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A Graphical Model of Allocation of Eggs to Nesting or Brood Parasitism

A simple graphical model illustrates how birds should allocate eggs between nesting and brood parasitism to maximize their total production of surviving offspring, and can also explain why females might vary in the degree to which they allocate eggs to nesting and parasitism (Fig. S-1A). Following Lack (1947), the optimal clutch size is reached with the addition to the clutch of the last egg that will have a positive marginal increase on fitness. The fitness increment per egg is net fitness, the difference between fitness costs (parental survival) and fitness benefits (offspring survival). Any female capable of producing more eggs than her optimal clutch size (e.g. female **a**, Fig. S-1A) benefits from laying the additional eggs parasitically whenever possible, given that parasitic eggs yield a net positive fitness benefits. In contrast, a female whose clutch size is limited by egg-laying capacity rather than food available for chicks will lay a smaller clutch than her optimal Lack clutch size and will not benefit from laying eggs parasitically (e.g. Fig S-1A, female **b**).

Changing the focus to non-nesting females, the key question becomes why refrain completely from nesting completely and lay all eggs parasitically. As with nesting females, the answer lies in tradeoffs among the three key life history traits — adult survival, fecundity and offspring survival — and we can see that parasitism by non-nesting and nesting females can represent different points along the same life history continuum as suggested by Sorenson (1991). Even when females have the option of nesting (i.e. no constraint), laying all eggs parasitically would be superior to nesting whenever all eggs laid in their own nest yield lower fitness than eggs laid parasitically (Fig. S-1A, female **c**). Non-nesting parasites are often young, inexperienced females or physiologically stressed individuals, so low fitness from nesting could be due to high costs of reproduction that impact adult survival (Eadie et al. 1988, Sorenson 1991) or low offspring survival due to low quality parental care. The decision as to nest or lay parasitically could also depend on host availability: a female with access to low quality hosts might be better off laying her eggs in her own nest, while a female with access to high quality hosts might be better off laying all of her eggs parasitically (Fig. 1B).

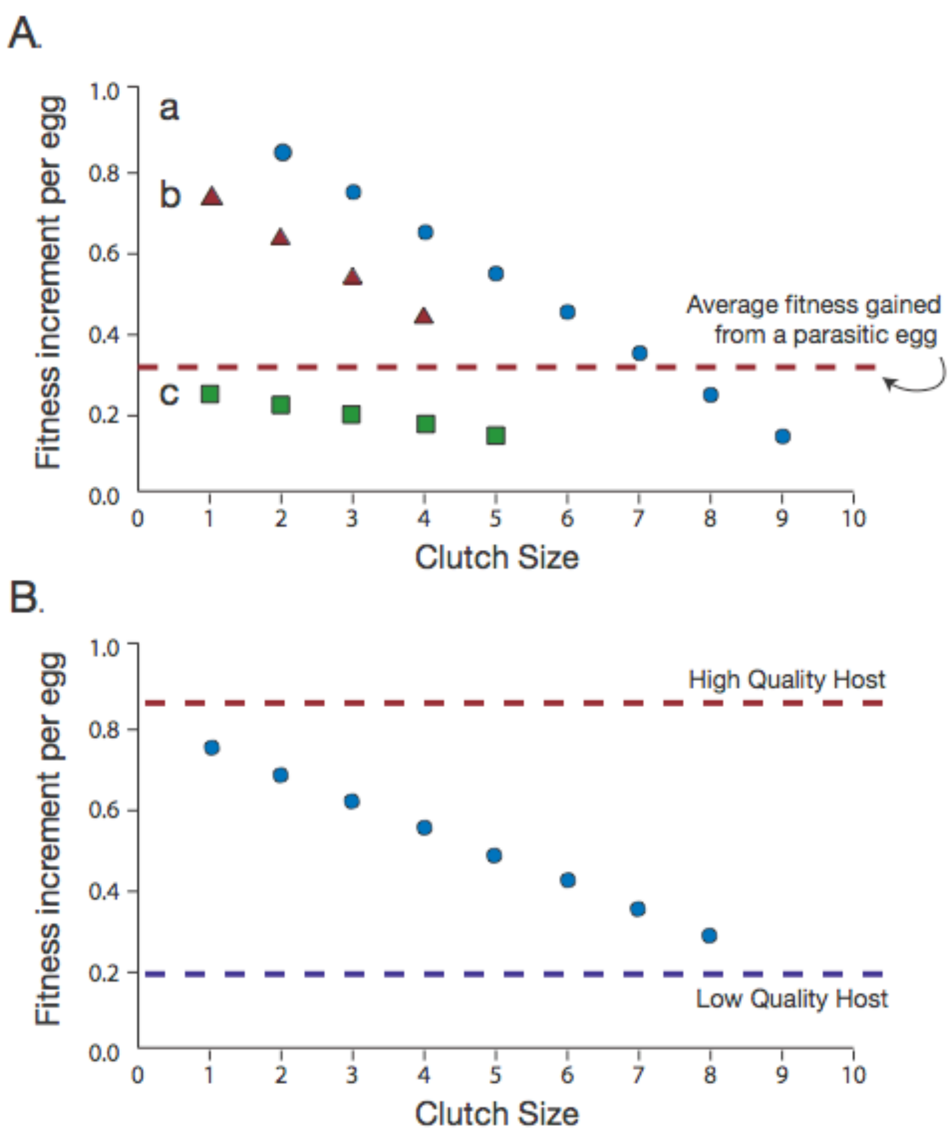

Figure S-1

A. Graphical model of fitness from laying eggs in a females own nest versus parasitically. Fitness increment is net fitness gain from increasing the clutch size by one additional egg. Red horizontal dashed line is the average fitness gained from laying an egg parasitically. Three females are shown that vary in the fitness gained from nesting and/or fecundity. The number of eggs shown for a female is her total fecundity. The actual order of laying in the nest versus parasitism is not important; we are simply interested in how the female should optimally allocate eggs between parasitism and nesting.

B. Graphical model of fitness from laying eggs in a female's own nest versus parasitically when host quality varies. Red dashed line is the average fitness gained from laying an egg parasitically in high quality host nests, blue dashed line is fitness gained per egg laid in low quality host nests. If the female can lay parasitically in high quality hosts, she should lay all of the eggs parasitically; if she only has access to low quality hosts she should lay the eggs in her own nest.

Table S-1 A summary of the features included in models of conspecific brood parasitism in birds

Model Characteristics	Andersson (1984)	May et al. (1991)	Sorenson (1991)	Eadie & Fryxell (1992)	Nee & May (1993) Model A	Nee & May (1993) Model B	Yamauchi (1993)	Yamauchi (1995)	Maruyama & Seno (1999a)	Maruyama & Seno (1999b)	Lyon (1998)	Yerkes & Koops (1999)	Zink (2000)	Andersson (2001)	Robert & Sorci (2001)	Lopeze-Sepulcre & Kokko (2002)	Ruxton & Broom (2002)	Broom & Ruxton (2002)	Broom & Ruxton (2004)	Takasu (2004)	Loeb & Zink (2005)	Poysa & Pesonen (2007)	de Valpine & Eadie (2008)	No. of Studies
Type of Model																								
Graphical			X			X					X													3
Optimal clutch size	X	X					X	X	X		X				X		X	X	X	X	X			12
Game-theoretic / ESS		X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			X	18
Quantitative / population genetic	X						X	X																4
Dynamic state variable												X												1
Simulation or Individual-based model				X																X		X		3
Type of Parasitism																								
BOBJ parasitism			X		X																		X	3
Specialist (pure) parasitism		X		X	X				X	X			X	X		X						X	X	10
Mixed strategy - nesting & parasitism		X	X			X	X	X			X	X			X		X	X	X	X	X		X	14
Factors Affecting Host / Parasite Fitness																								
Total clutch size affects fledge success	X	X		X			X	X	X	X	X			X	X	X	X	X	X	X	X		X	17
Parasite displaces/removes host eggs		X			X								X	X										4
Rejection of parasite eggs/females by host		X					X	X	X					X		X		X	X					8
Inherent lower value of parasite eggs		X		X	X	X		X	X	X		X			X		X		X				X	12
Cost of parasitic behavior (time, energy)							X	X						X							X			4
Randomness of parasite distribution		X		X	X													X	X	X		X	X	8
Laying order affects fledge success											X							X	X				X	4
Variation in nest susceptibility to predation																						X		1
Adult cost of reproduction																	X	X	X				X	4
Reproductive effort			X									X									X			3
Variation in maternal quality			X						X			X									X			4
Effects of kinship and inclusive fitness	X											X	X	X		X								5
Population Dynamics / Correlates																								
Population density		X	X			X																		3
Offspring survival depends on adult density																							X	1
Nest-site limitation		X		X	X																		X	4
Other resource limitation (e.g. food)			X									X												2
Host availability											X	X												2
Population dynamics modeled		X		X	X	X																	X	5

Table S-2 Ecological and life-history correlates suggested to influence the occurrence of CBP among avian taxa. These variables have either been hypothesized in review papers, or tested in formal comparative analyses. The type of analyses is indicated

Correlate	Yom-Tov (1980)	Andersson (1984)	Eadie et al (1988)	Rohwer & Freeman (1989)	Sorenson (1992)	Eadie (1991)	Sayler (1992)	Beauchamp (1997)	Andersson (2001)	Arnold & Owens (2002)	Geffen & Yom-Tov (2007)	No. of Studies
Type of Analysis												11
Review	X	X	X	X	X		X		X			7
Comparative Analysis			X			X		X		X	X	5
Life history Traits												
Precocial / self-feeding young		X		X	X		X			X	X	6
Early sexual maturity	X					X						2
Large clutch sizes	X	X			X	X				X	X	6
High reproductive effort (clutch mass/female mass)							X	X			X	4
Uniparental care								X				1
Low cost of parasitism		X		X			X		X	X	X	6
Host density / availability / access												
Lack of defense of territory or nest		X		X	X		X			X		5
Long egg-laying period				X		X					X	3
Long incubation period						X				X	X	3
Incubate after last egg laid											X	1
Long breeding season		X										1
Low degree of nest synchrony	X											1
Easily discovered nests (cavity, colony)		X	X	X	X	X	X	X			X	8
Easily accessible nests during laying					X							1
High density (host availability)				X		X	X	X			X	5
Limited options to nest												
Limited nest sites or other resources	X	X	X			X	X				X	6
High predation rates (nest loss)	X	X										2
Large number of young females	X											1
Kinship												
High levels of relatedness among females		X							X			2
Kin discrimination									X			1
Female philopatry						X						1

LITERATURE CITED

Andersson M. 1984. Brood parasitism within species. In *Producers and Scroungers: Strategies of Exploitation and Parasitism.*, ed. CJ Barnard, pp. 195 - 228. London: Croom Helm

Andersson M. 2001. Relatedness and the evolution of conspecific brood parasitism. *Am. Nat.* 158: 599-614

Arnold KE, Owens IPF. 2002. Extra-pair paternity and egg dumping in birds: life history, parental care and the risk of retaliation. *Proc. R. Soc. Lond., Ser. B: Biol. Sci.* 269: 1263-69

Beauchamp G. 1997. Determinants of intraspecific brood amalgamation in waterfowl. *Auk* 114: 11-21

Broom M, Ruxton GD. 2002. A game theoretical approach to conspecific brood parasitism. *Behav. Ecol.* 13: 321-27

Broom M, Ruxton GD. 2004. A framework for modelling and analysing conspecific brood parasitism. *J. Math. Biol.* 48: 529-44

de Valpine P, Eadie JM. 2008. Conspecific brood parasitism and population dynamics. *Am. Nat.* In press.

Eadie JM, Kehoe FP, Nudds TD. 1988. Pre-hatch and post-hatch brood amalgamation in North American Anatidae: a review of hypotheses. *Can. J. Zool.* 66: 1709-21

Eadie JM. 1991. Constraint and opportunity in the evolution of brood parasitism in waterfowl. *Proc. Int. Ornithol. Congr.* 20: 1031-40

Eadie JM, Fryxell JM. 1992. Density-dependence, frequency-dependence, and alternative nesting strategies in Goldeneyes. *Am. Nat.* 140: 621-41

Eadie JM, Semel B, Sherman PW. 1998. Conspecific brood parasitism, population dynamics, and the conservation of cavity-nesting birds. In *Behavioral ecology and conservation biology*, ed. T Caro, pp. 306-40: Oxford University Press

Geffen E, Yom-Tov Y. 2001. Factors affecting the rates of intraspecific nest parasitism among Anseriformes and Galliformes. *Anim. Behav.* 62: 1027-38

Lack D. 1947. The significance of clutch size. *The Ibis* 89: 302-52

Loeb MLG, Zink AG. 2006. Fitness conflicts and the costs of sociality in communal egg layers: a theoretical model and empirical tests. *J. Evol. Biol.*19: 889-99

Lopez-Sepulcre A, Kokko H. 2002. The role of kin recognition in the evolution of conspecific brood parasitism. *Anim. Behav.* 64: 215-22

Lyon BE. 1998. Optimal clutch size and conspecific brood parasitism. *Nature* 392: 380-83

Maruyama J, Seno H. 1999a. The optimal strategy for brood-parasitism: How many eggs should be laid in the host's nest? *Math. Biosci* .161: 43-63.

Maruyama J, Seno H. 1999b. Mathematical modelling for intra-specific brood-parasitism: coexistence between parasite and non-parasite. *Math. Biosci*. 156: 315-38

May RM, Nee S, Watts C. 1991. Could intraspecific brood parasitism cause population cycles. *Proc. Int. Ornithol. Congr.* 20: 1012-22

Nee S, May RM. 1993. Population-level consequences of conspecific brood parasitism in birds and insects. *J. Theor. Biol.* 161: 95-109

Pöysä H, Pesonen M. 2007. Nest predation and the evolution of conspecific brood parasitism: From risk spreading to risk assessment. *Am. Nat.* 169: 94-104

Robert M, Sorci G. 2001. The evolution of obligate interspecific brood parasitism in birds. *Behav. Ecol.* 12: 128-33.

Rohwer FC, Freeman S. 1989. The distribution of conspecific nest parasitism in birds. *Canadian Journal of Zoology* 67: 239-53
Ruxton GD, Broom M. 2002. Intraspecific brood parasitism can increase the number of eggs that an individual lays in its own nest. *Proc. R. Soc. Lond., Ser. B: Biol. Sci.* 269: 1989-92
Sayler RD. 1992. Ecology and evolution of brood parasitism in waterfowl. In *Ecology and management of breeding waterfowl*, ed. BDJ Batt, AD Afton, MG Anderson, CD Ankney, DH Johnson, et al, pp. 290-322. Minneapolis: University of Minnesota Press
Sorenson MD. 1991. The functional significance of parasitic egg laying and typical nesting in redhead ducks: An analysis of individual behaviour. . *Anim. Behav*. 42: 771-96
Sorenson MD. 1992. Why is conspecific nest parasitism more frequent in waterfowl than in other birds - Comment. *Can. J. Zool.* 70: 1856-58
Takasu F. 2004. How many eggs should be laid in one's own nest and others' in intra-specific brood parasitism? *Popul. Ecol.* 46: 221-29
Yamauchi A. 1993. Theory of intraspecific nest parasitism in birds. *Anim. Behav.* 46: 335-45
Yamauchi A. 1995. Theory of evolution of nest parasitism in birds. *Am. Nat.* 145: 434-56
Yerkes T, Koops MA. 1999. Redhead reproductive strategy choices: a dynamic state variable model. *Behav. Ecol.* 10: 30-40
Yom-Tov Y. 1980. Intraspecific nest parasitism in birds. *Biol. Rev. Camb. Philos. Soc.* 55: 93-108
Zink AG. 2000. The evolution of intraspecific brood parasitism in birds and insects. *Am. Nat.* 155: 395-405