

University of Groningen

Costs of avian incubation

de Heij, Maaïke Elisabeth

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2006

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

de Heij, M. E. (2006). *Costs of avian incubation: How fitness, energetics and behaviour impinge on the evolution of clutch size*. s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

References

A

- Allander, K. & Bennett, G. F. 1995. Retardation of breeding onset in great tits (*Parus major*) by blood parasites. *Functional Ecology* 9, 677-682.
- Arnold, S. J. & Wade, M. J. 1984. On the measurement of natural and sexual selection - applications. *Evolution* 38, 720-734.

B

- Biebach, H. 1981. Energetic costs of incubation on different clutch sizes in starlings (*Sturnus vulgaris*). *Ardea* 69, 141-142.
- Biebach, H. 1984. Effect of clutch size and time of day on the energy expenditure of incubating Starlings (*Sturnus vulgaris*). *Physiological Zoology* 57, 26-31.
- Biebach, H. 1986. Energetics of rewarming a clutch in Starlings (*Sturnus vulgaris*). *Physiological Zoology* 59, 69-75.
- Bosque, C. & Bosque, M. T. 1995. Nest predation as a selective factor in the evolution of developmental rates in altricial birds. *American Naturalist* 145, 234-260.
- Both, C., Visser, M. E., & Verboven, N. 1999. Density-dependent recruitment rates in great tits: the importance of being heavier. *Proceedings of the Royal Society of London Series B-Biological Sciences* 266, 465-469.
- Both, C., Tinbergen, J. M., & Visser, M.E. 2000. Adaptive density dependence of avian clutch size. *Ecology* 81, 3391-3403.
- Brinkhof, M. W. G., Cave, A. J., Hage F. J., & Verhulst, S. 1993. Timing of reproduction and fledging success in the coot *Fulica atra*: evidence for a causal relationship. *Journal of Animal Ecology* 62, 577-587.
- Brodie, E. D., Moore, A. J., & Janzen, F. J. 1995. Visualizing and quantifying natural selection. *Trends in Ecology & Evolution* 10, 313-318.
- Broggi, J., Orell, M., Hohtola, E., & Nilsson, J.Å. 2004. Metabolic response to temperature variation in the great tit: an interpopulation comparison. *Journal of Animal Ecology* 73, 967-972.
- Brommer, J. E., Merila, J., Sheldon, B. C., & Gustafsson, L. 2005. Natural selection and genetic variation for reproductive reaction norms in a wild bird population. *Evolution* 59, 1362-1371.
- Bryan, S. M. & Bryant, D. M. 1999. Heating nest-boxes reveals an energetic constraint on incubation behaviour in great tits, *Parus major*. *Proceedings of the Royal Society of London Series B-Biological Sciences* 266, 157-162.

C

- Charnov, E. L. & Krebs, J. R. 1974. On clutch-size and fitness. *Ibis* 116, 217-219.
- Cichon, M. 2000. Costs of incubation and immunocompetence in the collared flycatcher. *Oecologia* 125, 453-457.
- Cooper, C.B., Hochachka, W.M., Butcher, G., Dhondt, A.A. 2005. Seasonal and latitudinal trends in clutch size: Thermal constraints during laying and incubation. *Ecology* 86, 2018-2031.
- Cresswell, W., Holt, S., Reid, J. M., Whitfield, D. P., & Mellanby, R. J. 2003. Do energetic demands constrain incubation scheduling in a biparental species? *Behavioral Ecology* 14, 97-102.
- Cresswell, W. & McCleery, R. 2003. How great tits maintain synchronization of their hatch date with food supply in response to long-term variability in temperature. *Journal of Animal Ecology* 72, 356-366.
- Cresswell, W., Holt, S., Reid, J. M., Whitfield, D. P., Mellanby, R. J., Norton, D., & Waldron, S. 2004. The energetic costs of egg heating constrain incubation attendance but do not determine daily energy expenditure in the pectoral sandpiper. *Behavioral Ecology* 15, 498-507.

D

- Daan, S., Dijkstra, C., & Tinbergen, J. M. 1990. Family planning in the kestrel (*Falco tinnunculus*): the ultimate control of variation in laying date and clutch size. *Behaviour* 114, 83-116.
- Daan, S., Masman, D., Strijkstra, A. M., & Kenagy, G. J. 1991. Daily energy turnover during reproduction in birds and mammals: its relationship to basal metabolic rate. *Acta XX Congressus Internationalis Ornithologici: 1976-1987*.
- Daan, S., Deerenberg, C., & Dijkstra, C. 1996. Increased daily work precipitates natural death in the kestrel. *Journal of Animal Ecology* 65, 539-544.
- Daan, S. & Tinbergen, J. M. 1997. Adaptation of life histories. In: *Behavioural Ecology, An evolutionary approach*. Fourth edition (ed. Krebs, J. R. & Davies, N. B.), pp. 311-333. Oxford: Oxford University Press.
- Deeming, D. C. 2002. Behaviour patterns during incubation. In: *Avian Incubation: Behaviour, Environment, and Evolution* (ed. Deeming, D. C.), pp. 63-87. New York: Oxford University Press.
- Deerenberg, C., Apanius, V., Daan, S., & Bos, N. 1997. Reproductive effort decreases antibody responsiveness. *Proceedings of the Royal Society of London Series B-Biological Sciences* 264, 1021-1029.
- Dijkstra, C., Bult, A., Bijlsma, S., Daan, S., Meijer, T., & Zijlstra, M. 1990. Brood size manipulations in the kestrel *Falco tinnunculus*: effects on offspring and parent survival. *Journal of Animal Ecology* 59, 269-286.
- Drent, R.H., 1975. Incubation. *Avian Biology* 333-420.
- Drent, R. H. & Daan, S. 1980. The prudent parent: energetic adjustments in avian breeding. *Ardea* 68, 225-252.

E

- Engel, S., Biebach, H., & Visser, G. H. 2006. Metabolic costs of avian flight in relation to flight velocity: a study in rose coloured starlings (*Sturnus roseus*, Linnaeus). *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology* 176: 415-427.
- Engstrand, S. M. & Bryant, D. M. 2002. A trade-off between clutch size and incubation efficiency in the barn swallow *Hirundo rustica*. *Functional Ecology* 16, 782-791.
- Engstrand, S. M., Ward, S., & Bryant, D. M. 2002. Variable energetic responses to clutch size manipulations in white-throated dippers *Cinclus cinclus*. *Journal of Avian Biology* 33, 371-379.

F

- Fairbairn, D. J., & Preziosi, R. 1996. Sexual selection and the evolution of sexual size dimorphism in the water strider, *Aquarius remigis*. *Evolution* 50, 1549-1559.

G

- Garant, D., Kruuk, L. E. B., Wilkin, T. A., McCleery, R. H., & Sheldon, B. C. 2005. Evolution driven by differential dispersal within a wild bird population. *Nature* 433, 60-65.
- Garnett, M. C. 1981. Body size, its heritability and influence on juvenile survival among great tits, *Parus major*. *Ibis* 123, 31-41.
- Gebhardt-Henrich, S. G. & van Noordwijk, A. J. 1994. The genetical ecology of nestling growth in the great tit: Environmental influences on the expression of genetic variances during growth. *Functional Ecology* 8, 469-476.
- Grafen, A. 1988. On the uses of data on lifetime reproductive success. In: *Reproductive success*. (ed. Clutton-Brock, T. H.), pp. 454-471. Chicago: University of Chicago Press.
- Gustafsson, L. & Sutherland, W. J. 1988. Cost of reproduction in the Collared Flycatcher *Ficedula albicollis*. *Nature* 335, 813-817.

H

- Haftorn, S. & Reinertsen, R. E. 1985. The effect of temperature and clutch size on the energetic cost of incubation in a free-living blue tit (*Parus caeruleus*). *Auk* 102, 470-478.
- Haftorn, S. 1988. Incubating female passerines do not let the egg temperature fall below the 'physiological temperature' during their absences from the nest. *Ornis Scandinavica* 19, 97-110.
- Halupka, K. 1994. Incubation feeding in meadow pipit *Anthus pratensis* affects female time budget. *Journal of Avian Biology* 25: 251-253.
- Hansell, M. 2000. Bird nests and construction behaviour. Cambridge: Cambridge University Press.
- Hanssen, S.A., Folstad, I., & Erikstad, K.E., 2003. Reduced immunocompetence and cost of reproduction in common eiders. *Oecologia* 136, 457-464.
- Hanssen, S. A., Erikstad, K. E., Johnsen, V., & Bustnes, J. O. 2003. Differential investment and costs during avian incubation determined by individual quality: an experimental study of the common eider (*Somateria mollissima*). *Proceedings of the Royal Society of London Series B-Biological Sciences* 270, 531-537.
- Hanssen, S. A., Hasselquist, D., Folstad, I., & Erikstad, K. E. 2005. Cost of reproduction in a long-lived bird: incubation effort reduces immune function and future reproduction. *Proceedings of the Royal Society of London Series B-Biological Sciences* 272, 1039-1046.
- Heaney, V. & Monaghan, P. 1995. A within-clutch trade-off between egg production and rearing in birds. *Proceedings of the Royal Society of London Series B-Biological Sciences* 261, 361-365.
- Heaney, V. & Monaghan, P. 1996. Optimal allocation of effort between reproductive phases: The trade-off between incubation costs and subsequent brood rearing capacity. *Proceedings of the Royal Society of London Series B-Biological Sciences* 263, 1719-1724.
- Hébert, P. N. 2002. Ecological factors affecting initiation of incubation behaviour. In: *Avian Incubation; behaviour, environment and evolution* (ed. Deeming, D. C.), pp. 270-279. New York: Oxford University Press.
- Hill, R. W. 1972. Determination of oxygen consumption by use of the paramagnetic oxygen analyzer. *Journal of Applied Physiology* 33, 261-263.

I

- Ilmonen, P., Taarna, T., & Hasselquist, D. 2002. Are incubation costs in female pied flycatchers expressed in humoral immune responsiveness or breeding success? *Oecologia* 130, 199-204.

K

- Kalmbach, E., Griffiths, R., Crane, J. E., & Furness, R. W. 2004. Effects of experimentally increased egg production on female body condition and laying dates in the great skua *Stercorarius skua*. *Journal of Avian Biology* 35, 501-514.
- Kendeigh, S. C. 1963. Thermodynamics of incubation in the house wren, *Troglodytes aedon*. In: *Proceedings XIII International Ornithological Congress* (ed. Sibley, C. G., Hickey, J. J., & Hickey, M. B.), pp. 884-904. Baton Rouge, Louisiana: American Ornithologists' Union.
- Kendeigh, S. C., Dolnik, V. R., & Gavrillov, V. M. 1977. Avian energetics. In: *Granivorous birds in ecosystems*. (ed. Pinowski, J. & Kendeigh, S. C.), pp. 127-204. Cambridge UK: Cambridge University Press.
- King, J. R. 1973. Energetics of reproduction in birds. In: *Breeding biology of birds*. (ed. Farner, D. S.), pp. 78-107. Washington, D.C.: National Academy of Science.
- Kingsolver, J. G., Hoekstra, H. E., Hoekstra, J. M., Berrigan, D., Vignieri, S. N., Hill, C. E., Hoang, A., Gibert, P., & Beerli, P. 2001. The strength of phenotypic selection in natural populations. *American Naturalist* 157, 245-261.

Kluyver, H. N. 1951. The population ecology of the great tit, *Parus major* L. *Ardea* 39, 1-135.

Kruuk, L. E. B., Slate, J., Pemberton, J. M., Brotherstone, S., Guinness, F., & Clutton-Brock, T. H. 2002. Antler size in red deer: heritability and selection but no evolution. *Evolution* 56, 1683-1695.

L

Lack, D. 1947. The significance of clutch size. *Ibis* 89, 302-352.

Lack, D. 1968. Ecological adaptations for breeding in birds. London: Methuen.

Lande, R. C. & Arnold, S. J. 1983. The measurement of selection on correlated characters. *Evolution* 37, 1210-1226.

Larsen, V. A., Lislevand, T., & Byrkjedalt, I. 2003. Is clutch size limited by incubation ability in northern lapwings? *Journal of Animal Ecology* 72, 784-792.

Lessells, C. M. 1991. The evolution of life histories. In: *Behavioural Ecology; An evolutionary approach* (ed. Krebs, J. R. & Davies, N. B.), pp. 32-68. Oxford: Blackwell Scientific Publications.

Lessells, C. M. 1993. The cost of reproduction: do experimental manipulations measure the edge of the options set? *Etologia* 3, 95-111.

Lifson, N. & McClintock, R. 1966. Theory of use of the turnover rates of body water for measuring energy and material balance. *Journal of Theoretical Biology* 12, 46-74.

Lima, S. L. & Dill, L. M. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. *Canadian Journal of Zoology* 68, 619-640.

Lindén, M. & Møller, A. P. 1989. Cost of reproduction and covariation of life history traits in birds. *Trends in Ecology & Evolution* 4, 367-371.

Lindén, M. 1990. Reproductive investment and its fitness consequences in the great tit *Parus major*. Ph.D. thesis University of Uppsala, Uppsala, Sweden.

Lyon, B. E. & Montgomerie, R. D. 1985. Incubation feeding in snow buntings: female manipulation or indirect male parental care? *Behavioral Ecology and Sociobiology* 17: 279-284.

M

Martin, T. E. & Ghalambor, C. K. 1999. Males feeding females during incubation. I. Required by microclimate or constrained by nest predation. *American Naturalist* 153: 131-139.

Merila, J., Sheldon, B. C., & Kruuk, L. E. B. 2001. Explaining stasis: microevolutionary studies in natural populations. *Genetica* 112, 199-222.

Mertens, J. A. L. 1977. The energy requirements for incubation in great tits, *Parus major* L. *Ardea* 65, 184-196.

Mertens, J. A. L. 1980. The energy requirements for incubation in great tits and other bird species. *Ardea* 69, 185-192.

Mertens, J. A. L. 1987. The influence of temperature on the energy reserves of female great tits during the breeding season. *Ardea* 75, 73-80.

Monaghan, P. & Nager, R. G. 1997. Why don't birds lay more eggs. *Trends in Ecology & Evolution* 12, 270-274.

Monros, J. S., Belda, E. J., & Barba, E. 1998. Delays of the hatching dates in great tits *Parus major*: Effects on breeding performance. *Ardea* 86, 213-220.

Moreno, J. & Carlson, A. 1989. Clutch size and the costs of incubation in the pied flycatcher *Ficedula hypoleuca*. *Ornis Scandinavica* 20, 123-128.

Moreno, J., Gustafsson, L., Carlson, A., & Part, T. 1991. The cost of incubation in relation to clutch-size in the collard flycatcher *Ficedula albicollis*. *Ibis* 133, 186-192.

Moreno, J. & Sanz, J. J. 1994. The relationship between the energy expenditure during incubation and clutch size in the pied flycatcher *Ficedula hypoleuca*. *Journal of Avian Biology* 25, 125-130.

N

- Naef-Daenzer, B., Widmer, F., & Nuber, M. 2001. Differential post-fledging survival of great and coal tits in relation to their condition and fledging date. *Journal of Animal Ecology* 70, 730-738.
- Naef-Daenzer, L., Nager, R. G., Keller, L. F., & Naef-Daenzer, B. 2004. Are hatching delays a cost or a benefit for great tit *Parus major* parents? *Ardea* 92, 229-237.
- Nager, R. & van Noordwijk, A. J. 1995. Proximate and ultimate aspects of phenotypic plasticity in timing of great tit breeding in a heterogeneous environment. *American Naturalist* 146, 454-474.
- Nilsson, J. Å. & Svensson, E. 1993a. Energy constraints and ultimate decisions during egg-laying in the blue tit. *Ecology* 74, 244-251.
- Nilsson, J. Å. & Svensson, E. 1993b. The frequency and timing of laying gaps. *Ornis Scandinavica* 24, 122-126.
- Nilsson, J. Å. 1994. Energetic bottle-necks during breeding and the reproductive cost of being too early. *Journal of Animal Ecology* 63, 200-208.
- Norris, K. 1993. Seasonal variation in the reproductive success of blue tits: an experimental study. *Journal of Animal Ecology* 62, 287-294.
- Nur, N. 1986. Is clutch size variation in the blue tit (*Parus caeruleus*) adaptive? An experimental study. *Journal of Animal Ecology* 55, 983-999.
- Nussey, D. H., Postma, E., Gienapp, P., & Visser, M. E. 2005. Selection on heritable phenotypic plasticity in a wild bird population. *Science* 310, 304-306.

O

- Orell, M., Rytönen, S., Koivula, K., Ronkainen, M., & Rahiala, M. 1996. Brood size manipulations within the natural range did not reveal intragenerational cost of reproduction in the willow tit *Parus montanus*. *Ibis* 138, 630-637.

P

- Pearse, A. T., Cavitt, J. E., & Cully, J. F. 2004. Effects of food supplementation on female nest attentiveness and incubation mate feeding in two sympatric Wren species. *Wilson Bulletin* 116, 23-30.
- Pendlebury, C. J., MacLeod, M. G., & Bryant, D. M. 2004. Variation in temperature increases the cost of living in birds. *Journal of Experimental Biology* 207, 2065-2070.
- Perrins, C. M. 1970. The timing of birds' breeding seasons. *Ibis* 112, 242-255.
- Perrins, C. M. & Moss, D. 1975. Reproductive rates in the Great Tit. *Journal of Animal Ecology* 44, 695-706.
- Perrins, C. M. 1979. *British Tits*. London: Collins.
- Perrins, C. M. 1988. Survival of young great tits: relationships with weight. *Acta International Ornithological Congress, Ottawa, Canada XIX*, 892-899.
- Perrins, C. M. & McCleery, R. H. 1989. Laying dates and clutch size in the great tit. *Wilson Bulletin* 101, 236-253.
- Pettifor, R. A., Perrins, C. M., & McCleery, R. H. 1988. Individual optimization of clutch size in great tits. *Nature* 336, 160-162.
- Pettifor, R. A. 1993a. Brood-manipulation experiments. I. The number of offspring surviving per nest in blue tits (*Parus caeruleus*). *Journal of Animal Ecology* 62, 131-144.
- Pettifor, R. A. 1993b. Brood-manipulation experiments. II. A cost of reproduction in blue tits (*Parus caeruleus*)? *Journal of Animal Ecology* 62, 145-159.
- Pettifor, R.A., Perrins, C. M., & McCleery, R. 2001. Individual optimization of fitness: variation in reproductive output, including clutch size, mean nestling mass and offspring recruitment, in manipulated broods of great tits *Parus major*. *Journal of Animal Ecology* 70, 62-79.

- Piersma, T., Lindström, Å., Drent, R. H., Tulp, I., Jukema, J., Morrison, R. I. G., Reneerkens, J., Schekkerman, H., & Visser, G. H. 2003. High daily energy expenditure of incubating shorebirds on High Arctic tundra: a circumpolar study. *Functional Ecology* 17, 356-362.
- Postma, E. 2005. The evolutionary genetics of life-history traits in a structured environment: Understanding variation in clutch size and lay date in great tits (*Parus major*). Thesis Utrecht University, the Netherlands.
- Postma, E., and van Noordwijk, A. J. 2005a. Gene flow maintains a large genetic difference in clutch size at a small spatial scale. *Nature* 433, 65-68.
- Postma, E., and van Noordwijk, A. J. 2005b. Genetic variation for clutch size in natural populations of birds from a reaction norm perspective. *Ecology* 86, 2344-2357.
- Prinzinger, R., Pressmar, A., & Schleucher, E. 1991. Body temperature in birds. *Comparative Biochemistry and Physiology A Comparative Physiology* 99, 499-506.
- Prinzinger, R., Schmidt, M., & Dietz, V. 1995. Embryogeny of oxygen consumption in 13 altricial and precocial birds. *Respiration Physiology* 100, 283-287.

R

- Rasbash, J., Browne, W., Goldstein, H., Yang, M., Plewis, I., Healy, M., Woodhouse, G., Draper, D., Langford, I., & Lewis, T. 2000. *A User's Guide to MLwiN*. 2nd edn. London: Institute of Education.
- Reid, J. M., Monaghan, P., & Ruxton, G. D. 1999. The effect of clutch cooling rate on starling, *Sturnus vulgaris*, incubation strategy. *Animal Behaviour* 58, 1161-1167.
- Reid, J. M., Monaghan, P., & Ruxton, G. D. 2000a. Resource allocation between reproductive phases: The importance of thermal conditions in determining the cost of incubation. *Proceedings of the Royal Society of London Series B-Biological Sciences* 267, 37-41.
- Reid, J. M., Monaghan, P., & Ruxton, G. D. 2000b. The consequences of clutch size for incubation conditions and hatching success in starlings. *Functional Ecology* 14, 560-565.
- Reid, J. M., Monaghan, P., & Nager, R. G. 2002. Incubation and the costs of reproduction. In: *Avian Incubation: Behaviour, Environment, and Evolution* (ed. Deeming, D. C.), pp. 314-325. New York: Oxford University Press.
- Reid, J. M., Cresswell, W., Holt, S., Mellanby, R. J., Whitfield, D. P., & Ruxton, G. D. 2002. Nest scrape design and clutch heat loss in pectoral sandpipers (*Calidris melanotos*). *Functional Ecology* 16, 305-312.
- Ricklefs, R. E. 1996. Avian energetics, ecology and evolution. In: *Avian energetics and nutritional ecology* (ed. Carey, C.), pp. 1-30. New York: Chapman & Hall.
- Roff, D. A. 1992. *The evolution of life histories; theory and analysis*. New York: Chapman & Hall.
- Romanoff, A. L. & Romanoff, A. J. 1949. *The avian egg*. New York: Wiley.
- Royama, T. 1966. Factors governing feeding rate, food requirement and brood size of nestling great tits *Parus major*. *Ibis* 108, 313-347.
- Rytkönen, S & Orell, M. 2001. Great tits, *Parus major*, lay too many eggs: experimental evidence in mid-boreal habitats. *Oikos* 93, 439-450.

S

- Sanz, J. J. 1997. Clutch size manipulation in the pied flycatcher: Effects on nestling growth, parental care and moult. *Journal of Avian Biology* 28, 157-162.
- Sanz, J. J. & Tinbergen, J. M. 1999. Energy expenditure, nestling age, and brood size: an experimental study of parental behavior in the great tit *Parus major*. *Behavioral Ecology* 10, 598-606.
- Sanz, J. J., Kranenbarg, S., & Tinbergen, J. M. 2000. Differential response by males and females to manipulation of partner contribution in the great tit (*Parus major*). *Journal of Animal Ecology* 69, 74-84.

- Sheldon, B. C., Kruuk, L. E. B., & Merila, J. 2003. Natural selection and inheritance of breeding time and clutch size in the collared flycatcher. *Evolution* 57, 406-420.
- Siikamäki, P. 1995. Are large clutches costly to incubate: The case of the pied flycatcher. *Journal of Avian Biology* 26, 76-80.
- Siikamäki, P., Ratti, O., Hovi, M., & Bennett, G. F. 1997. Association between haematozoan infections and reproduction in the pied flycatcher. *Functional Ecology* 11, 176-183.
- Smith, H. G. 1989. Larger clutches take longer to incubate. *Ornis Scandinavica* 20, 156-158.
- Speakman, J. R. 1997. *Doubly labelled water: Theory and practice*. London: Chapman & Hall.
- Speakman, J. R., Visser, G. H., Ward, S., & Krol, E. 2001. The isotope dilution method for the evaluation of body composition. In: *Body composition analysis of animals: a handbook of non-destructive methods* (ed. Speakman, J. R.), pp. 56-98. New York: Cambridge University Press.
- Stearns, S. C. 1992. *The evolution of life histories*. Oxford: Oxford University Press.
- Stevenson, I. R. & Bryant, D. M. 2000. Climate change and constraints on breeding. *Nature* 406, 366-367.
- Svensson, E. 1997. Natural selection on avian breeding time: Causality, fecundity-dependent, and fecundity-independent selection. *Evolution* 51, 1276-1283.
- Szekely, T., Karsai, I., & Williams, T. D. 1994. Determination of clutch-size in the kentish plover *Charadrius alexandrinus*. *Ibis* 136, 341-348.
- Szentirmai, I., Szekely, T., & Liker, A. 2005. The influence of nest size on heat loss of penduline tit eggs. *Acta Zoologica Academiae Scientiarum Hungaricae* 51, 59-66.

T

- Tatner, P. & Bryant, D. M. 1989. The doubly labelled water technique for measuring energy expenditure. In: *Techniques in comparative respiratory physiology*. (ed. Bridge, C. R. & Butler, P. J.), pp. 77-112. Cambridge: Cambridge University Press.
- Thomson, D. L., Monaghan, P., & Furness, R. W. 1998. The demands of incubation and avian clutch size. *Biological Reviews* 73, 293-304.
- Tinbergen, J. M. & Boerlijst, M. C. 1990. Nestling weight and survival in individual great tits (*Parus major*). *Journal of Animal Ecology* 59, 1113-1127.
- Tinbergen, J. M. & Daan, S. 1990. Family planning in the great tit (*Parus major*): optimal clutch size as integration of parent and offspring fitness. *Behaviour* 114, 161-190.
- Tinbergen, J. M. & Dietz, M. W. 1994. Parental energy expenditure during brood rearing in the great tit (*Parus major*) in relation to body mass, temperature, food availability and clutch size. *Functional Ecology* 8, 563-572.
- Tinbergen, J. M. & Williams, J. B. 2002. Energetics of incubation. In: *Avian incubation: Behaviour, environment, and Evolution*. (ed. Deeming, D. C.), pp. 299-313. New York: Oxford University Press.
- Tinbergen, J. M. & Sanz, J. J. 2004. Strong evidence for selection for larger brood size in a great tit population. *Behavioral Ecology* 15, 525-533.
- Tinbergen, J. M. 2005. Biased estimates of fitness consequences of brood size manipulation through correlated effects on natal dispersal. *Journal of Animal Ecology* 74, 1112-1120.
- Tombre, I. M. & Erikstad, K. E. 1996. An experimental study of incubation effort in high-Arctic barnacle geese. *Journal of Animal Ecology* 65, 325-331.

V

- van Balen, J. H. & Cave, A. J. 1970. Survival and weight loss of nestling great tits, *Parus major*, in relation to brood-size and air temperature. *Netherlands Journal of Zoology* 20, 464-474.

- van Noordwijk, A. J., van Balen, J. H., & Scharloo, W. 1981a. Genetic and environmental variation in clutch size of the Great Tit (*Parus major*). *Netherlands Journal of Zoology* 31, 342-372.
- van Noordwijk, A. J., van Balen, J. H., & Scharloo, W. 1981b. Genetic variation in the timing of reproduction in the Great tit. *Oecologia* 49, 158-166.
- van Noordwijk, A. J., McCleery, R. H., & Perrins, C. M. 1995. Selection for the timing of great tit breeding in relation to caterpillar growth and temperature. *Journal of Animal Ecology* 64, 451-458.
- Vanderwerf, E. 1992. Lack's clutch size hypothesis: an examination of the evidence using meta-analysis. *Ecology* 73, 1699-1705.
- Verboven, N. & Visser, M. E. 1998. Seasonal variation in local recruitment of great tits: the importance of being early. *Oikos* 81, 511-524.
- Verboven, N. & Tinbergen, J. M. 2002. Nest desertion: a trade-off between current and future reproduction. *Animal Behaviour* 63, 951-958.
- Verhulst, S. & Tinbergen, J. M. 1991. Experimental evidence for a causal relationship between timing and success of reproduction in the great tit *Parus major*. *Journal of Animal Ecology* 60, 269-282.
- Verhulst, S. 1995. Reproductive decisions in great tits; an optimality approach. PhD Thesis University of Groningen, Groningen, The Netherlands.
- Verhulst, S., van Balen, J. H., & Tinbergen, J. M. 1995. Seasonal decline in reproductive success of the great tit: Variation in time or quality? *Ecology* 76, 2392-2403.
- Verhulst, S. 1998. Multiple breeding in the great tit; II. The costs of rearing a second clutch. *Functional Ecology* 12, 132-140.
- Vézina, F. & Williams, T. D. 2002. Metabolic costs of egg production in the european starling (*Sturnus vulgaris*). *Physiological and Biochemical Zoology* 75, 377-385.
- Visser, M. E., van Noordwijk, A. J., Tinbergen, J. M., & Lessells, C. M. 1998. Warmer springs lead to mistimed reproduction in great tits (*Parus major*). *Proceedings of the Royal Society of London Series B-Biological Sciences* 265, 1867-1870.
- Visser, M. E. & Lessells, C. M. 2001. The costs of egg production and incubation in great tits (*Parus major*). *Proceedings of the Royal Society of London Series B-Biological Sciences* 268, 1271-1277.
- Visser, M. E., Both, C., & Lambrechts, M. M. 2004. Global climate change leads to mistimed avian reproduction. *Advances in Ecological Research* 35, 89-110.
- Visser, M. E., Holleman, L. J. M., & Gienapp, P. 2006. Shifts in caterpillar biomass phenology due to climate change and its impact on the breeding biology of an insectivorous bird. *Oecologia* 147, 164-172.
- Vleck, C. M., Vleck, D., & Hoyt, D. F. 1980. Patterns of metabolism and growth in avian embryos. *American Zoologist* 405-416.
- Vleck, C. M. 1981. Energetic cost of incubation in the Zebra Finch. *Condor* 83, 229-237.

W

- Wallander, J. & Andersson, M. 2002. Clutch size limitation in waders: experimental test in redshank *Tringa totanus*. *Oecologia* 130, 391-395.
- Walsberg, G. E. 1983. Avian ecological energetics. In: *Avian Biology* (ed. Farner, D. S., King, J. R., & Parkes, K. C.), pp. 161-220. New York: Academic Press.
- Walsberg, G. E. & King, J. R. 1978. The heat budget of incubating Mountain White-crowned Sparrows (*Zonotrichia leucophrys oriantha*) in Oregon. *Physiological Zoology* 51, 92-103.
- Walsberg, G. E. & King, J. R. 1978. The energetic consequences of incubation for two passerine species. *Auk* 95, 644-655.
- Ward, S. 1996. Energy expenditure of female barn swallows *Hirundo rustica* during egg formation. *Physiological Zoology* 69, 930-951.
- Weathers, W. W. 1985. Energy cost of incubation in the canary. *Comparative Biochemistry and Physiology* 81, 411-413.

- Weathers, W. W., Davidson, C. L., Olson, C. R., Morton, M. L., Nur, N., & Famula, T. R. 2002. Altitudinal variation in parental energy expenditure by white-crowned sparrows. *Journal of Experimental Biology* 205, 2915-2924.
- Webb, D. R. 1987. Thermal tolerance of avian embryos: a review. *Condor* 89, 874-898.
- West, G. C., 1968. Bioenergetics of captive Willow Ptarmigan under natural conditions. *Ecology* 49: 1035-1045.
- Wiebe, K. L. & Martin, K. 2000. The use of incubation behavior to adjust avian reproductive costs after egg laying. *Behavioral Ecology and Sociobiology* 48, 463-470.
- Wiersma, P. & Tinbergen, J. M. 2003. No nocturnal energetic savings in response to hard work in free-living great tits. *Netherlands Journal of Zoology* 52, 263-279.
- Wiersma, P. & Verhulst, S. 2005. Effects of intake rate on energy expenditure, somatic repair and reproduction of zebra finches. *Journal of Experimental Biology* 208, 4091-4098.
- Wiersma P, Salomons HM, Verhulst S, 2005. Metabolic adjustments to increasing foraging costs of starlings in a closed economy. *Journal of Experimental Biology* 208: 4099-4108.
- Williams, G. C. 1966. Natural selection, the cost of reproduction, and a refinement of Lack's principle. *American Naturalist* 100, 687-690.
- Williams, J. B. & Dwinell, B. 1990. Field metabolism of free-living female savannah sparrows during incubation - A study using Doubly Labeled Water. *Physiological Zoology* 63, 353-372.
- Williams, J. B. 1996. Energetics of avian incubation. In: *Avian energetics and nutritional control* (ed. Carey, C.), pp. 375-415. New York: Chapman & Hall.
- Williams, J. B. & Tieleman, I. 2000. Flexibility in basal metabolic rate and evaporative water loss among hoopoe larks exposed to different environmental temperatures. *Journal of Experimental Biology* 203, 3153-3159.

Y

- Yom-Tov, Y. & Hilborn, R. 1981. Energetic constraints on clutch size and time of breeding in temperate zone birds. *Oecologia* 48, 234-243.