Emu 2013, **113**, 84–87
doi:10.1071/MU12020_AC

Supplementary material

Factors influencing the behavioural development of juvenile New Zealand Falcons (*Falco novaeseelandiae*)

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Observation methods

All four natural nests were monitored with remote videography and so the exact time of fledging was known. We were informed of release dates by volunteers working for the release program. Observations were carried out within 5 h of sunrise or sunset and were not undertaken in high winds, heavy rain, or temperatures well above the average range for the region (>32°C). If weather prevented observations, we returned to the same site later in the same week to carry out observations. Nonetheless, there were occasions when chicks could not be found or when poor weather prevented us from reaching a nest or release site in a given week.

Landing difficulty was classified based on the size and stability of perches, with perches scored on a scale of 1–5 as follows: 1, the ground; 2, a large, flat surface such as a log or feeding tray; 3, a smaller stable surface such as a thick branch or vineyard post; 4, a thin and fairly unstable surface, such as a small branch; 5, a very unstable surface such as a twig or the very top of a pine tree. We also classified *Landing accuracy* similarly, scored from 1 to 5 as follows: 1, landing not accomplished; 2, partial landing but individual unstable and immediately took off or fell off perch; 3, landing accomplished but individual had to flap wings to balance or stumbled; 4, landing accomplished with steps needed to balance; 5, clean landing with no need for extra balancing. The difficulty of *food-passes* was classified based on the speed and height of the adult Falcon in regard to the juvenile, as well as the presence of any other competing juveniles. The accuracy of food-passes between adult Falcons and juveniles was scored on a scale of 1–5 as follows: 1, juvenile attempted to catch food but missed by >1 m; 2, juvenile within 1 m of food but did not catch it; 3, juvenile made contact with food but did not catch it; 4, juvenile caught food poorly; 5, juvenile accurately caught food. Although these classifications were made with as much accuracy as possible, it is feasible that underlying factors such as wind, other juveniles and the behaviour of adults may have an effect on the accuracy of landing and food passes.

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Data analysis

We used an arcsin–square root transformations on data for the number of flights and number of hunting attempts per minute of observation time and used a square-root transformation on data for mean flight-distance, landing accuracy and landing difficulty. We used a Gaussian family of errors to model our transformed data and used a binomial family of errors to model our proportional data. Overdispersed models were re-fitted using penalised quasi likelihood (the 'glmmPQL' function) in the MASS package (Venables and Ripley 2002) in *R*.

Separate generalised linear mixed models were run for each response variable and maximal models included the following predictors: age, rearing method (wild-reared with parents or released without parents), sibling presence, sex and habitat type (vineyard or hill). Model fit was assessed by stepwise selection, using Akaike Information Criterion (AIC). We removed non-significant predictor variables until no significant reduction in AIC was achieved. The intercept represents the lowest values for all variables retained in the model, with Age 6 weeks old, released without parents, siblings absent, female and hill habitat as the lowest values for each of the variables above (Table S1). Sex was removed from all simplified models. Estimates from the binomial models are from a logit-link function and to convert the estimates to true proportions the values need to be inverse-linked ($e^{\eta}/(1 + e^{\eta})$).

Table S1. Summary of variables retained in the models for the measured behaviours

Colons (:) between two terms in the predictor variables represent an interaction effect within the model. The test statistic for all predictor variables represents a *t* value, except for un-penalised binomial models where a *Z* value is given. Estimates from the binomial models are from a logit-link function and to convert the estimates to true proportions the values need to be inverse-linked ($e^{\eta}/(1 + e^{\eta})$)

Response variable	Model used	Data transformation	Predictor variable	Estimate	s.e.	Test statistic	*P*
Proportion of time spent perching	Quasi-penalised GLMM (binomial)	None	Intercept	1.84	0.62	2.96	0.005
			Age 7 weeks	–0.67	0.52	–1.29	0.20
			Age 8 weeks	–0.95	0.51	–1.88	0.07
			Age 9 weeks	–0.92	0.51	–1.81	0.08
			Wild-reared	–2.24	0.79	–2.82	0.03
			Siblings	0.24	0.44	0.55	0.58
			Age 7 weeks: wild-reared	2.07	0.78	2.64	0.01
			Age 8 weeks: wild-reared	3.17	0.84	3.79	<0.001
			Age 9 weeks: wild-reared	3.13	0.86	3.64	<0.001
Proportion of time spent on ground	Quasi-penalised GLMM (binomial)	None	Intercept	–4.15	1.35	–3.08	0.004
			Age 7 weeks	2.83	1.31	2.15	0.04
			Age 8 weeks	1.70	1.37	1.24	0.22
			Age 9 weeks	2.23	1.35	1.66	0.11
			Wild-reared	1.59	0.79	2.00	0.09
			Siblings	2.53	1.37	1.85	0.07
			Age 7 weeks: wild-reared	–1.58	0.72	–2.19	0.03
			Age 8 weeks: wild-reared	–2.13	0.81	–2.64	0.01
			Age 9 weeks: wild-reared	–3.64	0.85	–4.25	<0.001
			Age 7 weeks: siblings	–2.75	1.41	–1.94	0.06
			Age 8 weeks: siblings	–2.17	1.47	–1.47	0.15
			Age 9 weeks: siblings	–1.75	1.43	–1.23	0.23

Table S1. ***(Cont.)***

Response variable	Model used	Data transformation	Predictor variable	Estimate	s.e.	Test statistic	*P*
Proportion of time spent playing	GLMM (binomial)	None	Intercept	–5.26	0.54	–9.80	<0.001
			Age 7 weeks	0.55	0.25	2.15	0.03
			Age 8 weeks	0.27	0.27	1.00	0.32
			Age 9 weeks	–0.01	0.28	–0.02	0.99
			Wild-reared	1.13	0.59	1.90	0.06
			Siblings	0.93	0.42	2.19	0.03
			Age 7 weeks: wild-reared	–1.17	0.32	–3.63	<0.001
			Age 8 weeks: wild-reared	–0.28	0.32	–0.864	0.39
			Age 9 weeks: wild-reared	–1.28	0.39	–3.26	0.002
Frequency of flights	GLMM (Gaussian)	Arcsin square-root	Intercept	0.12	0.08	1.54	0.06
			Age 7 weeks	0.07	0.05	1.32	0.22
			Age 8 weeks	0.20	0.05	3.74	<0.001
			Age 9 weeks	0.21	0.05	3.94	<0.001
			Siblings	0.17	0.06	2.75	0.08
Mean flight-distance (m)	GLMM (Gaussian)	Square root	Intercept	2.53	1.69	1.49	0.17
			Age 7 weeks	0.92	1.56	0.59	0.42
			Age 8 weeks	7.20	1.53	4.70	<0.001
			Age 9 weeks	10.97	1.62	6.76	<0.001
			Vineyard habitat	1.22	1.92	0.64	0.40
			Age 7 weeks: vineyard	–0.02	1.76	–0.01	0.80
			Age 8 weeks: vineyard	–4.29	1.73	–2.48	0.01
			Age 9 weeks: vineyard	–6.03	1.82	–3.32	0.002
Landing accuracy	GLMM (Gaussian)	Square root	Intercept	1.46	0.14	10.57	<0.001
			Age 7 weeks	0.39	0.14	2.74	0.008
			Age 8 weeks	0.45	0.14	3.18	0.002
			Age 9 weeks	0.68	0.15	4.55	<0.001
Landing difficulty	GLMM (Gaussian)	Square root	Intercept	1.48	0.11	13.46	<0.001

Table S1. ***(Cont.)***

Response variable	Model used	Data transformation	Predictor variable	Estimate	s.e.	Test statistic	*P*
Proportion of flights that are chases (conspecific pursuit flights)	GLMM (binomial)	None	Intercept	–8.12	1.22	–6.66	<0.001
			Age 7 weeks	2.08	0.64	3.23	0.001
			Age 8 weeks	2.05	0.62	3.32	<0.001
			Age 9 weeks	2.10	0.62	3.38	<0.001
			Siblings	4.02	0.96	4.21	<0.001
			Wild-reared	3.71	1.02	3.64	<0.001
			Age 7 weeks: wild-reared	–2.27	0.76	–3.01	0.003
			Age 8 weeks: wild-reared	–2.29	0.72	–3.16	0.002
			Age 9 weeks: wild-reared	–2.44	0.76	–3.21	0.001
Mean frequency of hunting attempts	GLMM (Gaussian)	Arcsin square-root	Intercept	0.03	0.02	1.30	0.19
			Wild-reared	0.03	0.02	1.48	0.19
			Siblings	0.12	0.05	2.65	0.01
			Wild-reared: Siblings	–0.16	0.05	–3.23	0.003

References

Venables, W. N., and Ripley, B. D. (2002). ‘Modern Applied Statistics with S’, 4th edn. (Springer: New York.)