Genetic diversity in the lion (panthera leo (Linnaeus 1758)) : unravelling the past and prospects for the future

Bertola, L.D.

Acknowledgements

Many people have played vital roles during my time as a PhD researcher, but even more have contributed to the path that has led to this point. I would like to start with thanking my two copromotores and supervisors, Hans de Iongh and Klaas Vrieling, for providing me the opportunity to work on this topic, first as a student, later as a PhD researcher. Thanks to your input and faith in the proposal it was possible to obtain funding for a PhD project. Due to your different backgrounds and the somewhat twofold character of the project, I was able to get “the best of both worlds”. Hans, thanks to your extensive network, we were able to set up numerous collaborations and obtain samples from a great part of the lion’s range. I am grateful for your guidance and the opportunity to become a part of this network. Klaas, I value our discussions and your critical questions, which have improved this work greatly. During the course of this project I have gained many new insights, thanks to your expertise. I’m thankful for the input from my promotor, Geert de Snoo. Despite busy schedules there was always time for challenging questions and discussions on how to proceed. I would like to thank my supervisors for their guidance and inspiration during the past years.

Many teachers who I have met when I started studying in Leiden (or even before) have played a role in preparing me for a scientific career. I am happy that many of these connections are still intact. Ruben, you have played an essential role in this when asking me to write an essay about “something that matters”. This proved to be the first step towards working on lion genetics. Although I hadn’t mentioned the lion anywhere in the paper (it just dealt with the use of genetic data to make recommendations for conservation strategies), I’m glad I ended up in Hans’ office and got the chance to work on a true flagship species. In this way, some of the people mentioned above became my colleagues and I’ve continued learning during discussions at the coffee table, both at the CML and the IBL. Collaborations with other institutes, such as NCB Naturalis and the LUMC, have created even more opportunities to benefit from different expertise.

I am very grateful for the opportunities that were given to me to visit conferences, workshops and courses. Visiting several African countries has contributed a great deal to my understanding of the challenges and opportunities in the field of conservation. Also trips outside the lion´s geographical range were sources of inspiration. An African proverb says “Traveling is learning” and I like to keep this in mind on my trips. A great charm of my working environment is the international character which provides the opportunity to gain a more in depth knowledge from different cultural perspectives. I learned much from my African fellow lion researchers, Etotepe, Pricelia and Tuqa, who have surely added new points of view for me to the topic of lion conservation. I have also learned a lot from the members of the African Lion Working Group, and I enjoyed meeting and traveling with some of them. Colleagues who we have directly collaborated with, some of them included as a coauthor on the chapters in this thesis, have been very helpful with their contributions and insights. Some preliminary work and part of the data presented in this thesis are the result of internships of three BSc. students and three MSc. students: Hermen, Lana, Mike, Hester, Laura and Ljamis. It was very instructive for me to supervise you during these projects and I hope that you look back on it as an

interesting and useful experience, even though it was not always easy to obtain the results we were expecting.

Thanks to my fellow PhD researchers who became my friends, working days were never dull. I enjoyed the concerts and events we visited together, the writing weekends, the after work beers, the movie nights and the rather random email messages that would occasionally clutter the mailbox. Although we regularly discussed scientific topics, I especially valued the discussions with Krijn, often leading to more questions than answers. I'm happy that we can continue our discussions in the view of the new project which will hopefully have a fruitful future.

In this place I would also like to express my gratitude to all people who have supported me in the past years. Tim, thanks for your friendship; I doubt that our emails will make much sense to others, who don´t share our fascination for "weird" creatures. Jasper, if we don't see each other in Delft or Madrid, we should simply pick a new destination to meet up. I'm happy that we succeeded in traveling a small part of Africa together (as had been the plan for many years), but there is more exploring to do and endemic species to score. Amar, it is time to catch up again and, after all, the other end of the globe is not that far away. In addition, I would like to thank Jasper and Coen for being my paranymphs.

I would like to finish by thanking my family and especially my parents. Both coming from a scientific background, they understood the path I was taking and were of great support. Dinner table conversation often turned into scientific discussions, and more than once additional research questions were proposed. I'm very grateful for your support.


Cameroon - Bénoué NP

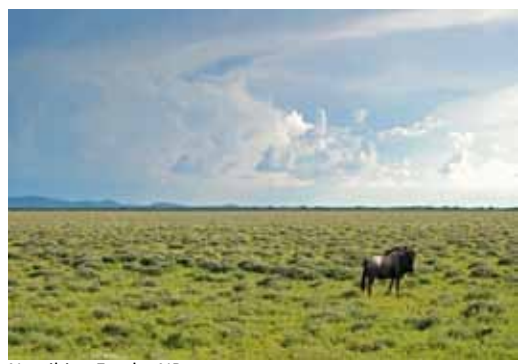

Kenya - Amboseli NP

Curriculum Vitae

Laura Bertola was born on the 30th of August 1984 in Delft. In 2002 she obtained her VWO diploma from the St. Stanislascollege in Delft. In the same year she started studying biology at Leiden University. After internships at the Ministery of Transport, Public Works and Water Management and different institutes in Leiden, she decided that she would like to combine theoretic research with direct applicability. Her Msc. project, supervised by Dr. Klaas Vrieling and Prof. dr. Hans de Iongh, was dealing with the genetics of the West and Central African lion, and served as a pilot for the study presented in this thesis. After earning a MSc. degree in 2008, it was decided to write a proposal for The Netherlands Organisation for Scientific Research (NWO) to obtain funding for a follow-up project on the genetic diversity of the lion. Funding was received in 2010 and the PhD project was started shortly after.

The PhD project was a collaboration between the Institute of Environmental Sciences (CML) and the Institute of Biology Leiden (IBL) of Leiden University, represented by co-promotores Prof. Dr. Hans de Iongh and Dr. Klaas Vrieling, and promotor Prof. Dr. Geert de Snoo. During the course of her PhD, Laura was enabled to visit multiple conferences and workshops abroad and became an active member of the African Lion Working Group (ALWG). She also supervised several students, assisted during courses and gave lectures for Bsc. and MSc. students. In addition, she followed several courses and obtained a diploma of the Netherlands Research School for the Socio-Economic and Natural Sciences of the Environment (SENSE).

Since 2014 Laura has a position as a researcher at the CML, working on environmental DNA. In this project the applicability of DNA isolated directly from aquatic samples is assessed for water quality monitoring.


Namibia - Etosha NP


Senegal - Niokolo Koba NP

Publications

In prep.

Bertola L.D, Vermaat M., White P.A., De Iongh H.H., Laros J. and Vrieling K. SNP discovery and phylogenetic analyses across ten populations of lions reveals a more complex evolutionary history.

Bertola L.D., Vrieling K. & De Iongh H.H. Phylogenetic structure of lions across their geographic range based on a SNP panel.

Submitted

Bertola L.D., Jongbloed H., Van der Gaag K.J., De Knijff P., Yamaguchi N., Hooghiemstra H., Bauer H., Henschel P., White P.A., Driscoll C.A., Tende T., Ottosson U., Saidu Y., Vrieling K. & De Iongh H.H. Phylogeographic patterns in Africa and high resolution delineation of genetic clades in the African lion.

Bertola L.D., Tensen L., Van Hooft P., White P.A., Driscoll C.A,, Henschel P., Caragiulo A., Dias-Freedman I., Sogbohossou E.A., Tumenta P.N., Jirmo T.H., De Snoo G.R, De Iongh H.H. & Vrieling K. Autosomal and mtDNA markers reveal concordant phylogenetic patterns of lion populations over the entire geographic range.

Published

Cho Y.S., Hu L., Hou H., Lee H., Xu J., Kwon S., Oh S., Kim H., Jho S., Kim S., Shin Y., Kim B.C., Kim H., Kim C., Turner J.A., Luo S., Johnson W.E., Koepfli K., Schmidt-ku A., Marker L., Harper C., Miller S.M., Jacobs W., Bertola L.D., Kim T.H., Lee S., Zhou Q., Jung H., Xu X., Gadhvi P., Xu P., Xiong Y., Luo Y., Pan S., Gou C., Chu X., Zhang J., Liu S., He J., Chen Y., Yang L., Yang Y., He J., Liu S., Wang J., Kim C.H., Kwak H., & Kim J. (2013) The tiger genome and comparative analysis with lion and snow leopard genomes. *Nature communications*, **4**, 2433.

Bertola L.D., Vrieling K. & De Iongh H.H. (2012) Conservation Genetics of the Lion: New Approaches to Species Conservation. In: Genetic Diversity: New Research. Cervantes Amaya J.A., Franco Jimenez M.M. (Eds.). Hauppage NY: Nova Science Publishers, Inc.. 61-82.

Bertola L.D., Vrieling K. & De Iongh H.H. (2011) Conservation Genetics of the African Lion. *Waza news*, **3**, 2–4.

Bertola L.D., van Hooft W.F., Vrieling K., Uit de Weerd D.R., York D.S., Bauer H., Prins H.H.T., Funston P.J., Udo de Haes H. a., Leirs H., van Haeringen W. a., Sogbohossou E., Tumenta P.N., & De Iongh H.H. (2011) Genetic diversity, evolutionary history and implications for conservation of the lion (Panthera leo) in West and Central Africa. *Journal of Biogeography*, **38**, 1356–1367.

Bertola L.D., Schoonheere E., Wilms I., Kabli S., Alia A., De Groot H.J.M. & Bagowski C.P. (2011) Effects of hypoxia on buoyancy control and the development of lordosis in physostomous and physoclistous fish species. *Research & Reviews in Biosciences.***5**(1).

Bertola L.D., Griepsma S., Vonk F.J. & Bagowski C.P. (2008) Developmental expression of the alpha-skeletal actin gene. *BMC Evolutionary Biology*, **8**(1): 166-166.

Abstracts for workshops & conferences

Bertola L.D., Vrieling K. & De Iongh H.H. (2015) Insights into the distribution of genetic diversity in the lion and implications for conservation. 1st Annual Meeting in Conservation Genetics – Science and Practice (Birmensdorf – Switserland).

Bertola L.D., Vrieling K. & De Iongh H.H. (2015) Phylogeographic patterns in Africa and high resolution delineation of genetic clades in the African lion. International Biogeography Society – 7th Biennial Conference (Bayreuth – Germany).

Bertola L.D., Vrieling K. & De Iongh H.H. (2013) Importance de la génétique pour la conservation du lion. L'atelier d'élaboration du Plan d'Action National sur la conservation du lion et du Iycaon au Sénégal (Dalaba – Senegal).

Bertola L.D., Vrieling K. & De Iongh H.H. (2012) Genetic methods for Lion Conservation. Felid Taxon Advisory Group (EAZA) (Amersfoort – The Netherlands).

Bertola L.D., Vrieling K. & De Iongh H.H. (2012) Genetics for lion conservation. Lion Range State meeting (Johannesburg – Republic of South Africa).

Bertola L.D., Vrieling K. & De Iongh H.H. (2012) Lion genetics: applications for conservation. African Lion Working Group meeting (Okaukuejo – Namibia).

Bertola L.D., Vrieling K. & De Iongh H.H. (2011) The Importance of Biogeographic Data for Lion Conservation. IUCN Conservation Breeding Specialist Group Annual meeting (Prague – Czech Republic).

Bertola L.D., Vrieling K. & De Iongh H.H. (2011) Use of genetic markers to unravel the phylogenetic position of the lion in West and Central Africa. 8th International Conference on Behaviour, physiology and genetics of wildlife (Berlin – Germany).

Bertola L.D., Vrieling K. & De Iongh H.H. (2011) The use of genetics for lion conservation. Nederland Annual Ecology Meeting (NAEM) (Lunteren – The Netherlands).

Bertola L.D., Vrieling K. & De Iongh H.H. (2010) Genetic diversity and phylogenetics of the lion in West and Central Africa. Carnivore Workshop (Maroua – Cameroon).

Bertola L.D., Vrieling K. & De Iongh H.H. (2010) Genetic diversity, evolutionary history and implications for conservation of the lion (Panthera leo) in West and Central Africa. Carnivore Researchers Meeting (Nairobi – Kenya).

Courses

Systems Biology: Statistical analysis of ~omics data (2010) (Wageningen University + LUMC + NBIC)

Next Generation Sequencing data analysis (2011) (LUMC + NBIC)

LU PhD course Time Management (2012) (Leiden University)

LU PhD course Communication in Science (2012) (Leiden University)

Using R in data analysis (2012) (Leiden University + LUMC)

Advanced NGS: de novo assembly (2013) (Wageningen University)

LU PhD course Effective Communication (2013) (Leiden University)

LU PhD course Scientific Integrity (2013) (Leiden University)

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(SENSE) declares that

Laura Diana Bertola

born on 30 August 1984 in Delft, The Netherlands

has successfully fulfilled all requirements of the
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Leiden, 18 March 2015

the Chairman of the SENSE board — Prof. dr. Huub Rijnaarts

the SENSE Director of Education — Dr. Ad van Dommelen

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AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that Ms Laura Bertola has successfully fulfilled all requirements of the Educational PhD Programme of SENSE with a work load of 47.8 EC, including the following activities:

SENSE PhD Courses

- Environmental Research in Context (2012)
- Research in Context Activity: Organisation of event 'Tiger conservation in Nepal', including discussion meetings and lectures, Kathmandu University, Nepal (2012-2014)

Other PhD and Advanced MSc Courses

- Systems Biology: Statistical analysis of ~omics data, Wageningen University (2010)
- Next Generation Sequencing data analysis, Netherlands Bioinformatics Centre (NBIC) and Leiden University Medical Center (LUMC) (2011)
- Time Management, Leiden University (2011)
- Communication in Science, Leiden University (2012)
- Using R in data analysis, Leiden University Medical Center (LUMC) and Leiden University (2012)
- Advanced Next Generation Sequencing: de novo assembly, Netherlands Bioinformatics Centre (NBIC), Wageningen University and Leiden University (2013)
- Effective Communication, Leiden University (2013)
- Scientific Integrity, Leiden University (2013)

Management and Didactic Skills Training

- Supervising three MSc and three BSc students (2010-2014)
- Teaching in BSc courses 'Moleculair biological techniques', 'Environmental biology theory' (2010-2012)
- Teaching in MSc courses 'Trends in conservation biology', 'Environmental processes and biodiversity' and 'Trends in behaviour and ecology' (2010-2014)
- Member of Institute of Environmental Sciences (CML) council (2011-2014)

Selection of Oral Presentations

- *The use of genetics for lion conservation*. Nederland Annual Ecology Meeting (NEAM), 8-9 February 2011, Lunteren, The Netherlands
- *Use of genetic markers to unravel the phylogenetic position of the lion in West and Central Africa*. 8th International Conference on Behaviour, physiology and genetics of wildlife, 14-19 September 2011, Berlin, Germany
- *The Importance of Biogeographic Data for Lion Conservation*. IUCN Conservation Breeding Specialist Group Annual meeting, 29 September-1 October 2011, Prague, Czech Republic
- *Genetics for lion conservation*. Lion Range State meeting, 29-30 March 2012, Johannesburg, South Africa

SENSE Coordinator PhD Education

Dr. ing. Monique Gulickx