



Universiteit
Leiden
The Netherlands

Tango to traffic : a field study into consequences of noisy urban conditions for acoustic courtship interactions in birds

Halfwerk, W.

Citation

Halfwerk, W. (2012, March 1). *Tango to traffic : a field study into consequences of noisy urban conditions for acoustic courtship interactions in birds*. Retrieved from <https://hdl.handle.net/1887/18535>

Version: Not Applicable (or Unknown)

License: [Leiden University Non-exclusive license](#)

Downloaded from: <https://hdl.handle.net/1887/18535>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/18535> holds various files of this Leiden University dissertation.

Author: Halfwerk, Wouter

Title: Tango to traffic : a field study into consequences of noisy urban conditions for acoustic courtship interactions in birds

Issue Date: 2012-03-01

Bibliography

- Angerbjorn A., Tannerfeldt M. & Erlinge S. (1999). Predator-prey relationships: Arctic foxes and lemmings. *Journal of Animal Ecology*, 68, 34-49.
- Bakelaar R.G. & Odum E.P. (1978). Community and population level responses to fertilization in an old-field ecosystem. *Ecology*, 59, 660-665.
- Barber J.R., Crooks K.R. & Fristrup K.M. (2009). The costs of chronic noise exposure for terrestrial organisms. *Trends in Ecology & Evolution*, 25, 180-189.
- Batzler D.P., Pusateri C.R. & Vetter R. (2000). Impacts of fish predation on marsh invertebrates: Direct and indirect effects. *Wetlands*, 20, 307-312.
- Bautista L.M., Garcia J.T., Calmaestra R.G., Palacin C., Martin C.A., Morales M.B., Bonal R. & Vinuela J. (2004). Effect of weekend road traffic on the use of space by raptors. *Conservation Biology*, 18, 726-732.
- Bayne E.M., Habib L. & Boutin S. (2008). Impacts of Chronic Anthropogenic Noise from Energy-Sector Activity on Abundance of Songbirds in the Boreal Forest. *Conservation Biology*, 22, 1186-1193.
- Bee M.A. & Micheyl C. (2008). The cocktail party problem: What is it? How can it be solved? And why should animal behaviorists study it? *Journal of Comparative Psychology*, 122, 235-251.
- Bee M.A. & Swanson E.M. (2007). Auditory masking of anuran advertisement calls by road traffic noise. *Animal Behaviour*, 74, 1765-1776.
- Bergen F. & Abs M. (1997). Etho-ecological study of the singing activity of the Blue Tit (*Parus caeruleus*), Great Tit (*Parus major*) and Chaffinch (*Fringilla coelebs*). *Journal Fur Ornithologie*, 138, 451-467.
- Berger K.M., Gese E.M. & Berger J. (2008). Indirect effects and traditional trophic cascades: A test involving wolves, coyotes, and pronghorn. *Ecology*, 89, 818-828.
- Bermudez-Cuamatzin E., Rios-Chelen A.A., Gil D. & Garcia C.M. (2010). Experimental evidence for real-time song frequency shift in response to urban noise in a passerine bird. *Biology Letters*, 7, 36-38.
- Bernays E.A. & Funk D.J. (1999). Specialists make faster decisions than generalists: experiments with aphids. *Proc. R. Soc. B-Biol. Sci.*, 266, 151-156.
- Bisson I.A., Butler L.K., Hayden T.J., Romero L.M. & Wikelski M.C. (2009). No energetic cost of anthropogenic disturbance in a songbird. *Proc. R. Soc. B-Biol. Sci.*, 276, 961-969.
- Blumenrath S.H., Dabelsteen T. & Pedersen S.B. (2004). Being inside nest boxes: Does it complicate the receiving conditions for great tit *Parus major* females? *Bioacoustics-the International Journal of Animal Sound and Its Recording*, 14, 209-223.
- Blumenrath S.H., Dabelsteen T. & Pedersen S.B. (2007). Vocal neighbour-mate discrimination in female great tits despite high song similarity. *Animal Behaviour*, 73, 789-796.

- Botero C.A., Rossman R.J., Caro L.M., Stenzler L.M., Lovette I.J., de Kort S.R. & Vehrencamp S.L. (2009). Syllable type consistency is related to age, social status and reproductive success in the tropical mockingbird. *Animal Behaviour*, 77, 701-706.
- Both C. (2004). Does mate-guarding give non-territorial birds the chance to settle? *ARDEA*, 92, 107-111.
- Both C., Van Turnhout C.A.M., Bijlsma R.G., Siepel H., Van Strien A.J. & Foppen R.P.B. (2010). Avian population consequences of climate change are most severe for long-distance migrants in seasonal habitats. *Proceedings of the Royal Society B-Biological Sciences*, 277, 1259-1266.
- Both C. & Visser M.E. (2001). Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. *Nature*, 411, 296-298.
- Bradbury J.W. & Vehrencamp S.L. (1998). *Principles of Animal Communication*. Sinauer Associates, Sunderland, MA.
- Brommer J.E., Alho J.S., Biard C., Chapman J.R., Charmantier A., Dreiss A., Hartley I.R., Hjernquist M.B., Kempenaers B., Komdeur J., Laaksonen T., Lehtonen P.K., Lubjuhn T., Patrick S.C., Rosivall B., Tinbergen J.M., van der Velde M., van Oers K., Wilk T. & Winkel W. (2010). Passerine Extrapair Mating Dynamics: A Bayesian Modeling Approach Comparing Four Species. *Am. Nat.*, 176, 178-187.
- Brumm H. (2004). The impact of environmental noise on song amplitude in a territorial bird. *Journal of Animal Ecology*, 73, 434-440.
- Brumm H., Lachlan R.F., Riebel K. & Slater P.J.B. (2009). On the function of song type repertoires: testing the 'antiexhaustion hypothesis' in chaffinches. *Animal Behaviour*, 77, 37-42.
- Brumm H. & Naguib M. (2009). Environmental Acoustics and the Evolution of Bird Song. *Advances in the Study of Behavior*, Vol 40, 40, 1-33.
- Brumm H., Robertson K.A. & Nemeth E. (2011). Singing direction as a tool to investigate the function of birdsong: an experiment on sedge warblers. *Animal Behaviour*, 81, 653-659.
- Brumm H. & Slabbekoorn H. (2005). Acoustic communication in noise. In: *Advances in the Study of Behavior*, Vol 35, pp. 151-209.
- Brumm H. & Slater P.J.B. (2006a). Ambient noise, motor fatigue, and serial redundancy in chaffinch song. *Behavioral Ecology and Sociobiology*, 60, 475-481.
- Brumm H. & Slater P.J.B. (2006b). Animals can vary signal amplitude with receiver distance: evidence from zebra finch song. *Animal Behaviour*, 72, 699-705.
- Brumm H. & Todt D. (2002). Noise-dependent song amplitude regulation in a territorial songbird. *Animal Behaviour*, 63, 891-897.
- Brumm H., Voss K., Kollmer I. & Todt D. (2004). Acoustic communication in noise: regulation of call characteristics in a New World monkey. *Journal of Experimental Biology*, 207, 443-448.
- Bucur V. (2006). *Urban Forest Acoustics*. Springer-Verlag, Berlin, Heidelberg.

- Burnham K.P. & Anderson D.R. (2002). *Model Selection and Multimodel Inference: A Practical-Theoretic Approach*. 2nd edn. Springer-Verlag, Berlin.
- Byers B.E. (2007). Extrapair paternity in chestnut-sided warblers is correlated with consistent vocal performance. *Behavioral Ecology*, 18, 130-136.
- Cardoso G.C. & Atwell J.W. (in press). On the relation between loudness and the increased song frequency of urban birds. *Animal Behaviour*.
- Catchpole C.K. & Slater P.J.B. (2008). *Bird Song: Biological themes and Variations*. Cambridge University press, Cambridge.
- Chan A.A.Y.-H. & Blumstein D.T. (2011). Attention, noise, and implications for wildlife conservation and management. *Applied Animal Behaviour Science*, 131, 1-7.
- Chan A.A.Y.-H., Giraldo-Perez P., Smith S. & Blumstein D.T. (2011). Anthropogenic noise affects risk assessment and attention: the distracted prey hypothesis. *Biology Letters*, 6, 458-461.
- Chiver I., Stutchbury B.J.M. & Morton E.S. (2008). Do male plumage and song characteristics influence female off-territory forays and paternity in the hooded warbler? *Behavioral Ecology and Sociobiology*, 62, 1981-1990.
- Clergeau P., Croci S., Jokimaki J., Kaisanlahti-Jokimaki M.L. & Dinetti M. (2006). Avifauna homogenisation by urbanisation: Analysis at different European latitudes. *Biological Conservation*, 127, 336-344.
- Codarin A., Wysocki L.E., Ladich F. & Picciulin M. (2009). Effects of ambient and boat noise on hearing and communication in three fish species living in a marine protected area (Miramare, Italy). *Marine Pollution Bulletin*, 58, 1880-1887.
- Copeland H.E., Doherty K.E., Naugle D.E., Pocewicz A. & Kiesecker J.M. (2009). Mapping oil and gas development potential in the US Intermountain West and estimating impacts to species. *PLoS ONE*, 4, e7400.
- Darwin, C. R. 1859. *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. John Murray, London.
- Davies N.B. & Halliday T.R. (1978). Deep croaks and fighting assessment in toads *Bufo bufo*. *Nature*, 274, 683-685.
- de Kort S.R., Eldermire E.R.B., Valderrama S., Botero C.A. & Vehrencamp S.L. (2009). Trill consistency is an age-related assessment signal in banded wrens. *Proceedings of the Royal Society B-Biological Sciences*, 276, 2315-2321.
- Dhondt A.A. & Eyckerman R. (1980). Competition between the great tit and the blue tit outside the breeding-season in field experiments. *Ecology*, 61, 1291-1296.
- Dingle C., Halfwerk W. & Slabbekoorn H. (2008). Habitat-dependent song divergence at subspecies level in the grey-breasted wood-wren. *Journal of Evolutionary Biology*, 21, 1079-1089.

- Dingle C., Poelstra J.W., Halfwerk W., Brinkhuizen D.M. & Slabbekoorn H. (2010). Asymmetric response patterns to subspecies-specific song differences in allopatry and parapatry in the gray-breasted wood-wren. *Evolution*, 64, 3537-3548.
- Doherty K.E., Naugle D.E., Walker B.L. & Graham J.M. (2008). Greater sage-grouse winter habitat selection and energy development. *Journal of Wildlife Management*, 72, 187-195.
- Dooling R.J., Lohr B. & Dent M.L. (2000). Hearing in birds and reptiles. In: *Comparative hearing in birds and reptiles*. Springer Berlin.
- Double M. & Cockburn A. (2000). Pre-dawn infidelity: females control extra-pair mating in superb fairy-wrens. *Proc. R. Soc. Lond. Ser. B-Biol. Sci.*, 267, 465-470.
- Drent P.J. (1987). The importance of nestboxes for territory settlement, survival and density of the great tit. *Ardea*, 75, 59-71.
- Driver J. & Spence C. (1998). Attention and the crossmodal construction of space. *Trends Cogn. Sci.*, 2, 254-262.
- Endler J.A. (1992). Signals, Signal Conditions, and the Direction of Evolution. *Am. Nat.*, 139, S125-S153.
- Falls J.B., Krebs J.R. & McGregor P.K. (1982). Song matching in the great tit (parus-major) - the effect of similarity and familiarity. *Animal Behaviour*, 30, 997-1009.
- Fernández-Juricic E., R. , Poston K., De Collibus T., Morgan B., Bastain C. & Martin K. (2005). Microhabitat selection and singing behavior patterns of male house finches (*Carpodacus mexicanus*) in urban parks in a heavily urbanized landscape in the Western U.S. *Urban Habitats*, 3, 49-69.
- Forman R.T.T. (2000). Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology*, 14, 31-35.
- Forman R.T.T., Reineking B. & Hersperger A.M. (2002). Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management*, 29, 782-800.
- Forstmeier W., Kempenaers B., Meyer A. & Leisler B. (2002). A novel song parameter correlates with extra-pair paternity and reflects male longevity. *Proc. R. Soc. Lond. Ser. B-Biol. Sci.*, 269, 1479-1485.
- Francis C.D., Ortega C.P. & Cruz A. (2009). Cumulative consequences of noise pollution: noise changes avian communities and species interactions. *Current Biology*, 19, 1415-1419.
- Francis C.D., Ortega C.P. & Cruz A. (2011a). Noise Pollution Filters Bird Communities Based on Vocal Frequency. *PLoS ONE*, 6, e27052.
- Francis C.D., Ortega C.P. & Cruz A. (2011b). Vocal frequency change reflects different responses to anthropogenic noise in two suboscine tyrant flycatchers. *Proceedings of the Royal Society B-Biological Sciences*, 278, 2025-2031.

- Franco P. & Slabbekoorn H. (2009). Repertoire size and composition in great tits: a flexibility test using playbacks. *Animal Behaviour*, 77, 261-269.
- Garamszegi L.Z., Calhim S., Dochtermann N., Hegyi G., Hurd P.L., Jorgensen C., Kutsukake N., Lajeunesse M.J., Pollard K.A., Schielzeth H., Symonds M.R.E. & Nakagawa S. (2009). Changing philosophies and tools for statistical inferences in behavioral ecology. *Behavioral Ecology*, 20, 1363-1375.
- Gil D. & Gahr M. (2002). The honesty of bird song: multiple constraints for multiple traits. *Trends in Ecology & Evolution*, 17, 133-141.
- Gil D., Slater P.J.B. & Graves J.A. (2007). Extra-pair paternity and song characteristics in the willow warbler *Phylloscopus trochilus*. *Journal of Avian Biology*, 38, 291-297.
- Goodwin S.E. & Shriver W.G. (2011). Effects of Traffic Noise on Occupancy Patterns of Forest Birds. *Conservation Biology*, 25, 406-411.
- Gorissen L. & Eens M. (2004). Interactive communication between male and female Great Tits (*Parus major*) during the dawn chorus. *Auk*, 121, 184-191.
- Gould S.J. & Lewontin R.C. (1979). Spandrels of san-marco and the panglossian paradigm - a critique of the adaptationist program. *Proceedings of the Royal Society of London Series B-Biological Sciences*, 205, 581-598.
- Grimm N.B., Faeth S.H., Golubiewski N.E., Redman C.L., Wu J.G., Bai X.M. & Briggs J.M. (2008). Global change and the ecology of cities. *Science*, 319, 756-760.
- Groot Bruinderink G.W.T.A., Brandjes G.J., van Eekelen R., Niewold F.J.J., ten Den P.G.A. & Waardenburg H.W. (2002). Faunabeheerplan Nationaal Park Sallandse Heuvelrug i.o. In: Alterra, Research Instituut voor de Groene Ruimte Wageningen.
- Gross K., Pasinelli G. & Kunc H.P. (2010). Behavioral Plasticity Allows Short-Term Adjustment to a Novel Environment. *Am. Nat.*, 176, 456-464.
- Gummbah (2000). *De tijd vliegt slecht*. De Harmonie, Amsterdam.
- Habib L., Bayne E.M. & Boutin S. (2007). Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. *Journal of Applied Ecology*, 44, 176-184.
- Halfwerk W., Bot S., Buikx J., van der Velde M., Komdeur J., ten Cate C. & Slabbekoorn H. (2011a). Low songs lose potency in urban noise conditions. *Proceedings of the National Academy of Sciences of the United States of America*, 108, 14549-14554.
- Halfwerk W., Holleman L.J.M., Lessells C.M. & Slabbekoorn H. (2011b). Negative impact of traffic noise on avian reproductive success. *Journal of Applied Ecology*, 48, 210-219.
- Halfwerk W. & Slabbekoorn H. (2009). A behavioural mechanism explaining noise-dependent frequency use in urban birdsong. *Animal Behaviour*, 78, 1301-1307.
- Hall M.L. (2009). A Review of Vocal Duetting in Birds. *Advances in the Study of Behavior, Vol 40*, 40, 67-121.

- Hamao S., Watanabe M. & Mori Y. (2011). Urban noise and male density affect songs in the great tit *Parus major*. *Ethol. Ecol. Evol.*, 23, 111-119.
- Hasselquist D., Bensch S. & vonSchantz T. (1996). Correlation between male song repertoire, extra-pair paternity and offspring survival in the great reed warbler. *Nature*, 381, 229-232.
- Helm B., Piersma T. & Van der Jeugd H. (2006). Sociable schedules: interplay between avian seasonal and social behaviour. *Animal Behaviour*, 72, 245-262.
- Herrera-Montes M.I. & Aide T.M. (2011). Impacts of traffic noise on anuran and bird communities. *Urban Ecosystems*, 14, 415-427.
- Holveck M.J. & Riebel K. (2009). Low-quality females prefer low-quality males when choosing a mate. *Proceedings of the Royal Society B-Biological Sciences*, 277, 153-160.
- Hu Y. & Cardoso G.C. (2009). Which birds adjust the frequency of vocalizations in urban noise? *Animal Behaviour*, 79, 863-867.
- Hunter M.L. & Krebs J.R. (1979). Geographic variation in the song of the great tit (*Parus Major*) in relation to ecological factors. *Journal of Animal Ecology*, 48, 759-785.
- Inouye R.S. & Tilman D. (1995). Convergence and divergence of old-field vegetation after 11 yr of nitrogen addition. *Ecology*, 76, 1872-1887.
- Johnstone R.A. (2011). Load lightening and negotiation over offspring care in cooperative breeders. *Behavioral Ecology*, 22, 436-444.
- Junker-Bornholdt R., Wagner M., Zimmermann M., Simonis S., Schmidt K.H. & Wiltshko W. (1998). The impact of a motorway in construction and after opening to traffic on the breeding biology of Great Tit (*Parus major*) and Blue Tit (*P-caeruleus*). *Journal Fur Ornithologie*, 139, 131-139.
- Kalinowski S.T., Taper M.L. & Marshall T.C. (2007). Revising how the computer program CERVUS accommodates genotyping error increases success in paternity assignment. *Molecular Ecology*, 16, 1099-1106.
- Kappes J.J. & Davis J.M. (2008). Evidence of positive indirect effects within a community of cavity-nesting vertebrates. *Condor*, 110, 441-449.
- Kemmerer E.P., Shields J.M. & Tidemann C.R. (2008). High densities of bell miners *Manorina melanophrys* associated with reduced diversity of other birds in wet eucalypt forest: Potential for adaptive management. *Forest Ecology and Management*, 255, 2094-2102.
- Kempenaers B., Borgstrom P., Loes P., Schlicht E. & Valcu M. (2010). Artificial Night Lighting Affects Dawn Song, Extra-Pair Siring Success, and Lay Date in Songbirds. *Current Biology*, 20, 1735-1739.
- Kempenaers B. & Dhondt A.A. (1991). Competition between blue and great tit for roosting sites in winter - an aviary experiment. *Ornis Scandinavica*, 22, 73-75.
- Kight C.R. & Swaddle J.P. (2011). How and why environmental noise impacts animals: an integrative, mechanistic review. *Ecology Letters*.

- King A.P., West M.J. & Goldstein M.H. (2005). Non-vocal shaping of avian song development: Parallels to human speech development. *Ethology*, 111, 101-117.
- Kirschel A.N.G., Blumstein D.T., Cohen R.E., Buermann W., Smith T.B. & Slabbekoorn H. (2009). Birdsong tuned to the environment: green hylia song varies with elevation, tree cover, and noise. *Behavioral Ecology*, 20, 1089-1095.
- Klump G.M. (1996). Bird communication in the noisy world. In: *Ecology and Evolution of Acoustic Communication in Birds* (eds. Kroodsma DE & Miller EH). Cornell University Press Ithaca, pp. 321-338.
- Cluyver H.N. (1951). The population ecology of the great tit, *Parus major* L. *Ardea*, 39, 1 - 135.
- Kociolek A.V., Clevenger A.P., Clair C.C.S. & Proppe D.S. (2011). Effects of Road Networks on Bird Populations. *Conservation Biology*, 25, 241-249.
- Krebs J., Ashcroft R. & Webber M. (1978). Song repertoires and territory defence in great tit. *Nature*, 271, 539-542.
- Kroodsma D.E. (2004). the diversity and plasticity of bird song. In: *Nature's Music: The Science of Bird Song* (eds. Marler P & Slabbekoorn H). Elsevier Academic Press London, pp. 108-130.
- Lachlan R.F. (2007). Luscinia: a bioacoustics analysis computer program. In.
- Lambrechts M. & Dhondt A.A. (1986). Male quality, reproduction, and survival in the great tit (*Parus major*). *Behavioral Ecology and Sociobiology*, 19, 57-63.
- Lambrechts M. & Dhondt A.A. (1988). The anti-exhaustion hypothesis - a new hypothesis to explain song performance and song switching in the great tit. *Animal Behaviour*, 36, 327-334.
- Lambrechts M.M. (1997). Song frequency plasticity and composition of phrase versions in Great Tits *Parus major*. *Ardea*, 85, 99-109.
- Langemann U., Gauger B. & Klump G.M. (1998). Auditory sensitivity in the great tit: perception of signals in the presence and absence of noise. *Animal Behaviour*, 56, 763-769.
- Laube M.M. & Stout R.W. (2000). Grand Canyon National Park - Assessment of transportation alternatives. *Transit: Planning, Intermodal Facilities, Management, and Marketing*, 59-69.
- Lengagne T. (2008). Traffic noise affects communication behaviour in a breeding anuran, *Hyla arborea*. *Biological Conservation*, 141, 2023-2031.
- Leonard M.L. & Horn A.G. (2008). Does ambient noise affect growth and begging call structure in nestling birds? *Behavioral Ecology*, 19, 502-507.
- Li B.G., Tao S., Dawson R.W., Cao J. & Lam K. (2002). A GIS based road traffic noise prediction model. *Applied Acoustics*, 63, 679-691.
- Lohr B., Wright T.F. & Dooling R.J. (2003). Detection and discrimination of natural calls in masking noise by birds: estimating the active space of a signal. *Animal Behaviour*, 65, 763-777.
- Lombard E. (1911). Le signe de l'elevation de la voix. *Annales des maladies de l'oreille, du larynx du nez et du pharynx*, 37, 101-119.

- Mace R. (1987). The dawn chorus in the great tit *parus-major* is directly related to female fertility. *Nature*, 330, 745-746.
- Magrath M.J.L., Vedder O., van der Velde M. & Komdeur J. (2009). Maternal Effects Contribute to the Superior Performance of Extra-Pair Offspring. *Current Biology*, 19, 792-797.
- Makarewicz R. & Kokowski P. (2007). Prediction of noise changes due to traffic speed control. *Journal of the Acoustical Society of America*, 122, 2074-2081.
- Manabe K., Sadr E.I. & Dooling R.J. (1998). Control of vocal intensity in budgerigars (*Melopsittacus undulatus*): Differential reinforcement of vocal intensity and the Lombard effect. *Journal of the Acoustical Society of America*, 103, 1190-1198.
- Marler P. & Slabbekoorn H. (2004). *Nature's music: The Science of Birdsong*. Elsevier Academic Press.
- Mathevon N., Aubin T. & Dabelsteen T. (1996). Song degradation during propagation: Importance of song post for the wren *Troglodytes troglodytes*. *Ethology*, 102, 397-412.
- Mayr E. (1983). How to carry out the adaptationist program. *American Naturalist*, 121, 324-334.
- McGregor P.K. & Krebs J.R. (1982). Mating and song types in the great tit. *Nature*, 297, 60-61.
- McGregor P.K. & Krebs J.R. (1989). Song learning in adult great tits (*parus-major*) - effects of neighbors. *Behaviour*, 108, 139-159.
- McGregor P.K., Krebs J.R. & Perrins C.M. (1981). song repertoires and lifetime reproductive success in the great tit (*parus-major*). *Am. Nat.*, 118, 149-159.
- McKinney M.L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, 127, 247-260.
- Mennill D.J., Ratcliffe L.M. & Boag P.T. (2002). Female eavesdropping on male song contests in songbirds. *Science*, 296, 873-873.
- Miller S.G., Knight R.L. & Miller C.K. (1998). Influence of recreational trails on breeding bird communities. *Ecological Applications*, 8, 162-169.
- Minot E.O. & Perrins C.M. (1986). Interspecific interference competition - nest sites for blue and great tits. *Journal of Animal Ecology*, 55, 331-350.
- Mockford E.J. & Marshall R.C. (2009). Effects of urban noise on song and response behaviour in great tits. *Proceedings of the Royal Society B-Biological Sciences*, 276, 2979-2985.
- Moller A.P. (1991). Why mated songbirds sing so much - mate guarding and male announcement of mate fertility status. *Am. Nat.*, 138, 994-1014.
- Moller A.P., Nielsen J.T. & Garamszegi L.Z. (2006). Song post exposure, song features, and predation risk. *Behavioral Ecology*, 17, 155-163.
- Morton E.S. (1975). Ecological sources of selection on avian sounds. *Am. Nat.*, 109, 17-34.

- Naguib M., Kunc H.P., Sprau P., Roth T. & Amrhein V. (2011). Communication Networks and Spatial Ecology in Nightingales. In: *Advances in the Study of Behavior, Vol 43* (eds. Brockmann HJ, Roper TJ, Naguib M, Mitani JC & Simmons LW). Elsevier Academic Press Inc San Diego, pp. 239-271.
- Naguib M., Schmidt R., Sprau P., Roth T., Florcke C. & Amrhein V. (2008). The ecology of vocal signaling: male spacing and communication distance of different song traits in nightingales. *Behavioral Ecology*, 19, 1034-1040.
- Nelson B.S. (2000). Avian dependence on sound pressure level as an auditory distance cue. *Animal Behaviour*, 59, 57-67.
- Nemeth E. & Brumm H. (2010). Birds and Anthropogenic Noise: Are Urban Songs Adaptive? *Am. Nat.*, 176, 465-475.
- Nystrom J., Ekenstedt J., Engstrom J. & Angerbjorn A. (2005). Gyr Falcons, ptarmigan and microtine rodents in northern Sweden. *Ibis*, 147, 587-597.
- Oberweger K. & Goller F. (2001). The metabolic cost of birdsong production. *Journal of Experimental Biology*, 204, 3379-3388.
- Ohms V.R., Snelderwaard P.C., ten Cate C. & Beckers G.J.L. (2010). Vocal Tract Articulation in Zebra Finches. *PLoS ONE*, 5.
- Osmanski M.S. & Dooling R.J. (2009). The effect of altered auditory feedback on control of vocal production in budgerigars (*Melopsittacus undulatus*). *Journal of the Acoustical Society of America*, 126, 911-919.
- Ovenden N.C., Shaffer S.R. & Fernando H.J.S. (2009). Impact of meteorological conditions on noise propagation from freeway corridors. *Journal of the Acoustical Society of America*, 126, 25-35.
- Padgham M. (2004). Reverberation and frequency attenuation in forests--implications for acoustic communication in animals. *J Acoust Soc Am*, 115, 402-10.
- Parks S.E., Johnson M., Nowacek D. & Tyack P.L. (2011). Individual right whales call louder in increased environmental noise. *Biology Letters*, 7, 33-35.
- Parris K.M. & Schneider A. (2009). Impacts of Traffic Noise and Traffic Volume on Birds of Roadside Habitats. *Ecology and Society*, 14.
- Patricelli G.L. & Blickley J.L. (2006). Avian communication in urban noise: Causes and consequences of vocal adjustment. *Auk*, 123, 639-649.
- Peake T.M., Matessi G., McGregor P.K. & Dabelsteen T. (2005). Song type matching, song type switching and eavesdropping in male great tits. *Animal Behaviour*, 69, 1063-1068.
- Penna M., Pottstock H. & Velasquez N. (2005). Effect of natural and synthetic noise on evoked vocal responses in a frog of the temperate austral forest. *Animal Behaviour*, 70, 639-651.
- Pick H.L., Siegel G.M., Fox P.W., Garber S.R. & Kearney J.K. (1989). Inhibiting the lombard effect. *Journal of the Acoustical Society of America*, 85, 894-900.

- Podos J. (2001). Correlated evolution of morphology and vocal signal structure in Darwin's finches. *Nature*, 409, 185-188.
- Podos J., Lahti D.C. & Moseley D.L. (2009). Vocal Performance and Sensorimotor Learning in Songbirds. In: *Advances in the Study of Behavior*, Vol 40 (ed. Naguib M.), pp. 159-195.
- Pohl N.U., Slabbekoorn H., Klump G.M. & Langemann U. (2009). Effects of signal features and environmental noise on signal detection in the great tit, *Parus major*. *Animal Behaviour*, 78, 1293-1300.
- Potash L.M. (1972). Noise-induced changes in calls of the Japanese quail. *Psychonomic Science*, 26, 252-254.
- Potvin D.A., Parris K.M. & Mulder R.A. (2011). Geographically pervasive effects of urban noise on frequency and syllable rate of songs and calls in silvereyes (*Zosterops lateralis*). *Proceedings of the Royal Society B: Biological Sciences*.
- Quinn J.L., Whittingham M.J., Butler S.J. & Cresswell W. (2006). Noise, predation risk compensation and vigilance in the chaffinch *Fringilla coelebs*. *Journal of Avian Biology*, 37, 601-608.
- Rabin L.A. & Greene C.M. (2002). Changes to acoustic communication systems in human-altered environments. *Journal of Comparative Psychology*, 116, 137-141.
- Reijnen R. & Foppen R. (1991). Effect of road traffic on the breeding site tenacity of male willow warblers (*phylloscopus-trochilus*). *Journal Fur Ornithologie*, 132, 291-295.
- Reijnen R. & Foppen R. (1995). The effects of car traffic on breeding bird populations in woodland .4. influence of population-size on the reduction of density close to a highway. *Journal of Applied Ecology*, 32, 481-491.
- Reijnen R. & Foppen R. (2006). Impact of road traffic on breeding bird populations. In: *The Ecology of Transportation: Managing Mobility for the Environment* (eds. Davenport J & Davenport J.L). Springer-Verlag Heidelberg, pp. 255-274.
- Reijnen R., Foppen R., Terbraak C. & Thissen J. (1995). The effects of car traffic on breeding bird populations in woodland .3. reduction of density in relation to the proximity of main roads. *Journal of Applied Ecology*, 32, 187-202.
- Rendell L.E., Matthews J.N., Gill A., Gordon J.C.D. & Macdonald D.W. (1999). Quantitative analysis of tonal calls from five odontocete species, examining interspecific and intraspecific variation. *Journal of Zoology*, 249, 403-410.
- Rheindt F.E. (2003). The impact of roads on birds: Does song frequency play a role in determining susceptibility to noise pollution? *Journal Fur Ornithologie*, 144, 295-306.
- Richards D.G. & Wiley R.H. (1980). Reverberations and Amplitude Fluctuations in the Propagation of Sound in a Forest - Implications for Animal Communication. *Am. Nat.*, 115, 381-399.

- Riebel K. & Slater P.J.B. (1999). Song type switching in the chaffinch, *Fringilla coelebs*: timing or counting? *Animal Behaviour*, 57, 655-661.
- Riebel K. & Slater P.J.B. (2000). Testing the flexibility of song type bout duration in the chaffinch, *Fringilla coelebs*. *Animal Behaviour*, 59, 1135-1142.
- Ripmeester E.A.P., Kok J.S., van Rijssel J.C. & Slabbekoorn H. (2010a). Habitat-related birdsong divergence: a multi-level study on the influence of territory density and ambient noise in European blackbirds. *Behavioral Ecology and Sociobiology*, 64, 409-418.
- Ripmeester E.A.P., Mulder M. & Slabbekoorn H. (2010b). Habitat-dependent acoustic divergence affects playback response in urban and forest populations of the European blackbird. *Behavioral Ecology*, 21, 876-883.
- Rivera-Gutierrez H.F., Pinxten R. & Eens M. (2010). Multiple signals for multiple messages: great tit, *Parus major*, song signals age and survival. *Animal Behaviour*, 80, 451-459.
- Rivera-Gutierrez H.F., Pinxten R. & Eens M. (2011). Songs differing in consistency elicit differential aggressive response in territorial birds. *Biology Letters*, 7, 339-342.
- Ryan M.J. & Brenowitz E.A. (1985). The role of body size, phylogeny, and ambient noise in the evolution of bird song. *The American Naturalist*, 126, 87-100.
- Schaub A., Ostwald J. & Siemers B.M. (2008). Foraging bats avoid noise. *Journal of Experimental Biology*, 211, 3174-3180.
- Seehausen O., vanAlphen J.J.M. & Witte F. (1997). Cichlid fish diversity threatened by eutrophication that curbs sexual selection. *Science*, 277, 1808-1811.
- Slabbekoorn H. (2004). Singing in the wild: the ecology of birdsong. In: *Nature's music: The Science of Birdsong* (eds. Marler P & Slabbekoorn H). Elsevier Academic Press.
- Slabbekoorn H., Bouton N., van Opzeeland I., Coers A., ten Cate C. & Popper A.N. (2010). A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends in Ecology & Evolution*, 25, 419-427.
- Slabbekoorn H. & den Boer-Visser A. (2006). Cities change the songs of birds. *Current Biology*, 16, 2326-2331.
- Slabbekoorn H. & Halfwerk W. (2009). Behavioural Ecology: Noise Annoys at Community Level. *Current Biology*, 19, R693-R695.
- Slabbekoorn H. & Peet M. (2003). Ecology: Birds sing at a higher pitch in urban noise *Nature*, 424, 267-267.
- Slabbekoorn H. & Ripmeester E.A.P. (2008). Birdsong and anthropogenic noise: implications and applications for conservation. *Molecular Ecology*, 17, 72-83.
- Slabbekoorn H. & Smith T.B. (2002a). Bird song, ecology and speciation. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, 357, 493-503.
- Slabbekoorn H. & Smith T.B. (2002b). Habitat-dependent song divergence in the little greenbul: an analysis of environmental selection pressures on acoustic signals. *Evolution* 56, 1849-58.

- Slabbekoorn H., Yeh P. & Hunt K. (2007). Sound transmission and song divergence: A comparison of urban and forest acoustics. *Condor*, 109, 67-78.
- Snow D. W., Perrins C. M., Gillmor R. & Hillcoat B (1998). *The birds of the Western Palearctic (concise edition)*. Oxford University Press, Oxford.
- Smith T.B., Mila B., Grether G.F., Slabbekoorn H., Sepil I., Buermann W., Saatchi S. & Pollinger J.P. (2008). Evolutionary consequences of human disturbance in a rainforest bird species from Central Africa. *Molecular Ecology*, 17, 58-71.
- Spruit, B. 2008. An experimental test of song frequency plasticity in adult great tits. BSc thesis, Leiden University.
- Steele C. (2001). A critical review of some traffic noise prediction models. *Applied Acoustics*, 62, 271-287.
- Stoddard P.K., Beecher M.D. & Willis M.S. (1988). Response of territorial-male song sparrows to song types and variations. *Behavioral Ecology and Sociobiology*, 22, 125-130.
- Stone E. (2000). Separating the noise from the noise: A finding in support of the "Niche Hypothesis," that birds are influenced by human-induced noise in natural habitats. *Anthrozoos*, 13, 225-231.
- Svensson L., Zetterström D. & Mullarney K. (2010). *Birds of Europe (second edition)*. Princeton field guides.
- Swaddle J.P. & Page L.C. (2007). High levels of environmental noise erode pair preferences in zebra finches: implications for noise pollution. *Animal Behaviour*, 74, 363-368.
- Thijssen J.P., (1906). *Het intieme leven der vogels*. Uitgeverij Veen, Amsterdam
- Tinbergen N. (1963). On aims and methods of ethology. *Zeitschrift für Tierpsychologie*, 20, 410-433.
- Tratalos J., Fuller R.A., Evans K.L., Davies R.G., Newson S.E., Greenwood J.J.D. & Gaston K.J. (2007). Bird densities are associated with household densities. *Global Change Biology*, 13, 1685-1695.
- Van Bael S.A. & Brawn J.D. (2005). The direct and indirect effects of insectivory by birds in two contrasting Neotropical forests. *Oecologia*, 143, 106-116.
- van Dijk, L. E. 2010. Frequency-dependent transmission under noisy conditions between neighboring territories of great tits. BSc thesis, Leiden University.
- van der Klugt, I. & Diepeveen, F. 2011. Does fearfulness affect song in male-male and male-female interactions in the great tit? BSc thesis, Leiden University.
- van der Sluijs I., Gray S.M., Amorim M.C.P., Barber I., Candolin U., Hendry A.P., Krahe R., Maan M.E., Utne-Palm A.C., Wagner H.J. & Wong B.B.M. (2011). Communication in troubled waters: responses of fish communication systems to changing environments. *Evol. Ecol.*, 25, 623-640.
- van der Zande A.N., ter Keurs W.J. & van der Weijden W.J. (1980). The impact of roads on the densities of four bird species in an open field habitat--evidence of a long-distance effect. *Biological Conservation*, 18, 299-321.

- Vasconcelos R.O., Amorim M.C.P. & Ladich F. (2007). Effects of ship noise on the detectability of communication signals in the Lusitanian toadfish. *Journal of Experimental Biology*, 210, 2104-2112.
- Verzijden M.N., Ripmeester E.A.P., Ohms V.R., Snelderwaard P. & Slabbekoorn H. (2010). Immediate spectral flexibility in singing chiffchaffs during experimental exposure to highway noise. *Journal of Experimental Biology*, 213, 2575-2581.
- Vignieri, S.N. (2011). Evolution: oh the noise! *Science*, 333, 1360.
- Vitousek P.M., Mooney H.A., Lubchenco J. & Melillo J.M. (1997). Human domination of Earth's ecosystems. *Science*, 277, 494-499.
- Walther G.R., Post E., Convey P., Menzel A., Parmesan C., Beebee T.J.C., Fromentin J.M., Hoegh-Guldberg O. & Bairlein F. (2002). Ecological responses to recent climate change. *Nature*, 416, 389-395.
- Warren P.S., Katti M., Ermann M. & Brazel A. (2006). Urban bioacoustics: it's not just noise. *Animal Behaviour*, 71, 491-502.
- Weary D.M., Krebs J.R., Eddyshaw R., McGregor P.K. & Horn A. (1988). Decline in song output by great tits - exhaustion or motivation. *Animal Behaviour*, 36, 1242-1244.
- Weary D.M., Lambrechts M.M. & Krebs J.R. (1991). Does singing exhaust male great tits. *Animal Behaviour*, 41, 540-542.
- Whittingham M.J., Swetnam R.D., Wilson J.D., Chamberlain D.E. & Freckleton R.P. (2005). Habitat selection by yellowhammers *Emberiza citrinella* on lowland farmland at two spatial scales: implications for conservation management. *Journal of Applied Ecology*, 42, 270-280.
- Wiley R.H. & Richards D.G. (1978). Physical constraints on acoustic communication in atmosphere - implications for evolution of animal vocalizations. *Behavioral Ecology and Sociobiology*, 3, 69-94.
- Wilkin T.A., Garant D., Gosler A.G. & Sheldon B.C. (2006). Density effects on life-history traits in a wild population of the great tit *Parus major*: analyses of long-term data with GIS techniques. *Journal of Animal Ecology*, 75, 604-615.
- Wollerman L. & Wiley R.H. (2002). Background noise from a natural chorus alters female discrimination of male calls in a Neotropical frog. *Animal Behaviour*, 63, 15-22.
- Wood W.E. & Yezerinac S.M. (2006). Song sparrow (*Melospiza melodia*) song varies with urban noise. *Auk*, 123, 650-659.
- Zelick R. & Narins P.M. (1985). characterization of the advertisement call oscillator in the frog *eleutherodactylus-coqui*. *Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology*, 156, 223-229.
- Zollinger S.A., Goller F. & Brumm H. (2011). Metabolic and Respiratory Costs of Increasing Song Amplitude in Zebra Finches. *PLoS ONE*, 6.

Acknowledgements

The work covered in this thesis would not have been possible without the help and support of many people, to whom I am greatly indebted.

I have experienced all the support I needed from my family and friends: Assia, Hidde, Bert, Carla, Maarten, Koen, Lotte, Klaas, Jeanne, Peter, Joost, Gerard, Henk, Marten, Vivian, Sander, Janne, Bas, Christiaan, Lucia, Ulrich, Daan, Jojanneke, Jeroen, Frank, Eva, Joost, Martijn, Roald, Erik & Lude thanks!

This thesis would not exist without the supervision of Carel ten Cate and in particular Hans Slabbekoorn, from whom I learned most of the things that were necessary to carry out the research and to write down the results. Additionally, I enjoyed almost every day of the past 7 years that I spend at the Leiden behavioural biology group. Katharina, Peter, Hennie, Ardie, Machteld, Marie, Paula, Erwin, Sita, Caroline, Verena, Jelle, Nicole, Rob, Tudor, Sander, Aukje, Niels, Jiani, Xiao-Jing, Marine, Errol, Konstantinos, Sabine, Simeon, Bram, Peter-Paul, Padu, Hector, Carel & Hans, thanks!

I had the pleasure to supervise several bachelor and master students and I am grateful for all the work they carried out for me in the field as well as in the lab. Ben, Sander, Jasper, Lars, Iris & Flemming thanks!

Several people/institutions contributed to the work by facilitating field sites or equipment, among which, Lenze Hofstee, Jan Komdeur, Staatsbosbeheer, Natuurmonumenten and in particular Christiaan Both, who allowed me to work at his field sites, for which I am very grateful.

I had support from abroad by people who helped to shape this thesis through scientific discussion, reviewing of manuscripts, or who helped me out with grant applications. Caroline Dingle, Tom & Mariella, Jacintha Ellers, Jeff Podos, Henrik Brumm, Nathalie Seddon, Joe Tobias, Kate Lessells, Hansjoerg Kunc, Clinton Francis, Sue-Ann Zollinger, Mike Ryan, Ryan Taylor & Rachel Page Cheers! I also like to thank all referees, colleagues and members of the reading committee for their effort and fruitful comments on any of my manuscripts.

Curriculum vitae

- 1980 Born in Kampen, the Netherlands
- 1994 – 1999 Vrije school, Zutphen, the Netherlands
- 2000 – 2003 BSc Biology/ philosophy, Nijmegen University, the Netherlands
- 2003 – 2006 MSc Biology, Utrecht University, the Netherlands
- MSc project studying binocular rivalry during biological motion perception to understand organization of human vision supervised by dr J. A. Beintema and prof. dr R.J.A. van Wezel
- MSc project studying the relationship between geographic variation in song and environmental selection pressures, supervised by dr H.W. Slabbekoorn (Leiden University) and dr C. Dingle (Cambridge University).
- 2006 – 2007 Research project Ecuador, Leiden/ Cambridge University, UK
- 2007 – 2012 PhD research, Behavioural Biology, IBL, Leiden University
- Project title: Acoustic communication in a noisy world
- Supervisors: dr Hans Slabbekoorn and prof. dr Carel ten Cate
- During my PhD research I supervised several BSc and MSc students both in the field and in the lab and assisted several courses on animal behaviour and communication. I presented my work at several national (NVG '07/'08/'10/'11) and international scientific meetings (IEC '09, ISBE '10, IEC/ABS '11). I was invited to present my work during several seminars for professionals as well as amateurs. Furthermore, I participated in a documentary on the perception of noise and I gave several interviews for national and international media.
- 2012 – 2014 Post-doc project, Smithsonian Tropical Research Institute, PA

Publications

1. **Halfwerk, W.** Bot, S. Buikx, J.van der Velde, M. Komdeur, J. ten Cate, C. & Slabbekoorn, H. reply to Eens et al: urban noise can alter sexual selection on bird song. PNAS, *In press*.
2. Slabbekoorn, H. **Halfwerk, W.** & Yang, X. Birds and anthropogenic noise: singing higher may matter. American Naturalist. *In press*.
3. **Halfwerk, W.** Bot, S. Buikx, J.van der Velde, M. Komdeur, J. ten Cate, C. & Slabbekoorn, H. Low-frequency songs lose their potency in noisy urban conditions. PNAS, 2011.
4. **Halfwerk, W.** Holleman, L. Lessells, K. & Slabbekoorn, H. Negative impact of traffic noise on avian reproductive success. Journal of Applied Ecology, 2011.
5. Tobias, J.A. , Aben, J., Brumfield, R.T., Derryberry E.P., **Halfwerk, W.**, Slabbekoorn, H. & Seddon N. 2010. Song divergence by sensory drive in Amazonian birds. Evolution, 2010.
6. Dingle, C. Poelstra, J.W. **Halfwerk, W.** Brinkhuizen, D.M. & Slabbekoorn, H. Asymmetric response patterns to subspecies-specific song differences in allopatry and parapatry in the gray-breasted wood-wren. Evolution, 2010.
7. **Halfwerk, W.** & Slabbekoorn, H. A behavioural mechanism explaining noise-dependent pitch shift in urban birdsong. Animal Behaviour, 2009.
8. Slabbekoorn, H. & **Halfwerk, W.** Behavioural Ecology: Noise annoys at community level. Current Biology, 2009.
9. Dingle, C. **Halfwerk, W.** & Slabbekoorn, H. Habitat-dependent song divergence at subspecies level in the grey-breasted wood-wren. Journal of Evolutionary Biology, 2008.
10. Beintema, J.A. **Halfwerk, W.** & van Wezel, R.J.A. Less rivalry with more biological motion. Journal of Vision, 2004.
- **Halfwerk, W.** Bot, S. & Slabbekoorn, H. Female control over noise-dependent song perch adjustment. *In review*
- **Halfwerk, W.** Both, C. & Slabbekoorn, H. Anthropogenic noise alters heterospecific competition over nest sites. *In review*
- **Halfwerk, W.** Dingle, C. Brinkhuizen, D.M. Poelstra, J.W. Komdeur, J. & Slabbekoorn, H. Cultural and genetic transmission under avian contact. *In prep.*

