Peter Kirkland, Elizabeth McArthur Agricultural Institute, NSW, personal communication). Modelling that uses an understanding of BVDV epidemiology in Australia (McGowan *et al*. 1993a; McGowan *et al.* 1993b; Kirkland *et al.* 1990) suggests that, depending on the relative prevalence of BVDV strains with varying abortigenic effect, weaning rate is conservatively estimated to be lower by between 1% and 4.5% as a result of between 3% and 7% of cows being infected in early pregnancy each year. Each percentage unit reduction in weaning rate equates to >40,000 calves in northern Australia. Modelling of available data suggests that, irrespective of the virus's effect on pregnancy, >100,000 persistently-infected calves are born annually in north Australia.

N.caninum infection was not associated with increased reproductive wastage in north Australian beef herds in two large recent studies (Fordyce *et al*. 2013; McGowan *et al*. 2014). However, there was a non-significant (P=0.5) trend for herds with a moderate to high seroprevalence to have a higher predicted mean percentage foetal/calf loss than those with either nil or a low seroprevalence in the latter study (Table 5). These findings contrast sharply with studies of the impact of *N.caninum* infection of dairy cattle on the Atherton Tableland in northern Australia (Landmann *et al*. 2011) and elsewhere in the world. The reason for this difference is not apparent, but one could speculate that because wild dogs have been shown to be a carrier of this organism (King *et al*. 2012) and are common across the beef breeding regions of northern Australia, exposure of young heifers to pastures contaminated with faeces from wild dogs may result in them becoming immune to infection (Williams *et al*. 2009).

Campylobacteriosis has primarily been associated with embryo loss (Clark 1971), which usually occurs prior to the typical time for foetal ageing of commercial beef herds. However, in a large north Australian study, high prevalence of vaginal mucus samples positive for antibodies to *C.fetus* sp*.veneralis* had no impact on percent pregnant within 4 months of calving, but was associated with 7% higher reproductive wastage than in herds where the prevalence was low to moderate (Table 5). The contribution to reproductive wastage of *Tritrichomonas fetus,* which also is reported to cause abortions, was not measured in the study. This effect of campylobacteriosis requires further study, part of which is to develop practical and efficacious diagnostic tests of clinical infection.

Although leptospirosis is recognised as a cause of calf loss (McGowan 2003), the incidence of this effect in north Australian beef herds is not well established. In a large recent project, vaccination against leptospirosis (*L.pomona* and *L. hardjo*) was associated with a 3.4% reduction in reproductive wastage (McGowan *et al*. 2014). Only 3/27 herds in 2009 and 0/41 herds in 2011 had evidence of recent infection with *L.pomona* (≥10% with a MAT titre ≥800). The three herds in which 10-30% of cows had evidence of recent infection tended to have higher (+6%) reproductive wastage than herds with a low prevalence of recent infection.

Professional opinion is that botulism is a highly prevalent disease across north Australia (Sackett *et al*. 2006). The disease is associated with deficient appetites, which is a common occurrence in north Australia; vast areas have low soil and pasture phosphorus (McCosker and Winks 1994). The incidence of clinical disease which has a high mortality rate, has not been quantified in the region. Deaths due to botulism in unvaccinated cattle will be associated with reproductive wastage where the affected animal is either pregnant or lactating.

Environmental, nutritional and management influences on reproductive wastage

The large effects of a range of environmental, nutritional and management risk factors in north Australia on reproductive wastage, including through causing cow mortality has recently been quantified (Table 6). These data emphasise that the overall effect of these risk factors on reproductive wastage in northern Australia is just as high, and higher in many cases, that that due to disease and animal effects.

Other than infectious diseases, predation and dehorning, calf death is likely to be the outcome of either the cow not providing enough milk, or the calf unable to suckle effectively (low vigour). When ambient temperatures are not high, non-suckling calves lose about 7% of their weight daily, which is equivalent to about 2.5 litres of milk daily (Fordyce *et al*. 2014b). When calves lose 15% of their weight, they need intervention to survive. When ambient temperatures approach 40^{O}C, calves can lose this weight in one day, that is, neonates need at least 5 litres daily. Many cows may not be able to provide this if they have inadequate tissue reserves or are nutritionally-stressed. This is a likely outcome for many of the risk factors listed for reproductive wastage. Fordyce *et al*. (1996) reported daily milk yield of first-lactation Brahman cross cows in mid-lactation of 3.6 kg. McBryde *et al*. (2013) found average milk yields of 3.3 kg/day from moderately-conditioned Brahman cows with a trend for milk yield to increase by 1 kg/day per unit increase in body condition score (5-point scale). These reports highlight the potential loss of calves that can occur when nutritional stress is experienced or when the temperature-humidity index is elevated.

Post-natal loss of calves due to dehorning (Bunter *et al*. 2014a) may be reduced through simple methods that reduce associated haemorrhage (Fordyce *et al*. 2014a).

Losses associated with predators are counter-intuitive. Wild dogs are prevalent across all north Australian beef production areas. McGowan *et al*. (2014) and Allen (2014) both reported that when producers took typical measures to reduce wild dog populations in northern Australian beef herds are more likely to be associated with an increase in calf predation than a decrease. Allen (2014) has suggested this is due to poison-baiting impacts on dog behaviour which causes them to target non-preferred species when they would usually prey native species.

Table 6. Increases in reproductive wastage and cow mortality in recent north Australian studies due to risk factors other than infectious disease when compared to reference values in analyses

Risk factor		Av effect	#
Cow and calf factors on reproductive wastage			
Previously failed to lactate in the year after diagnosed pregnancy		3.5%	a
Birth weight < 29 kg where population average ±sd is 33.5 ±5.9 kg		8%	b
Teat score 5 (1-5 scale) = Bottle teats		20%	b
Udder score 5 (1-5 scale)		6%	b
Hip height > 140 cm = Large mature size		3.5%	a
Environmental, nutritional and management factors on reproductive wastage			
THI* >79 for > 15 days in the expected month of calving		4-7%	a
Low-protein dry-season feed, ie, CP:DMD ratio < 0.125		4%	a
Vit A deficiency after consecutive low-rainfall years on treeless plains		≤25%	b
Low herd phosphorus status and low-growth tropical environment		10%	a
Low herd phosphorus status and BCS <3.5 ## mid-pregnancy		3.5%	a
Mustering within 2 months of calving month:	mature cows	2%	a
	first-lactation cows	9%	a
Wild dog predation considered a problem, irrespective of regular control		5%	a
Dehorning		2%	b
Mustering efficiency < 90%		9%	a
Factors affecting breeding cow mortality rate			
Dystocia when calving at 2 years without strategic nutritional support		5-10%	d
Cows > 11 years of age		6%	c
Low-growth tropical environment		7%	a
Pasture available < 2 tonnes/ha in the early dry season		5.5%	a
No rainfall within 30 days of 50 mm at the end of the dry season		4%	a
Body condition score < 3 (1-5 scale) mid-pregnancy		3-8%	a
No dry season segregation based on foetal age		10%	c
No wet season phosphorus supplementation		1%	c

Source – a: McGowan *et al*. 2014; b: Bunter *et al*. 2014a; c: Henderson *et al*. 2013; d: Fordyce *et al*. 2009
Body condition score on a 1-5 scale
* Temperature-humidity index (Hahn *et al*. 2009)

Dead cows provide very little milk and have a negative impact on herd live weight production (no reference available so we hope it is true). Mayer *et al*. (2012) derived a model to predict cattle mortality rates using data from multiple north Australian databases with observed annual mortality rates of 3% in pre-breeding age cattle and 11% in breeding-age cattle. Their modelling found that survival is a complex relationship between body condition score, dry season weight change and age. This supports the analysis of Fordyce *et al*. (1990) that identified the major risk factors for higher cow mortality to be aged > 8 years, lower body condition and more advanced reproductive status (conception to weaning); the latter is associated with higher energy demand, thus greater weight loss during the dry season.

Animal factors and reproductive wastage

Reproductive wastage is lowly repeatable as cows that experienced it in one year will only have a 3.5% higher chance of wastage in a subsequent year (McGowan *et al*. 2014; Table 6), independently of other animal effects including udder and teat score and effects of birth weight (Bunter *et al*. 2014a). Mature size will contribute to repeatability as tall cows were shown to have higher loss than short and medium-height cows in northern Australia (McGowan *et al*. 2014). It is hypothesised that being tall is associated with a higher probability that energy is diverted away from milk production towards the cows itself in order to sustain its own survival.

Bunter and Johnston (2014b) also showed that reproductive wastage in tropical cattle in northern Australia is lowly heritable as previously reported for USA Brahmans (Riley *et al*. 2004). However, large teats and udders which are phenotypically and genetically correlated with calf loss are highly heritable (Table 6; Bunter and Johnston 2014b). This research was unable to discern a specific effect of common breeds used in northern Australia on calf loss. This contrasts to the report from the USA where Brahman calves had a higher incidence of low vigour at birth than Brahman cross calves with a trend to high mortality (Riley *et al*. 2004).

Both the repeatability and heritability elements of reproductive wastage may also be partially related to factors that affect calves' ability to acquire adequate milk for survival. In their review, Burns *et al*. (2010) reported that behavioural influences on reproductive wastage were another potential contributor to repeatable and heritable calf loss.

Other than *in utero* infections such as with BVD, reasons for low calf vigour that may affect their ability to access milk and utilise nutrients are unclear. Riley *et al*. (2004) reported this trait to be heritable in Brahmans. Yates *et al*. (2012) in their review suggested that heat stress may also cause this outcome, in association with reduction in birth weight.

Dystocia is not commonly associated with calf loss in tropical cattle in north Australia. However, Fordyce *et al*. (2009) reported the large effects of dystocia in cows calving at two years of age (Table 6) when nutritional management did not adequately counter foeto-pelvic disproportion. The true extent of the effects of dystocia on calf viability and survival are unknown as this has been an extremely difficult aspect to study under extensive management conditions. Riley *et al*. (2004) has previously reported that dystocia in Brahman and Brahman cross cows reduces vigour of their calves at birth and increases mortality rates.

Unknown causes of reproductive wastage

Although there appears to be considerable variation in pregnancy rate per oestrus cycle in north Australian herds as a consequence of variation in fertilisation rates and embryo mortality, no research in the region has yet identified non-infectious causes for this variation.

Burns *et al*. (2010) reported that in northern Australia, the majority of reproductive wastage events had no discernable aetiology. The large epidemiological study of McGowan *et al*. (2014) has demonstrated the large impacts of environmental, nutrition, and management factors on reproductive wastage as discussed above. Although calf hydration appears to be a key element, the specific pathophysiology that results in calf death has not been explained in most cases; therefore, the exact manner of loss is not resolved. This reduces the ability to develop and apply remedial management. The likely role of aberrations in cow and calf behaviour contributing to loss is high and has previously been reported by Brown *et al*. (2003). Overcoming these behavioural effects relies on a better understanding of how this occurs.

Impact of reproductive wastage in north Australia

The loss of a foetus or calf reduces lactation rate and causes loss of annual net live weight production per cow, especially when associated with cow mortality. Economic herd modelling of herds in the region has shown that a 1% reduction in lactation rate and a 1% increase in mortality rate are independently associated with reductions in herd gross margins per adult equivalent (450 kg) of approximately AUD$1 and AUD$2, respectively (Niethe and Homes 2008). In a typical business that can sustain 3,000 adult equivalents, where management changes can increases lactation rate by 5% and decrease mortality rates by 2%, inputs to achieve these outcomes of up to AUD$27,000 are likely to be viable options. The effect of substantial reproductive wastage that is occurring above achievable levels has impacts on business that can be calculated in a similar manner for individual businesses.

Specific opportunities to remediate reproductive wastage are indicated by the risk factors associated with loss. However, further research is required to confirm the effects of management changes as much of the research has been of an epidemiological nature and not controlled testing of cause-and-effects. Further, many of the risk factors identified do not provide a direct indication of specific strategies, which must be developed through further research.

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