The influence of risk factors associated with captive rearing on post-release survival in translocated cirl buntings *Emberiza cirlus* in the UK

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Abstract Population decline resulting from agricultural intensification led to contraction of the range of the cirl bunting *Emberiza cirlus* in the UK to a small area of south Devon. As part of the UK Biodiversity Action Plan for the species, a project to re-establish a population in suitable habitat in Cornwall was undertaken during 2006–2011, in which chicks were removed from the nest in Devon, hand-reared and then delayed-released. The survival of the birds to four time points in the year after release was analysed in relation to the effect of rearing factors, using a multivariable logistic regression model. Individuals with higher body weight at capture were more likely to survive to 1 January and 1 May in the year following release, and individuals released in June and July were more likely to survive than those released in August. Individuals released in 2006 and 2011 had a higher survival rate than those released during 2007–2010. Timing of capture, time spent at each stage in captivity, medication and the detection of parasites in the brood had no significant effect. Immunosuppressive disease, weather factors and predator activity may have led to some of the observed differences in survival. This analysis provides evidence with which to plan future translocation projects for cirl buntings and other passerine birds.

Keywords Capture body weight, cirl bunting, immunosuppressive disease, multivariable logistic regression, passerine, predation, rearing factors

Introduction

Conservation programmes involving the release of captive-reared animals have had varying degrees of success (Griffith et al., 1989; Fischer & Lindenmayer, 2000). However, there is a lack of evidence on which to base decisions about the most favourable rearing and release methods (Parker et al., 2012), and few studies have examined the effect of factors in the captive-rearing process on the post-release survival and reproductive performance of released individuals (Parker et al., 2012). Many reintroduction programmes either have not conducted adequate monitoring or have not reported the results (Ewen et al., 2012; Nichols & Armstrong, 2012). A common finding in avian and mammal reintroductions is a high rate of mortality shortly after release (Tavecchia et al., 2009; Bernardo et al., 2011; Burnside et al., 2012). In reintroduced captive-bred grey partridges *Perdix perdix* there were high levels of post-release mortality as a result of sub-optimal habitat selection and poor predator avoidance by inexperienced birds (Rantanen et al., 2010). Predation was the only confirmed cause of mortality in radio-tagged eastern loggerhead shrikes *Lanius ludovicianus migrans* (Imlay et al., 2010). The choice of rearing and release strategy has an impact on the rate of mortality in some species, and no effect on others (Bernardo et al., 2011). More time spent in pre-release enclosures and release of larger cohorts were found to increase post-release survival in captive-bred red-billed curassows *Crax blumenbachii* (Bernardo et al., 2011) but negatively affected post-release survival in captive-reared marbled teal *Marmaronetta angustirostris* (Green et al., 2005). Post-release survival in reintroduced grey partridges was lowest in captive-reared adults, compared to wild adults and fostered captive-reared chicks (Buner & Schaub, 2008). Stress is often cited as a factor affecting the success of avian conservation activities (Teixeira et al., 2007), and captivity is the critical factor that induces a significant and prolonged loss of the negative feedback mechanism of the stress response axis (Dickens et al., 2009). This renders released birds less able to cope with acute stressors in the wild and may blunt the normal flight response for evasion of predators.

The cirl bunting *Emberiza cirlus*, a sedentary passerine, is categorized as Least Concern on the IUCN Red List on the basis of its extensive range throughout south and western Europe (BirdLife International, 2012). It was once widespread at the northern edge of its range, in the UK, but suffered dramatic declines in the 20th century as a result of changes in farming methods, such as the removal of

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hedgerows, the decline in cultivation of spring-sown cereal crops and the loss of the resulting overwinter stubbles (Jeffs & Evans, 2004). Cirl buntings form pairs in spring and may raise up to three broods. During winter they flock to feed on seeds and insects in stubble and weedy marginal land (Evans, 1992). A residual population in Devon was estimated to comprise only 118 pairs in 1989 (Evans, 1992). Conservation action by partner organizations under the government's agri-environmental schemes to reduce the frequency of hedgerow cutting, allow the growth of scrub and unimproved grassland areas, particularly in field margins, and allow stubble to remain overwinter resulted in an increase in the population but with little increase in range (Peach et al., 2001). To establish a second population in a geographically separate area birds were translocated to Cornwall during 2006–2011. The factors that had led to extinction in the area were addressed and the project was assessed using the IUCN guidelines on reintroductions (IUCN, 1998). Previous mist-netting of adult birds had led to an unacceptably high mortality rate (Jeffs & Evans, 2004), and therefore chicks from nests in Devon were hand-reared and delayed-released at a suitable site. Following an outbreak of disease caused by isosporosis during a trial translocation, a preventative protocol was developed for the first true translocation (McGill et al., 2010). During the planning stage a disease risk analysis was conducted (McGill & Sainsbury, 2006) and detailed protocols were put in place to reduce the risk from disease, including the introduction of exotic pathogens into the release area while maintaining the native parasite fauna of the birds. This project is the first example of a passerine translocation in the UK but the project managers were able to draw on experience from passerine translocations in New Zealand (Castro et al., 1994; Taylor et al., 2005; Robertson et al., 2006; Leech et al., 2007) and elsewhere (Komdeur, 1997; Tweed et al., 2003; Cristinacce et al., 2006).

To increase the evidence base for planning future translocations of cirl buntings and other passerines, we sought to examine the effects of various capture, rearing, health and release risk factors on the survival and reproduction of cirl buntings post-release in a reintroduction programme in Cornwall during 2006–2011, and to assess the impact of the preventive medicine protocols developed during the disease risk analysis on survival.

Methods

Chicks were collected from nests at up to 10 sites in Devon. Each year 20–30 broods were collected at an estimated 5–7 days of age. Chicks were placed in a cardboard travel box and transported c. 100 miles by car to a dedicated rearing facility in Cornwall, a journey of c. 2.5 hours duration. There were no travel-related mortalities and no morbidity except for one occasion when chicks required rehydration following traffic delays on a hot day.

Body weight at collection Chicks were weighed using spring balance scales upon collection from the nest. Following a review in 2008 of captive mortality during 2006–2008, chicks < 10 g were identified as having a higher risk of mortality than those > 13 g, and therefore no chicks < 10 g were collected after July 2009 (K. Fountain et al., unpubl. data).

Rearing Each brood of chicks was maintained in quarantine for the duration of their captivity, with dedicated tools and equipment, and strict hygiene was practised. Chicks were placed in a heated brooder cage maintained at 28°C, and individually hand-fed every 2 hours during 06.00–22.00 with brooder pellets mixed with boiled eggs and banana, and locusts and mealworms. When they reached a sufficient size they were transferred to a box cage (canary cage), and hand-feeding was continued until they began feeding themselves, when mixed seed and millet was added. Their diet was developed specifically for this project by the aviculture department at Paignton Zoo, in Devon. To avoid stress, birds were not handled after fledging, unless sick. They were transferred to pre-release aviaries and delayed-released, with food provided at the release site. The duration spent in each type of housing varied, as chicks were moved on when they were considered to be sufficiently developed. The time spent in each type of housing during rearing was recorded.

Faecal examination for parasites In 2006, 2007 and 2008 pooled faecal samples were collected from the nest when the chicks were collected, from the box used for transport to the rearing site, on day 3 in the brooders, on day 10 in the canary cages, on days 17 and 24 in the pre-release aviaries, and post-release from any individuals returning to aviaries to roost. Samples were examined either by light microscopy or by salt flotation (McGill & Sainsbury, 2006). Parasites found included coccidial oocysts, which were not identified to species level, *Hymenolepsis*-like ova, and strongyle-type ova. During 2009 the frequency of faecal sampling was reduced ($n = 28$), and in 2010 and 2011 no faecal screening was undertaken. Individual birds were noted as parasite positive or negative on the basis of the results for pooled samples collected from a brood.

Medication Toltrazuril (Baycox, Bayer, Leverkusen, Germany) was administered orally to all birds as a protozoal prophylaxis on days 5 and 6, 12 and 13, 19 and 20, and 26 and 27 post-capture. During 21 July 2006–12 July 2007 the dosing frequency was reduced to days 5, 12,

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19 and 26. On days 5 and 6 a dose of 12.5 mg kg^{-1} body weight was given with food, and subsequent treatments were administered in drinking water at 1.8 ml of 2.5% solution per litre of water. Some individuals with clinical signs of disease received toltrazuril on days additional to the routine prophylactic protocol and were included in the medication category for the purposes of the risk factor analysis. Other medication administered to individuals showing signs of illness or following trauma, or on a prophylactic basis to broods following outbreaks of disease, included enrofloxacin (Baytril, Bayer, 20 mg kg^{-1} body weight four times per day by mouth) and meloxicam (Metacam, Boehringer, Ingelheim, Germany, 0.2 mg kg^{-1} body weight four times per day by mouth). Where the information was available the medication of individuals was noted, otherwise the whole brood was recorded as medicated.

Post-release survival After collection from the nest, each bird was fitted with coloured leg rings to facilitate identification. The birds were released within an area of suitable habitat of c. 10 × 4 km, in which farmers undertook active habitat creation as part of agri-environment schemes (Peach et al., 2001). There was no specific assessment of predator activity prior to choosing the release site. During 2006–2009 a single release location was used, and in 2010 a second location on the site was added; in 2011 a new site was used for release. Released birds tended to stay in the release field for a period of approximately 1 week before dispersal, with some individuals staying or returning regularly. To reduce the impact of predators the pre-release aviaries and feeding site were surrounded by an electric fence. Sparrowhawks *Accipiter nisus* were observed preying on cirl buntings at the site, prompting the deployment of scarecrows, coloured hazard tape and human volunteers to attempt to scare them away. During 2010 diversionary feeding of a nesting sparrowhawk pair in the proximity of the release site was undertaken. No sparrowhawks were observed at the new release site used from 2011 onwards. Approximately 31 km^2 of habitat was monitored post release by a single dedicated staff member to estimate the survival rate. Three individuals fulfilled this role during the course of the project (June–December 2006, January–December 2007 and January 2008 onwards). A total of 50 volunteers assisted in the spotting effort, which varied in intensity through the year. The probability of re-sighting was estimated to be > 80% (S. Croft, pers. comm.). As adult cirl buntings are sedentary (Evans, 1997), the sudden absence of a breeding bird from an area was considered to be evidence of death. Absence of a young bird may indicate either mortality or dispersal; however, studies in Devon (Evans, 1997) have shown that cirl buntings tend not to move > 2 km between breeding and wintering habitat, and none of the ringed birds were observed > 5 km from the release site. Survival at each of four dates was recorded: 30 days post release, 1 October, and 1 January and 1 May the following year. Breeding success was determined by the production of at least one fledgling in the year following release. The sex ratio of surviving birds could not be determined until the first post-juvenile moult, at which time it was c. 1 : 1.

Post mortem examination Birds found dead post release were examined according to standard avian post-mortem procedure (Latimer & Rakich, 1994), with tissues examined where appropriate by histology, bacteriology and virology.

Statistical analysis The data were analysed using *R v. 3.0.2* (R Development Core Team, 2013). Summary statistics were presented as mean ± SD for continuous variables, and percentage for categorical variables. A simple linear regression model was used to establish whether captive mortality could be used to describe post-release mortality over time. A univariate logistic regression model was used to assess each risk factor against the post-release survival at 30 days, 1 October, and 1 January and 1 May the following year, and production of at least one fledgling. Risk factors with $P < 0.1$ were included in a multivariable logistic regression model. Factors with resulting $P > 0.05$ were eliminated one by one until only factors with $P < 0.05$ remained. Odds ratios and 95% confidence intervals were calculated. The following risk factors were used: capture body weight, days in brooder, days in canary cage, days in aviary, total days in captivity, year of capture/release, month captured (May, June, July, August), month released (June, July, August, September), number released per day, parasite positive and medicated. For the risk factor 'year', 2006 was used as the baseline in the model. For 'month captured' and 'month released', August was used as the baseline. Odds ratios are quoted relative to these factor levels.

Results

Post-release survival varied considerably from year to year, with the greatest losses within 30 days of release in 2007 and 2008, and poor over-winter survival in 2009 (Table 1). The simple linear regression model indicated no significant correlation between captive and post-release mortality. Month of release had an impact on post-release survival, with birds released in June and July being significantly more likely to survive to 30 days, 1 October and 1 May, and birds released in July more likely to survive to 1 January, compared to birds released in August. Summary statistics of risk factors that potentially affect survival are in Table 2. Capture body

TABLE 1 Mortality and survival data for cirl buntings *Emberiza cirlus* reintroduced in Cornwall, UK, during 2006–2011, with pre-release mortality, number of birds released, number of birds surviving to 30 days post release, 1 October, 1 January and 1 May, and number of birds fledging at least one young.

Year	Pre-release mortality (%)	Birds released	Birds surviving 30 days (%)	Birds surviving to 1 Oct. (%)	Birds surviving to 1 Jan. (%)	Birds surviving to 1 May (%)	Birds fledging at least one young (%)
2006	3 (4)	72	57 (79.2)	47 (65.3)	34 (47.2)	27 (37.5)	12 (16.7)
2007	26 (35.6)	47	16 (34)	11 (23.4)	10 (21.3)	9 (19.1)	3 (6.4)
2008	7 (9.3)	68	25 (36.8)	24 (35.3)	19 (27.9)	13 (19.1)	8 (11.8)
2009	13 (16.2)	67	39 (58.2)	24 (35.8)	9 (13.4)	6 (9)	4 (6)
2010	6 (7.9)	70	40 (57.1)	32 (45.7)	23 (32.9)	17 (24.3)	11 (15.7)
2011	24 (31.6)	52	43 (82.7)	38 (73.1)	29 (55.8)	23 (44.2)	12 (23.1)
Total	79 (17.4)	376	220 (58.5)	176 (46.8)	124 (33)	95 (25.3)	50 (13.3)

TABLE 2 Summary statistics for the risk factors capture body weight, no. of days in brooder, canary cage, aviary and captivity (mean ± SD), parasite positive, medicated, month captured, month released and number released per day (mean ± SD), at each time point. The numbers in parentheses indicate the percentages of total birds with this risk factor released that survived to each time point.

Risk factor	Birds surviving 30 days	Birds surviving to 1 Oct.	Birds surviving to 1 Jan.	Birds surviving to 1 May	Birds fledging at least one young
Capture body weight (g)	14.89 ± 2.23	14.98 ± 2.1	15.19 ± 2.02	15.26 ± 1.98	15.10 ± 1.93
Days in brooder	8.07 ± 1.6	8.04 ± 1.57	8.07 ± 1.68	8.02 ± 1.77	7.66 ± 1.61
Days in canary cage	8.58 ± 2.82	8.43 ± 2.75	8.44 ± 2.82	8.67 ± 2.99	8.70 ± 2.92
Days in aviary	7.59 ± 2.31	7.43 ± 1.12	7.41 ± 0.95	7.47 ± 0.99	7.48 ± 1.01
Days in captivity	24.24 ± 3.72	23.9 ± 2.75	23.93 ± 2.64	24.17 ± 2.78	23.84 ± 2.67
No. parasite positive (%)	18 (41.9)*	13 (30.2)*	10 (23.3)*	7 (16.3)*	4 (9.3)
No. medicated (%)	25 (25.5)	19 (19.4)	14 (14.3)	13 (13.3)	7 (7.1)
Captured in May (%)	25 (78)	19 (59.4)	12 (37.5)	10 (31.3)	7 (21.9)
Captured in June (%)	78 (64.5)	59 (48.8)	43 (35.5)	36 (29.8)	23 (19.0)
Captured in July (%)	103 (59.9)	84 (48.8)	57 (33.1)	42 (24.4)	19 (11.0)
Captured in Aug. (%)	14 (27.5)	14 (27.5)	12 (23.5)	7 (13.7)	1 (2.0)
Released in June (%)	38 (70.4)	31 (57.4)	19 (35.2)	17 (31.5)	10 (18.5)
Released in July (%)	108 (71)	80 (52.6)	59 (38.8)	46 (30.3)	28 (18.4)
Released in Aug. (%)	68 (45.6)	59 (39.6)	41 (27.5)	28 (18.8)	11 (7.4)
Released in Sep. (%)	6 (28.6)	6 (28.6)	5 (23.8)	4 (19)	1 (4.8)
Mean no. released together per day	7.38 ± 4.74	7.35 ± 4.74	7.43 ± 4.63	7.51 ± 4.85	7.06 ± 4.47

*Data for 2006, 2007, 2008 and 2009, when testing was undertaken.

weight had a small positive impact on post-release survival, with heavier birds more likely to survive to 1 January and 1 May in the following year (Table 3). In the multivariate model the strength of the effect of year was measured against 2006, and it was found that 2007, 2008, 2009 and 2010 negatively influenced post-release survival to 30 days and 1 October (Table 3). Survival to 1 January in the following year was reduced in 2007 and 2009, whereas survival to 1 May was reduced in 2009 and 2010, compared to the reference year, 2006 (Table 3). None of the risk factors was found to significantly influence the likelihood of fledging at least one young.

Of the eight birds examined post mortem after release (Table 4), six had died within 1 month of release. Three were believed to have died as a result of acute trauma. One had chronic aspergillosis, which may have been associated with stress-induced immunosuppression during captivity and after release. Other pathological findings were of uncertain significance in the death of the birds.

Discussion

During the 6 years of the project a total of 376 cirl buntings were released. Of these, 220 (58.5%) survived to 30 days, 95 (25.3%) survived to 1 May of the year following release, and 50 (13.3%) were observed to produce at least one fledgling (Table 1). The multivariate logistic regression model showed a significant effect of year, month of release and capture body weight on post-release survival (Table 3). The results of the multivariate regression model suggest that, with all other factors held the same, there was no significant effect

TABLE 3 Odds ratio (OR) and 95% confidence intervals for the multivariable logistic regression of risk factors for survival of cirl buntings to 30 days post release, 1 October, and 1 January and 1 May in the year following release.

Risk factor	OR (95% CI) for survival to 30 days post release	OR (95% CI) for post-release survival to 1 Oct.	OR (95% CI) for post-release survival to 1 Jan.	OR (95% CI) for post-release survival to 1 May
Capture weight			1.14 (1.03–1.28)*	1.15 (1.02–1.3)*
2007	0.14 (0.05–0.33)*	0.17 (0.07–0.40)*	0.32 (0.13–0.77)*	0.42 (0.16–1.03)
2008	0.14 (0.06–0.31)*	0.29 (0.14–0.59)*	0.52 (0.25–1.09)	0.46 (0.19–1.02)
2009	0.26 (0.11–0.57)*	0.23 (0.11–0.49)*	0.18 (0.07–0.42)*	0.14 (0.05–0.38)*
2010	0.24 (0.11–0.53)*	0.36 (0.17–0.72)*	0.49 (0.24–1.02)	0.42 (0.19–0.92)*
2011	0.89 (0.35–2.40)	1.14 (0.51–2.60)	1.23 (0.59–2.79)	1.03 (0.46–2.29)
Released in July	3.38 (2.00–5.77)*	1.81 (1.10–2.99)*	2.09 (1.2–3.6)*	2.43 (1.36–4.43)*
Released in June	2.94 (1.40–6.36)*	2.27 (1.10–4.70)*	1.86 (0.84–4.12)	3.00 (1.28–7.09)*
Released in Sep.	1.14 (0.36–3.26)	1.23 (0.39–3.54)	1.33 (0.38–4.05)	1.5 (0.38–5.05)

*Variables have a significant effect on survival.

TABLE 4 Findings of post mortem examination of cirl buntings found dead after release.

Year	Age (days)	Time post release (days)	Pathological findings	Pathological finding considered likely to be related to death	Comments
2007	34	2	Trauma, *Eimeria* sp. detected in intestine	Trauma	Found close to window
2007	35	5	Decomposed	Unknown	
2007	31	2	Emaciated, enlarged liver & spleen, autolysed	Unknown	Too autolysed for histopathology
2007	32*	3	Suspected enteritis (isosporosis): autolysed	Unknown	Suspected isosporosis, too autolysed to confirm
2007	30*	1	Suspected enteritis (isosporosis), *Isospora* sp. detected in intestine	Unknown	Suspected isosporosis, no histopathology
2007	55	26	Aspergillosis, isosporosis	Aspergillosis	Chronic disease
2008	647	c. 600	Trauma, one testis	Trauma	Road accident
2009	109	77	Trauma	Trauma	Flew into window

*Birds from the same brood

on post-release survival of time spent in captivity or at each stage of rearing, and no effect of medication or the detection of parasites in the brood. Month of capture and number released per day also had no significant effect on survival. None of the risk factors showed any significant effect on the likelihood of fledging at least one young.

At the planning stage of the project, projections of the expected post-release survival of the cirl buntings were made based on intensive monitoring of wild birds over many years (A.D. Evans, pers. comm.). A 30-day survival of 55% was expected, and a survival of 33% for the first year from 1 October to 1 May. The observed 30-day survival in the released birds was 58.5%, with 25.3% survival from 1 October to 1 May. However, the confidence intervals for the data were wide, and although it appears that the post-release survival is comparable to the expected survival in the wild, there is a degree of uncertainty in these results.

The causes of post-release mortality are largely unknown because only eight individuals were found dead and examined (Table 4). The infectious agents associated with disease were either known to occur in these birds prior to release (*Isospora* sp.) or are ubiquitous in the environment (*Aspergillus* sp.). The four individuals with signs of infectious disease were all reared in 2007, which was characterized by a particularly high rate of mortality as a result of immunosuppressive disease during rearing (K. Fountain et al., unpubl. data), and during this year the coccidial prophylaxis protocol was reduced. However, the simple linear regression analysis did not find a significant correlation between captive mortality and post-release mortality. A more detailed understanding of the causes of post-release mortality could be gained by using tracking devices in future release programmes so that dead birds are detected more easily, although this involves some additional risk to the birds (Kesler, 2011).

The variation in survival between years and with month of release and capture body weight may have been caused by controllable factors intrinsic to the project, such as stocking density, or by extrinsic factors such as weather and predator activity, which are less easily controlled. Studies of post-fledging survival in free-ranging passerines have shown an advantage for earlier broods, in which phenotypic quality may be higher (Verhulst & Nilsson, 2008), with lower risk of predation by sparrowhawks (Newton & Marquiss, 1982; Gőtmark, 2002), higher fledging mass (Naef-Daenzer et al., 2001; Tarwater et al., 2011), and variation in predation from year to year (Schmidt & Ostfeld, 2003), which suggests that extrinsic factors may have been a major factor in the variation in survival. The use of a novel release site at which no sparrowhawks were observed in 2011 may have helped to reduce predation, thus resulting in the highest survival rate during the project (82.7%; Table 1). Apart from this change the methodology was similar from year to year, although stocking density was held more rigorously at or below the recommended level after the disease outbreak in 2007 (Molenaar et al., 2010).

Weather factors may have caused some of the variation in post-release survival between years. Severe winter weather is known to affect the survival of individual passerines (Salewski et al., 2013). Meteorological records describe extreme events in November and December 2010, with flooding in Cornwall, followed by snow, which may have been partly the cause of the low winter survival to 1 May in 2011. The winter of 2009 was also exceptionally cold and wet (Met Office, 2015) and this year had the lowest overwinter survival to 1 May in the following year (9%; Table 1).

Weather factors may have affected captive birds during rearing by producing extremes of temperature or humidity in the rearing rooms, which were not routinely monitored. The recommended ambient temperature for passerine birds in captivity is 15–25°C (Sandmeier & Couteel, 2006) but measurements from 2008 indicate that these limits were exceeded in the room with brooders on 2 days (1 higher, 1 lower), and in the room with box cages on 9 days (7 higher, 2 lower). Temperature during the nestling period is known to affect the post-fledging survival of free-ranging passerines; for example, high temperatures during development in a Mediterranean habitat reduce the survival of great tits *Parus major* (Greno et al., 2008). Given the potential for weather factors to affect survival, and the unexplained inter-year variation in survival, future projects should incorporate routine monitoring and control of temperature and humidity in the facilities.

The last records reported here were from 2012 but intensive monitoring of the population continued until 2015, when there were 50 breeding pairs, which is considered to be a self-sustaining population (C. Jeffs, pers. comm.). Future conservation efforts for cirl buntings will focus on habitat improvement through agri-environment schemes, to facilitate natural expansion of the range of both UK populations.

In analysing the results of 6 years of translocations of cirl buntings we have extended the evidence base that will inform future translocations. We recommend that the capture of chicks is best focused on a time interval leading to release in June and July. The policy of capturing only birds of higher body weight should be continued. Routine environmental monitoring and/or a controlled environment during rearing, and monitoring of the effects of predators immediately after release would help to answer some of the questions raised by this analysis.

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