Research Square

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Long Term Breeding Performance in Golden Lizard Canaries Fed Ad Libitum with Imported Mixed Seed and Imported Egg Food: A Retrospective Evaluation of Two Years of Breeding Records

ERCAN MEVLİYAOĞULLARI

emevliya@gmail.com

Başkent University

Research Article

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Abstract

Background

Quantitative breeding records for ornamental canaries are scarce, and field reports often emphasize egg number without modelling the repeated clutch structure of the data. This retrospective study describes two consecutive breeding seasons of Golden Lizard canaries maintained under a constant ad libitum imported seed-mix and imported egg-food regimen. The feeding programme is treated as the management background, not as an experimental treatment.

Methods

Routine breeder records from 15 pair-season records in each of two consecutive years were decoded into clutch-level egg and hatched-chick counts for four successive clutches. Apparent hatching success (AHS) was calculated as hatched chicks divided by eggs. Pair-season totals were summarized descriptively and compared with non-parametric tests. The primary clutch-level analyses used generalized estimating equations with pair-season as the repeated unit: Poisson models for egg and chick counts and a binomial model for AHS. A binomial mixed-effects sensitivity analysis with a random intercept for pair-season was also fitted.

Results

The first year included 212 eggs and 149 hatched chicks; the second year included 215 eggs and 172 hatched chicks. Aggregate AHS was 70.3% (95% Wilson CI: 63.8–76.0) in Year 1 and 80.0% (95% Wilson CI: 74.1–84.8) in Year 2. Seasonal egg output per pair-season was stable (median 14 eggs in both years; Mann-Whitney U p = 0.605). Hatched chicks per pair-season were numerically higher in Year 2 (median 12 vs 10; p = 0.056), and pair-season AHS showed the same direction (median 78.6% vs 69.2%; p = 0.061). Repeated-measures modelling found no evidence of a year or clutch-order effect on egg count. In contrast, chick count and AHS declined with clutch order, with the clearest reduction in Year 1. In the binomial GEE, each successive clutch in Year 1 was associated with lower AHS (OR = 0.56; 95% CI: 0.37–0.85; p = 0.006), whereas the positive Year 2 x clutch-order interaction suggested attenuation of this decline (OR = 1.60; 95% CI: 0.97–2.65; p = 0.067). Fourth-clutch AHS was 43.1% in Year 1 and 74.0% in Year 2; the clustered fourth-clutch contrast favoured Year 2 (OR = 3.78; 95% CI: 1.53–9.32; p = 0.004).

Conclusions

Under a constant imported seed-mix and egg-food background, Golden Lizard canaries maintained similar seasonal egg production across two years, whereas late-season egg-to-chick conversion differed markedly between years. These findings support the use of AHS and clutch-specific chick output, rather

than egg count alone, as practical performance indicators in canary breeding records. Because this was a retrospective single-loft study without measured feed batches, fertility data, health screening, body-condition scoring, environmental monitoring, or genetic verification, the results are descriptive and should not be interpreted as causal evidence for a feed effect.

1. Background

Domestic canary breeding is a specialised form of ornamental bird production in which reproductive output, chick viability, feather quality, and show condition depend on the combined effects of genetic background, pair management, seasonal preparation, health status, and nutrition. Despite the long history of canary breeding, much of the practical knowledge in this field remains breeder-derived, and published quantitative data are limited [1].

Seed mixtures and egg foods are widely used during breeding, growth, and moult. In commercial products available to breeders in Turkey, imported seed mixtures have been reported to contain, on average, 20.64% crude protein, 16.89% crude fat, 38.77% starch, and 11.61% crude fibre on a dry-matter basis; imported egg foods contained 18.04% crude protein, 12.23% crude fat, 44.52% starch, and 7.89% crude fibre [2]. These data provide a nutritional frame for routine breeder rations, but they do not by themselves predict reproductive performance in a particular loft.

Recent descriptive work in red mosaic canaries kept on an imported seed-mixture and egg-food background showed that reproductive and phenotypic outcomes can be recorded in a way that separates field observation from causal inference [3]. The same distinction is essential here. The present study does not compare diets or test the biological effect of imported products. It evaluates whether routine breeding records collected under a fixed feeding background reveal stable or changing patterns in egg output, hatched-chick output, and AHS over two breeding seasons and four successive clutches.

Evidence from chickens cannot be transferred quantitatively to Golden Lizard canaries, but it provides a relevant avian framework for how reproductive records should be interpreted. The chicken has been central to both classical Mendelian genetics and genome-era avian biology [4]. QTL and GWAS studies in layer chickens show that egg production, egg weight, egg uniformity, and egg quality are genetically complex, stage-dependent traits in which both major loci and polygenic background may contribute [5–8]. Reviews and candidate-gene studies further link laying performance to hypothalamic-pituitary-gonadal regulation and to loci including DRD2, IGF-I, NPY, VIP, and VIPR-1 in chicken populations [9, 10]. These findings are not used here to infer canary genotypes; rather, they support the conservative treatment of egg number and AHS as phenotypic record endpoints that may reflect unmeasured genetic, endocrine, environmental, and management effects.

The same caution applies to population-level interpretation. Breed-improvement reviews emphasise that productivity records should be interpreted within genetic background, population structure, and management environment rather than as universal breed constants [11]. Experimental work in genetically divergent layer lines also illustrates that reproductive output may require concurrent

measurement of functional traits such as eggshell production and bone mineral density before biological mechanisms are proposed [12].

The main objective was to analyse two years of Golden Lizard canary breeding records using a statistical framework that respects the repeated clutch structure of the data. A secondary objective was to clarify which aspects of the observed pattern can be supported by the available records and which require prospective veterinary, nutritional, environmental, or genetic measurements.

2. Materials and Methods

2.1. Study design and animal material

This was a retrospective, single-loft analysis of routine breeding records from two consecutive breeding seasons. The breeding records were obtained from Dr. Ercan Mevliyaogullari's hobby canary breeding facility and were not supplied by an external breeder or association. Fifteen pair-season records were available in each year. All evaluated birds were Golden Lizard canaries (Serinus canaria domestica) produced in the same breeding environment and introduced into breeding at the first breeding season after hatching. The spreadsheet supplied for analysis contained annual row codes for 15 pairs in each year, but it did not contain permanent ring numbers or molecular identifiers sufficient to verify the same biological pair identity across years. Therefore, the statistical unit for repeated clutch observations was defined as the pair-season, and year was interpreted as an annual cohort factor.

During the breeding season, birds were kept as breeding pairs. Outside the breeding phase, females were kept in groups of five in roll-system cages measuring 100 x 40 x 40 cm, and males were kept individually in cages measuring 50 x 40 x 40 cm. Nipple drinkers and separate feeders were used in the male cages. The breeding season extended from early February to mid-August. Environmental variables such as exact photoperiod, temperature, humidity, and ventilation rate were not recorded numerically and were therefore not analysed.

2.2. Feeding and management background

All breeding stock were provided ad libitum with an imported mixed seed product and an imported bird egg food throughout the year. The exact feed batches used in the two seasons were not chemically or physically analysed as part of this retrospective study. For this reason, the feeding regimen is described only as a constant management background. The study was not designed as, and should not be read as, a diet-comparison or feed-efficacy trial.

The nutritional interpretation of this feeding background is limited to the published composition ranges for imported canary seed mixtures and egg foods available in Turkey [2]. No data were available on actual individual feed intake, selective seed consumption, feed wastage, batch-to-batch nutrient variation, vitamin-mineral status, calcium intake, body-condition score, or parent provisioning behaviour.

2.3. Data decoding and outcome definitions

Egg and hatch records were stored as four-digit codes. Each digit represented the value for one clutch, in order from the first to the fourth clutch. For example, an egg code of 3343 was decoded as 3, 3, 4, and 3 eggs across four successive clutches. The same decoding rule was applied to hatched-chick codes.

The primary clutch-level outcomes were egg count, hatched-chick count, and AHS. AHS was calculated as hatched chicks / eggs x 100 for each pair-season and clutch. The term AHS is used deliberately because the records did not include candling, fertility diagnosis, early embryo loss, late embryo mortality, or chick survival beyond hatching. Therefore, the data cannot support strict embryological terms such as fertility rate or true hatchability of fertile eggs.

After decoding, internal consistency was checked by confirming that hatched-chick counts did not exceed egg counts in any clutch record. The data structure and analytical workflow are summarized in Fig. 1.

2.4. Statistical analysis

Seasonal pair-level summaries were reported as totals, medians, and ranges. Aggregate AHS was presented with Wilson 95% confidence intervals. Because permanent biological pair identity across years could not be verified, annual pair-season totals were compared as independent annual records using the Mann-Whitney U test; these comparisons were treated as descriptive rather than confirmatory.

The primary analyses of clutch-level data used generalized estimating equations (GEE) to account for four repeated clutch observations within each pair-season. Egg count and hatched-chick count were analysed with Poisson GEE models. AHS was analysed with a binomial GEE model using the paired outcome of hatched and unhatched eggs. The working correlation structure was exchangeable, pair-season was the clustering variable, and robust sandwich standard errors were used.

The fixed effects were year, clutch order, and the year x clutch-order interaction. Clutch order was centred so that zero corresponded to the first clutch; therefore, the year coefficient represents the Year 2 versus Year 1 contrast at the first clutch, while the clutch-order coefficient represents the change per successive clutch in Year 1. A separate fourth-clutch binomial GEE contrast was reported because the descriptive results identified the fourth clutch as the main late-season difference. To assess sensitivity to a random-effect formulation, an egg-level binomial mixed-effects model with a random intercept for pair-season was fitted. All p values are two-sided and exploratory; no multiplicity adjustment was applied.

3. Results

3.1. Raw-data verification and seasonal totals

The decoded dataset contained 120 clutch-level records: 2 years x 15 pair-season records x 4 clutches. All decoded records were internally consistent; no hatched-chick count exceeded its corresponding egg count.

Across the two seasons, 427 eggs and 321 hatched chicks were recorded. Year 1 contained 212 eggs and 149 hatched chicks, giving an aggregate AHS of 70.3% (95% Wilson CI: 63.8–76.0). Year 2 contained 215 eggs and 172 hatched chicks, giving an aggregate AHS of 80.0% (95% Wilson CI: 74.1–84.8). Seasonal egg totals per pair-season were nearly identical between years, whereas hatched-chick output and AHS were numerically higher in Year 2 (Table 1; Fig. 2).

Table 1
Seasonal breeding performance by year.

Year	Pair-seasons (n)	Total eggs	Hatched chicks	Aggregate AHS, % (95% CI)	Eggs/pair-season, median (range)	Chicks/pair-season, median (range)	Pair-season AHS, median % (range)
1	15	212	149	70.3 (63.8–76.0)	14 (12–16)	10 (7–13)	69.2 (46.7–92.9)
2	15	215	172	80.0 (74.1–84.8)	14 (12–17)	12 (7–17)	78.6 (57.1–100.0)

Mann-Whitney U comparisons of pair-season totals gave $p = 0.605$ for eggs, $p = 0.056$ for hatched chicks, and $p = 0.061$ for pair-season AHS. These p values should be interpreted cautiously because the study was retrospective and not powered as a prospective comparison.

3.2. Clutch-specific performance

Clutch-specific summaries showed stable egg counts across the season in both years. The main divergence was in chick output and AHS during the fourth clutch. In Year 1, aggregate AHS fell from 83.3% in the first clutch to 43.1% in the fourth clutch. In Year 2, aggregate AHS remained higher across the later clutches and was 74.0% in the fourth clutch (Table 2; Fig. 3).

Table 2
Clutch-specific egg output, chick output, and apparent hatching success.

Year	Clutch	Total eggs	Hatched chicks	Aggregate AHS, % (95% CI)	Eggs/pair-season, median (range)	Chicks/pair-season, median (range)
1	1	54	45	83.3 (71.3–91.0)	4 (3–4)	3 (1–4)
1	2	55	42	76.4 (63.7–85.6)	4 (3–4)	3 (2–4)
1	3	52	40	76.9 (63.9–86.3)	3 (3–4)	3 (1–4)
1	4	51	22	43.1 (30.5–56.7)	3 (2–4)	2 (0–3)
2	1	55	46	83.6 (71.7–91.1)	4 (3–5)	3 (1–5)
2	2	57	46	80.7 (68.7–88.9)	4 (3–4)	3 (1–4)
2	3	53	43	81.1 (68.6–89.4)	4 (2–4)	3 (2–4)
2	4	50	37	74.0 (60.4–84.1)	3 (2–4)	2 (1–4)

3.3. Repeated-measures models

The Poisson GEE model for egg count did not show evidence of a year effect at the first clutch, a clutch-order decline, or a year x clutch-order interaction. This supports the descriptive finding that egg production was stable under the recorded management background.

For hatched-chick count, the GEE model showed a decline with successive clutch order in Year 1 (IRR = 0.82; 95% CI: 0.73–0.93; p = 0.001). The Year 2 x clutch-order interaction was positive but did not meet the conventional 0.05 threshold (IRR = 1.13; 95% CI: 0.99–1.29; p = 0.069).

For AHS, the binomial GEE similarly showed a clutch-order decline in Year 1 (OR = 0.56; 95% CI: 0.37–0.85; p = 0.006), with a positive Year 2 x clutch-order interaction (OR = 1.60; 95% CI: 0.97–2.65; p = 0.067). The fourth-clutch contrast favoured Year 2 (OR = 3.78; 95% CI: 1.53–9.32; p = 0.004), consistent with the descriptive fourth-clutch difference in AHS (43.1% versus 74.0%). Model estimates are shown in Table 3 and Fig. 4.

Table 3
Repeated-measures model estimates. Ratios are incidence rate ratios for Poisson GEE models and odds ratios for binomial GEE models.

Outcome and model	Model term	Ratio estimate	95% CI	p value
Egg count (Poisson GEE)	Year 2 vs Year 1 at first clutch	1.03	0.95–1.13	0.465
Egg count (Poisson GEE)	Successive clutch order	0.98	0.95–1.01	0.137
Egg count (Poisson GEE)	Year 2 x clutch order	0.99	0.93–1.04	0.655
Hatched chick count (Poisson GEE)	Year 2 vs Year 1 at first clutch	0.98	0.79–1.21	0.850
Hatched chick count (Poisson GEE)	Successive clutch order	0.82	0.73–0.93	0.001
Hatched chick count (Poisson GEE)	Year 2 x clutch order	1.13	0.99–1.29	0.069
Apparent hatching success (binomial GEE)	Year 2 vs Year 1 at first clutch	0.74	0.27–2.09	0.575
Apparent hatching success (binomial GEE)	Successive clutch order	0.56	0.37–0.85	0.006
Apparent hatching success (binomial GEE)	Year 2 x clutch order	1.60	0.97–2.65	0.067
Fourth-clutch AHS contrast (binomial GEE)	Year 2 vs Year 1	3.78	1.53–9.32	0.004

The binomial mixed-effects sensitivity analysis, fitted at egg level with a random intercept for pair-season, gave the same qualitative pattern: lower hatching odds with successive clutch order in Year 1 and a positive Year 2 x clutch-order interaction. The estimated pair-season random-intercept standard deviation on the logit scale was 0.45 (approximate 95% interval: 0.35–0.58), indicating measurable between-pair-season heterogeneity (Table 4).

Table 4
Binomial mixed-effects sensitivity analysis with pair-season random intercept.

Binomial mixed-effects sensitivity term	Odds ratio	Approximate 95% interval
Intercept / first clutch, Year 1	6.48	5.15–8.15
Year 2 vs Year 1 at first clutch	0.86	0.61–1.22
Successive clutch order	0.54	0.48–0.61
Year 2 x clutch order	1.56	1.30–1.86
Pair-season random-intercept SD (logit scale)	0.45	0.35–0.58

4. Discussion

This retrospective analysis provides a two-year quantitative description of Golden Lizard canary breeding records under a fixed imported seed-mix and egg-food feeding background. Its principal finding is not that the feed regimen caused the observed results. Rather, the data show that seasonal egg production remained stable while chick output and AHS were more sensitive to year and clutch order, especially late in the breeding season.

The stability of egg output is consistent with the nutritional frame reported for imported commercial canary feeds, which can provide substantial crude protein, lipid, starch, and predicted energy density [2]. However, this should be interpreted narrowly. Because the exact feed batches, actual intake, nutrient digestibility, mineral-vitamin status, and body condition of the birds were not measured, the present records cannot establish that the feeding programme was nutritionally optimal or that feed composition explains the late-season difference.

The more informative result is the separation between egg production and egg-to-chick conversion. Yearly egg totals were almost identical, yet fourth-clutch AHS differed markedly. A similar practical lesson can be drawn from other descriptive canary records in which reproductive output and phenotypic observations were recorded without claiming nutritional causality [3]. For routine breeder monitoring, egg count alone may therefore be an insensitive endpoint; clutch-specific AHS and hatched-chick output provide a closer view of reproductive efficiency.

The repeated-measures analysis was central to the revised interpretation. Conventional ANOVA or unclustered comparisons would treat clutch observations as independent, which is inappropriate when four clutch records come from the same pair-season. The GEE and mixed-effects sensitivity analyses both indicated that the late-season pattern was driven mainly by hatching conversion rather than egg output. The positive year x clutch-order term should still be read cautiously because the sample contained only 30 pair-season clusters.

The broader chicken literature strengthens the need for this caution rather than providing a basis for genetic inference in the present study. Work from classical chicken genetics through genome-era QTL

and GWAS studies shows that egg-related traits are influenced by multiple genomic regions, stage-specific effects, and endocrine pathways [4–10]. The current canary dataset contains no genotypes, pedigree depth beyond breeder records, endocrine assays, egg-quality measurements, or functional skeletal measurements. Accordingly, this manuscript does not claim genetic architecture, inherited egg-laying capacity, endocrine status, or selection response in Golden Lizard canaries.

The discussion of possible biological mechanisms must remain limited. Parental condition, micronutrient balance, calcium metabolism, environmental stress, mating behaviour, pathogen exposure, embryo viability, and parental incubation are plausible domains in avian reproduction, but none was measured here. Experimental work in layer hens illustrates that proposed links between reproduction, eggshell output, bone mineral density, and skeletal status require direct phenotypic measurement rather than inference from egg count alone [12]. The present data cannot distinguish infertility, early embryo mortality, late embryo mortality, parental incubation behaviour, or immediate post-hatch losses. Future studies should include candling records, egg-failure categories, chick survival, body condition, feed intake, mineral-vitamin measurements, and health screening.

Feed evaluation should also extend beyond label values. Physical and processing characteristics can influence handling, hydration, texture, matrix structure, and in vitro digestibility in animal feeds. Work on an imported extruded pigeon feed showed that water-holding capacity, particle-size homogeneity, structural hardness, and microstructure can be characterised as functional feed properties [13]. Similarly, processing and ingredient substitution in pet food can modify colour, expansion, hardness, porosity, and in vitro digestibility [14]. These studies do not directly test canary seed mixtures or egg foods, but they justify the recommendation that future canary feed studies should characterise the actual products used, rather than relying only on nominal feed category.

Veterinary interpretation also requires caution. No clinical disease, faecal testing, or pathogen screening was included in the records. This is a relevant limitation because pet birds may carry pathogens without obvious signs; for example, molecular work on pet birds identified *Cryptosporidium* species and genotypes and highlighted potential public-health relevance [15]. The present study should therefore be viewed as a breeding-record analysis, not a flock-health assessment.

Genetic and parentage limitations should also be stated explicitly. The birds were managed as breeding pairs and the records were routine in-house records from Dr. Ercan Mevliyaogullari's hobby canary breeding facility, but no molecular parentage confirmation was performed. Non-destructive feather-based DNA sampling has long been available for avian genetic studies [16], and broader avian literature shows that social parentage and genetic parentage can diverge in birds [17]. These references do not imply that extra-pair parentage occurred in this loft; they simply define why future high-resolution breeding studies should include ring-level identity and, where relevant, molecular parentage verification.

Finally, this manuscript does not investigate the genetic or developmental basis of ornamental phenotype expression. Studies of avian traits such as eye colour show that visible phenotypes may reflect interacting mechanistic, genetic, developmental, and evolutionary factors [18]. For Golden Lizard

canaries, future work that links reproductive records with show-standard phenotypes should therefore use standardised phenotypic scoring and, where feasible, genetic or lineage confirmation.

5. Conclusions

Golden Lizard canaries maintained under a constant ad libitum imported seed-mix and egg-food feeding background showed stable egg production across two consecutive years. The main variation occurred after eggs were laid: hatched-chick output and AHS, particularly in the fourth clutch, were lower in Year 1 than in Year 2.

For applied canary breeding records, AHS and clutch-specific chick output should be monitored alongside egg number. For veterinary and nutritional research, future studies should be prospective, include ring-level pair identity, use repeated-measures or mixed-effects models, and measure feed composition, body condition, environmental variables, fertility, embryo loss, chick survival, health status, and parentage where relevant.

Abbreviations

AHS: apparent hatching success; CI: confidence interval; GEE: generalized estimating equation; IRR: incidence rate ratio; OR: odds ratio; SD: standard deviation.

Declarations

Ethics approval and consent to participate

This study used pre-existing routine breeding records generated in Dr. Ercan Mevliyaogullari's hobby canary breeding facility. No animals were handled, treated, sampled, or exposed to an intervention for the purpose of this retrospective analysis. Because the records were the author's own in-house records, no external breeder or association permission was involved.

Consent for publication

Not applicable.

Availability of data and materials

The decoded dataset and analysis workflow are available from the corresponding author on reasonable request.

Competing interests

Dr. Ercan Mevliyaogullari is the founder and owner of Mevli Pet Food and Animal Nutrition Ltd. (Mahfesigmaz No: 1/1B, Cukurova, 01170, Adana, Turkey), where the experimental work was conducted

under his project leadership. This affiliation, ownership role, and potential product-development interest in the experimental bird-food formulation are disclosed. No other competing interests are declared.

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Authors' contributions

E.M. conceived the study, curated the records, performed the analysis, interpreted the results, and wrote the manuscript.

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No external canary breeder or association supplied the records. The breeding records were obtained from Dr. Ercan Mevliyaogullari's hobby canary breeding facility.

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Figures

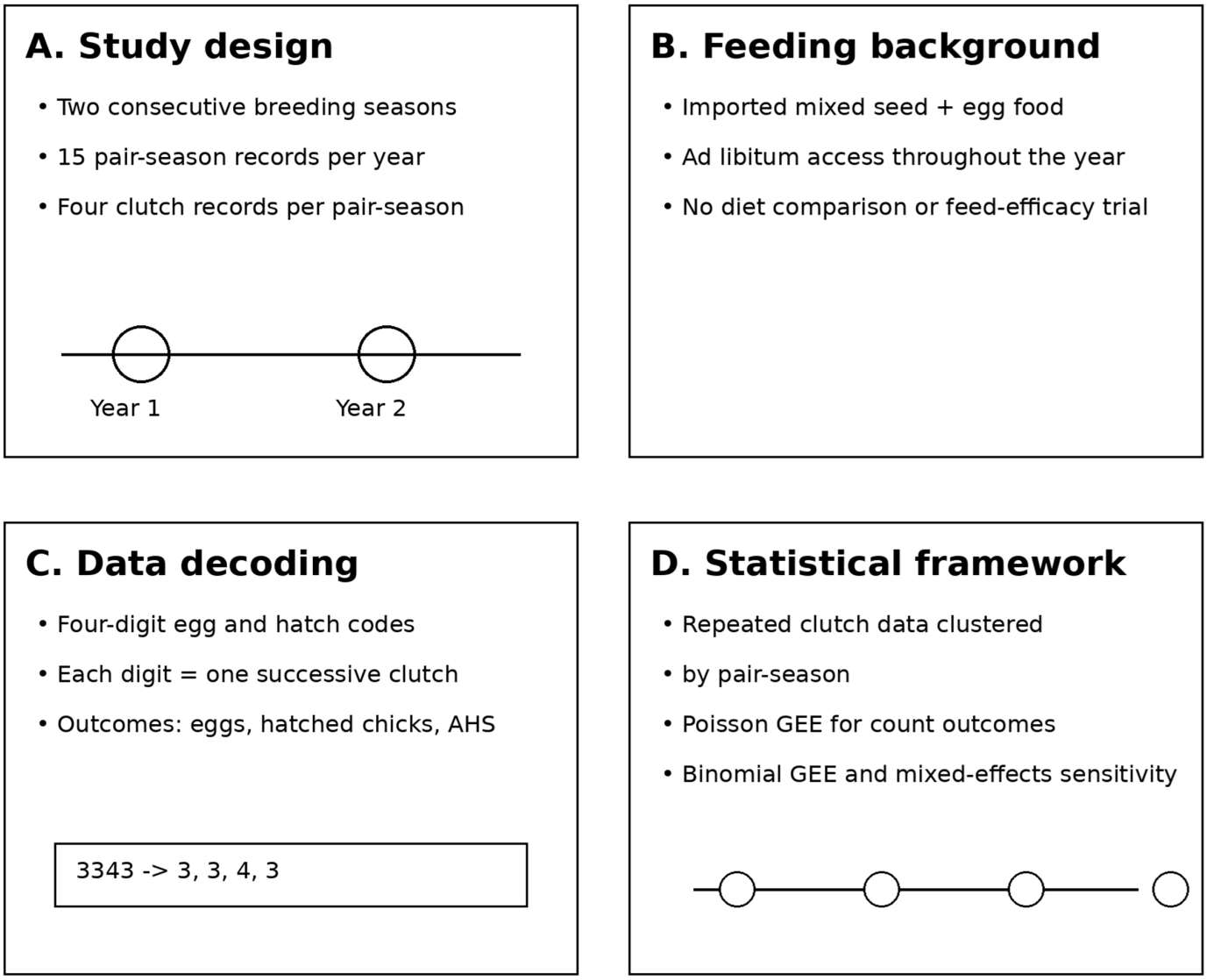


Figure 1

Study design and analytical workflow used for the retrospective Golden Lizard canary breeding-record analysis: (A) annual cohort structure; (B) constant feeding background; (C) four-digit clutch-code decoding; and (D) clustered repeated-measures statistical framework.

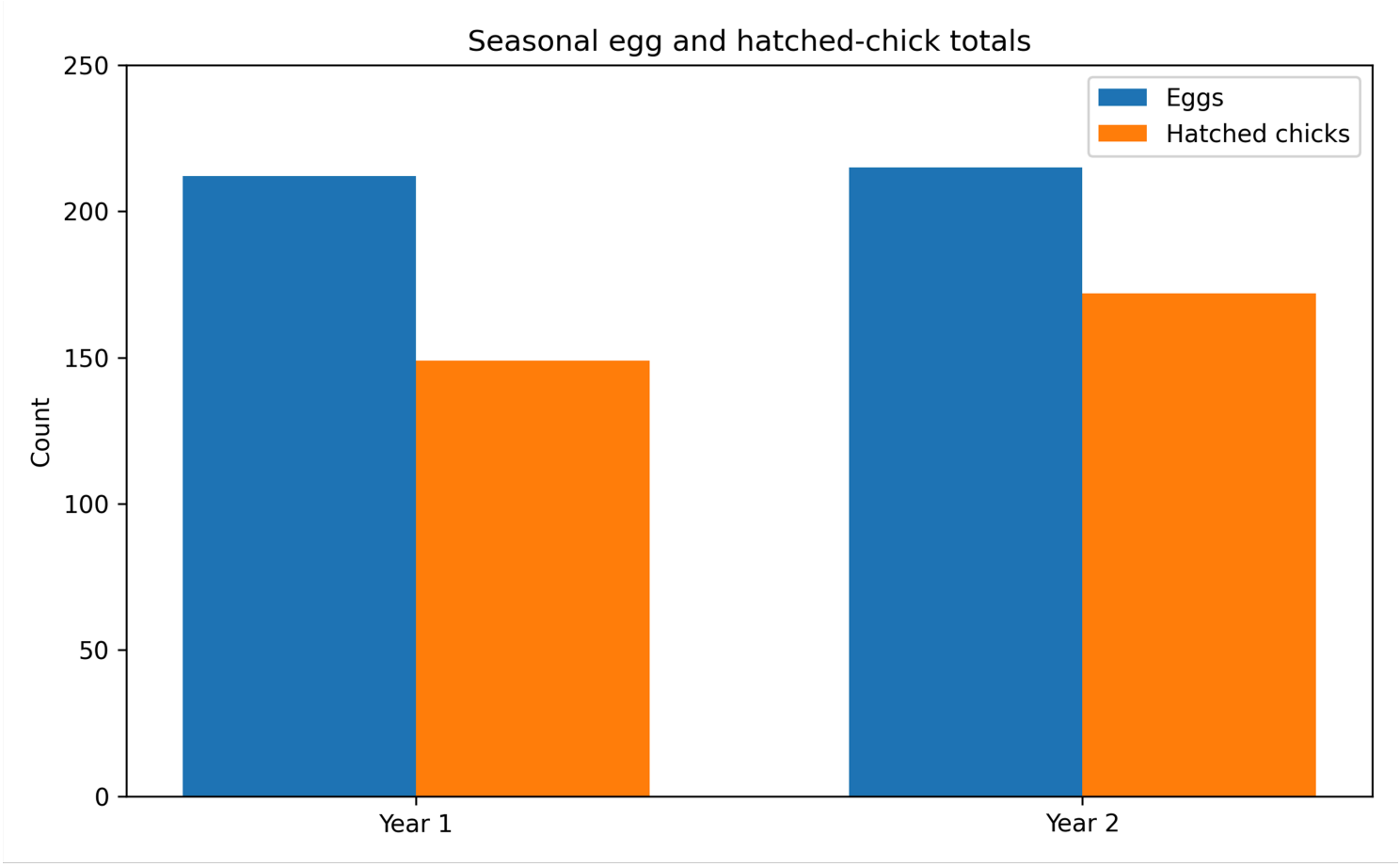


Figure 2

Seasonal egg and hatched-chick totals by year. Counts refer to decoded breeding records from 15 pair-season records in each year under the same imported seed-mix and egg-food feeding background.

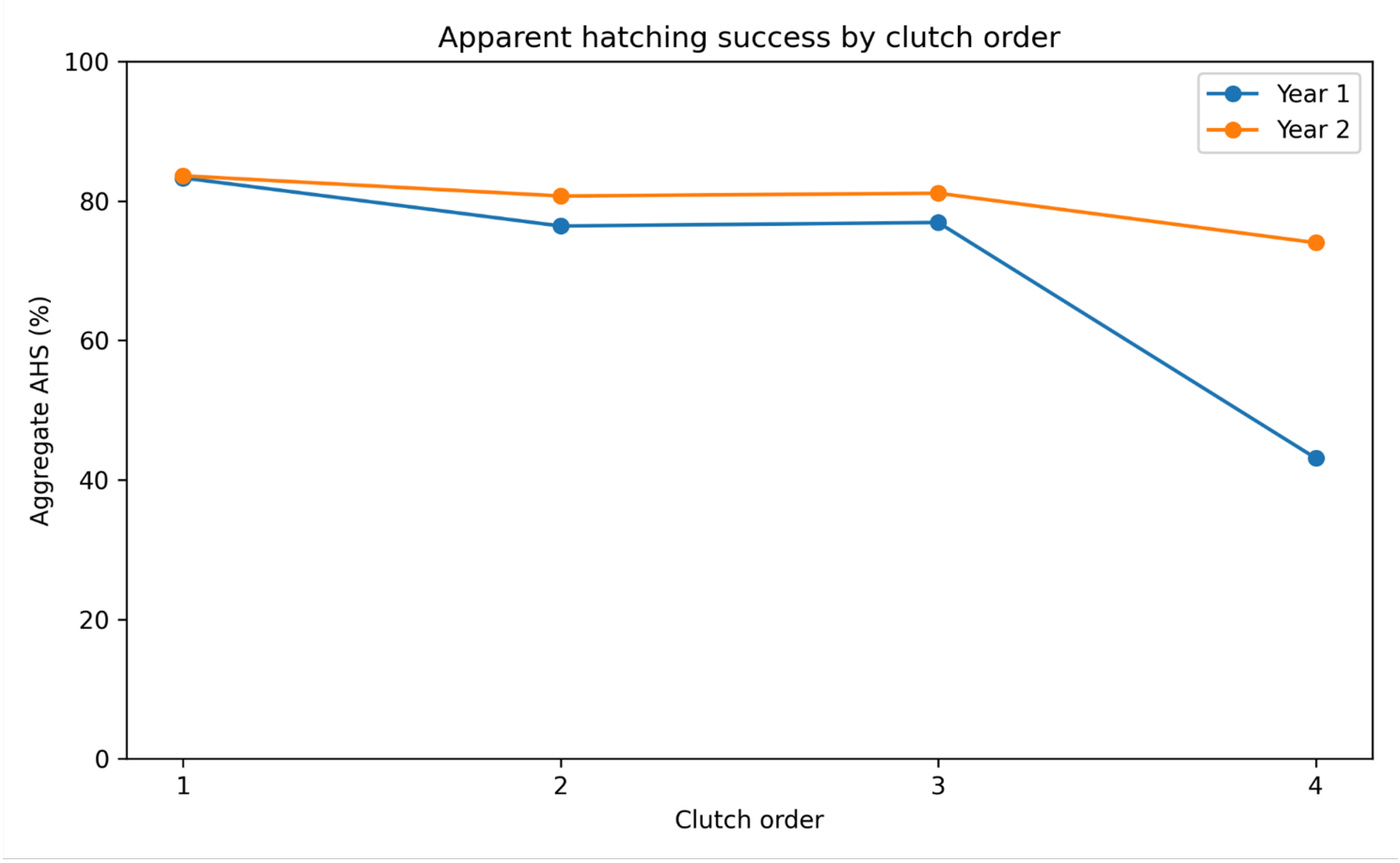


Figure 3

Clutch-specific apparent hatching success by year. Values are aggregate AHS percentages calculated as hatched chicks divided by total eggs for each clutch order.

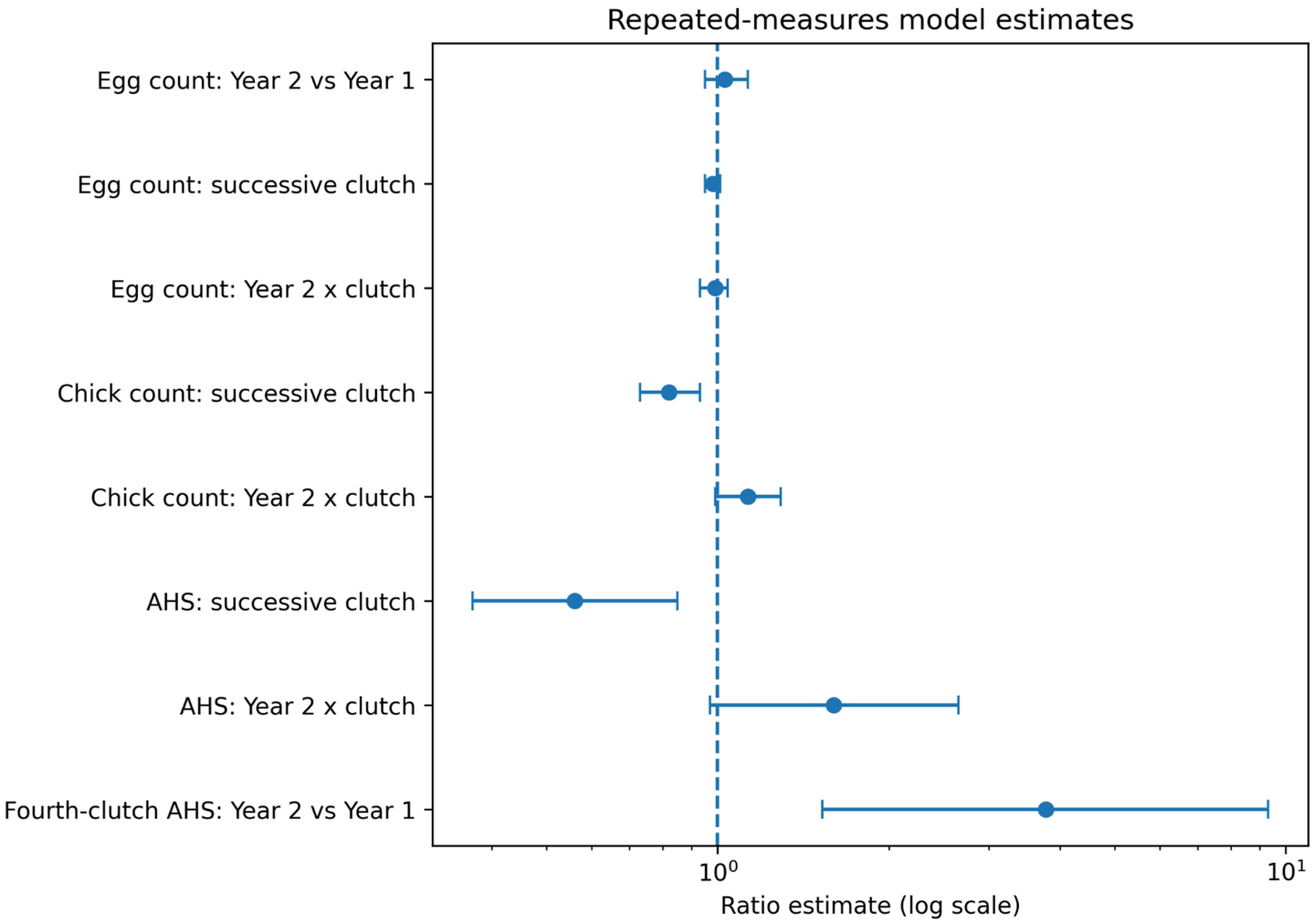


Figure 4

Repeated-measures model estimates. Ratio estimates are shown on a log scale with 95% confidence intervals; the vertical reference line indicates a ratio of 1.0.