Ecography

ECOG-05170
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Supplementary material

Appendix 1.

Table A1. Databases and search criteria of systematic search on May 19th, 2020. Titles and abstracts were screened for relevance of physiological data on each species' response to hypoxia or high elevations.

Data base	Biosis Citation Index, Zoological Record, Medline
Terms included in Boolean search	TS = (("bar-headed goose" OR "anser indicus") And ("high-altitude" OR "hypox*" OR "high elevation")) TS = (("canada goose" OR "branta canadensis") And ("high-altitude" OR "hypox*" OR "high elevation")) TS = (("evening grosbeak" OR "Coccothraustes vespertinus") And ("high-altitude" OR "hypox*" OR "high elevation")) - 0
Selection Criteria	1. Must be a published article. No meeting abstracts or presentations. 2. Must include the species in question as one of the primary species being reported on. Reporting on another species and simple comparisons (e.g. hemoglobin structure of a species not of interest compared to species of interest) do not meet the requirements. 3. Be associated with high elevation/altitude or hypoxia research.

Bar-headed Goose (*Anser indicus*) Systematic Search Results:

Bakkeren, C. et al. 2020. A morphometric analysis of the lungs of high-altitude ducks and geese. - J Anat in press.

Bishop, C. M. et al. 2015. The roller coaster flight strategy of bar-headed geese conserves energy during Himalayan migrations. - Sci New York N Y 347: 250–4.

Black, C. P. and Tenney, S. M. 1980a. Oxygen transport during progressive hypoxia in high-altitude and sea-level waterfowl. - Resp Physiol 39: 217–239.

Black, C. P. and Tenney, S. M. 1980b. Pulmonary hemodynamic responses to acute and chronic hypoxia in two waterfowl species. - Comp Biochem Physiology Part Physiology 67: 291–293.

Black, C. P. et al. 1978. Oxygen transport during progressive hypoxia in bar-headed geese (*Anser indicus*) acclimatized to sea level and 5600 meters. *Respiratory function in birds, adult and embryonic.* -Springer, Berlin, Heidelberg: 79–83.

Butler, P. J. 2010. High fliers: The physiology of bar-headed geese. - Comp Biochem Physiology Part Mol Integr Physiology 156: 325–329.

Butler, P. J. 2016. The physiological basis of bird flight. - Philosophical Transactions Royal Soc Lond Ser B Biological Sci 371: 20150384.

Faraci, F. M. and Fedde, M. R. 1986. Regional circulatory responses to hypocapnia and hypercapnia in bar-headed geese. - Am J Physiology-regulatory Integr Comp Physiology 250: R499–R504.

Faraci, F. M. et al. 1984a. Attenuated pulmonary pressor response to hypoxia in bar-headed geese. - Am J Physiology-regulatory Integr Comp Physiology 247: R402–R403.

Faraci, F. M. et al. 1984b. Oxygen delivery to the heart and brain during hypoxia: Pekin duck vs. bar-headed goose. - Am J Physiology-regulatory Integr Comp Physiology 247: R69–R75.

Faraci, F. M. et al. 1985. Blood flow distribution during hypocapnic hypoxia in pekin ducks and bar-headed geese. - Resp Physiol 61: 21–30.

Fedde, M. R. 1987. Wonders of the bar-headed goose. Vigorous exercise in a low-oxygen environment. - Explorer 29: 31–34.

Fedde, M. 1990. High-Altitude Bird Flight: Exercise in a Hostile Environment. - Physiology 5: 191–193.

Fedde, M. R. et al. 1989. Cardiopulmonary function in exercising bar-headed geese during normoxia and hypoxia. - Resp Physiol 77: 239–252.

Harter, T. S. et al. 2015. Validation of the i-STAT and HemoCue systems for the analysis of blood parameters in the bar-headed goose, *Anser indicus*. - Conserv Physiol 3: cov021.

Hawkes, L. A. et al. 2011. The trans-Himalayan flights of bar-headed geese (*Anser indicus*). - Proc National Acad Sci 108: 9516–9519.

Hawkes, L. A. et al. 2012. The paradox of extreme high-altitude migration in bar-headed geese *Anser indicus*. - Proc Biological Sci Royal Soc 280: 20122114.

Hawkes, L. A. et al. 2014. Maximum Running Speed of Captive Bar-Headed Geese Is Unaffected by Severe Hypoxia. - Plos One 9: e94015.

Hawkes, L. A. et al. 2017. Do Bar-Headed Geese Train for High Altitude Flights? - Integr Comp Biol 57: 240–251.

Hiebl, I. and Braunitzer, G. 1988. Adaption of the hemoglobins of Bar-headed goose (*Anser indicus*), Andean goose (*Chloephaga melanoptera*) and Ruppells griffon (*Gyps rueppellii*) to life under hypoxic conditions. - Journal Fur Ornithologie 2: 217–226.

Hiebl, I. et al. 1986. High-altitude respiration of birds. The primary structures of the alpha D-chains of the Bar-headed Goose (*Anser indicus*), the Greylag Goose(*Anser anser*) and the Canada Goose (*Branta canadensis*). - Biol Chem H-s 367: 591–9.

Jendroszek, A. et al. 2018. Allosteric mechanisms underlying the adaptive increase in hemoglobin-oxygen affinity of the bar-headed goose. - J Exp Biology 221: jeb185470.

Knight, K. 2016. High-altitude bar-headed geese outperform Vancouver cousins. - J Exp Biology 219: 1933.2-1934.

Kumar, S. et al. 2010. A brief note on bar-headed geese fitted with satellite transmitters. - Telemetry in Wildlife Science, ENVIS Bulletin: 131–134.

Laguë, S. L. 2017. High-altitude champions: birds that live and migrate at altitude. - J Appl Physiol 123: 942–950.

Lague, S. L. et al. 2016. Altitude matters: differences in cardiovascular and respiratory responses to hypoxia in bar-headed geese reared at high and low altitudes. - J Exp Biology 219: 1974–84.

Lague, S. L. et al. 2017. Divergent respiratory and cardiovascular responses to hypoxia in bar-headed geese and Andean birds. - J Exp Biology 220: 4186–4194.

Lee, S. Y. et al. 2008. Have wing morphology or flight kinematics evolved for extreme high altitude migration in the bar-headed goose? - Comp Biochem Physiology Toxicol Pharmacol Cbp 148: 324–31.

Liang, Y. et al. 2001. The crystal structure of bar-headed goose hemoglobin in deoxy form: the allosteric mechanism of a hemoglobin species with high oxygen affinity. - J Mol Biol 313: 123–37.

Liu, X.-Z. et al. 2001. Avian haemoglobins and structural basis of high affinity for oxygen: structure of bar-headed goose aquomet haemoglobin. - Acta Crystallogr Sect D Biological Crystallogr 57: 775–783.

Llanos, A. J. et al. 2011. Counterpoint: high altitude is not for the birds! - J Appl Physiology Bethesda Md 1985 111: 1515–8.

McCracken, K. G. et al. 2010. Phylogenetic and structural analysis of the HbA (alphaA/betaA) and HbD (alphaD/betaA) hemoglobin genes in two high-altitude waterfowl from the Himalayas and the Andes: Bar-headed goose (*Anser indicus*) and Andean goose (*Chloephaga melanoptera*). - Mol Phylogenet Evol 56: 649–58.

Meir, J. U. and Milsom, W. K. 2013. High thermal sensitivity of blood enhances oxygen delivery in the high-flying bar-headed goose. - J Exp Biol 216: 2172–2175.

Meir, J. et al. 2019. Reduced metabolism supports hypoxic flight in the high-flying bar-headed goose (*Anser indicus*). - eLife in press.

Milsom, W. K. 2011. Cardiorespiratory support of avian flight. - J Exp Biol 214: 4071–4072.

Milsom, W. K. 2017. Different solutions to restoring oxygen delivery at altitude. - Acta Physiol 222: e12926.

Mu, C.-Y. et al. 2016. The complete mitochondrial genome of *Anser indicus* (Aves, Anseriformes, Anatidae). - Mitochondrial Dna Part 27: 4588–4589.

Natarajan, C. et al. 2018. Molecular basis of hemoglobin adaptation in the high-flying bar-headed goose. - Plos Genet 14: e1007331.

Nice, P. V. et al. 1980. A comparative study of ventilatory responses to hypoxia with reference to hemoglobin o2-affinity in llama, cat, rat, duck and goose. - Comp Biochem Physiology Part Physiology 66: 347–350.

Parr, N. et al. 2019. Tackling the Tibetan Plateau in a down suit: insights into thermoregulation by bar-headed geese during migration. - J Exp Biology 222: jeb203695.
Petschow, D. et al. 1977. Causes of high blood O2 affinity of animals living at high altitude. - J Appl Physiol 42: 139–143.
Prins, H. and Namgail, T. 2017. Bird migration across the Himalayas: wetland functioning amidst mountains and glaciers.
Saunders, D. K. and Fedde, M. R. 1991. Physical conditioning: Effect on the myoglobin concentration in skeletal and cardiac muscle of bar-headed geese. - Comp Biochem Physiology Part Physiology 100: 349–352.
Scott, G. R. and Milsom, W. K. 2007. Control of breathing and adaptation to high altitude in the bar-headed goose. - Am J Physiology-regulatory Integr Comp Physiology 293: R379–R391.
Scott, G. R. et al. 2008. Body temperature depression and peripheral heat loss accompany the metabolic and ventilatory responses to hypoxia in low and high altitude birds. - J Exp Biol 211: 1326–1335.
Scott, G. R. et al. 2009a. Control of respiration in flight muscle from the high-altitude bar-headed goose and low-altitude birds. - Am J Physiology-regulatory Integr Comp Physiology 297: R1066–R1074.
Scott, G. R. et al. 2009b. Evolution of muscle phenotype for extreme high altitude flight in the bar-headed goose. - Proc Royal Soc B Biological Sci 276: rspb20090947 3653.
Scott, G. R. et al. 2011a. Molecular evolution of cytochrome C oxidase underlies high-altitude adaptation in the bar-headed goose. - Mol Biol Evol 28: 351 363.
Scott, G. R. et al. 2011b. Point: high altitude is for the birds! - J Appl Physiology Bethesda Md 1985 111: 1514–5.
Scott, G. R. et al. 2015. How Bar-Headed Geese Fly Over the Himalayas. - Physiology 30: 107–115.
Snyder, G. K. et al. 1982. Development and Metabolism during Hypoxia in Embryos of High Altitude *Anser indicus* versus Sea Level *Branta canadensis* Geese. - Physiol Zool 55: 113–123.
Snyder, G. K. et al. 1984. Effects of hypoxia on tissue capillarity in geese. - Resp Physiol 58: 151–160.
Spivey, R. J. and Bishop, C. M. 2014. An implantable instrument for studying the long-term flight biology of migratory birds. - Rev Sci Instruments 85: 014301.
Storz, J. F. et al. 2010. Phenotypic plasticity and genetic adaptation to high-altitude hypoxia in vertebrates. - J Exp Biology 213: 4125 4136.
Sunnucks, P. et al. 2017. Integrative Approaches for Studying Mitochondrial and Nuclear Genome Co-evolution in Oxidative Phosphorylation. - Frontiers Genetics 8: 25.
Wang, H.-C. et al. 2000. Crystallization and preliminary crystallographic studies of bar-headed goose fluoromethaemoglobin with inositol hexaphosphate. - Acta Crystallogr Sect D Biological Crystallogr 56: 1183–1184.
Wang, W. et al. 2020. First de novo whole genome sequencing and assembly of the bar-headed goose. - Peerj 8: e8914.
Weber, R. E. 2007. High-altitude adaptations in vertebrate hemoglobins. - Resp Physiol Neurobi 158: 132–142.
Winslow, R. M. 2007. The role of hemoglobin oxygen affinity in oxygen transport at high altitude. - Resp Physiol Neurobi 158: 121–127.

York, J. M. et al. 2017. Respiratory mechanics and morphology of Tibetan and Andean high-altitude geese with divergent life histories. - J Exp Biology 221: jeb170738.
Zhang, J. et al. 1996. The Crystal Structure of a High Oxygen Affinity Species of Haemoglobin (Bar-headed Goose Haemoglobin in the Oxy Form). - J Mol Biol 255: 484–493.
Zhao, J. et al. 2013. Influence of HbCO Structure of the Bar-Headed Goose on Photolysis Thermodynamics as Studied by the Nanosecond Laser-Ultrasonic Technique. - Biosci Biotechnology Biochem 77: 1251–1257.

Canada Goose (*Branta canadensis*) Systematic Search Results:

Evans, B. and Jones, D. 1996. Physiological mechanisms for underwater endurance: Canada goose (*Branta canadensis*) versus Pekin duck (*Anas platyrhynchos*). - Journal of Comparative Physiology 166: 46–54.

Funk, G. et al. 1989. Effects of changes in locomotor intensity, hypoxia and hypercapnia on locomotor respiratory synchrony during walking running in Canada geese. 147: 343–360.

Scott, G. R. and Milsom, W. K. 2006. Flying high: A theoretical analysis of the factors limiting exercise performance in birds at altitude. - Resp Physiol Neurobi 154: 284–301.

Snyder, G. K. et al. 1982. Development and Metabolism during Hypoxia in Embryos of High Altitude *Anser indicus* versus Sea Level *Branta canadensis* Geese. - Physiol Zool 55: 113–123.

Snyder, G. K. et al. 1984. Effects of hypoxia on tissue capillarity in geese. - Resp Physiol 58: 151–160.

Table A2. Representative of each aquatic order in Fig. 3, as well as the year, author, and title of the publication.

Hypoxia Regime	Order	Species	Citation
Rare-Weak	Salmoniformes	*Oncorhynchus mykiss*	(Mandic and Regan 2018)
Rare-Strong	Scorpaeniformes	*Oligocottus maculosus*	(Mandic and Regan 2018)
-	Orectolobiformes	*Hemischyllium ocellatum*	(Mandic and Regan 2018)
-	Perciformes	*Bellapiscis medius*	(Mandic and Regan 2018)
Common-Weak	Lophogastrida	*Gnathophausia ingens*	(Mandic and Regan 2018)
-	Gasterosteiformes	*Gasterosteus aculeatus*	(Mandic and Regan 2018)
-	Osmeriformes	*Bajacalifornia burragei*	(Torres et al. 1978)
-	Myctophiformes	*Parvilux ingens*	(Torres et al. 1978)
Common-Strong	Cypriniformes	*Carassius carassius*	(Mandic and Regan 2018)
-	Perciformes	*Lepomis gibbosus*	(Mandic and Regan 2018)
-	Scorpaeniformes	*Sebastolobus alascanus*	(Mandic and Regan 2018)

Mandic, M. and Regan, M. D. 2018. Can variation among hypoxic environments explain why different fish species use different hypoxic survival strategies? - J Exp Biol 221: jeb161349.

Torres, J. J. et al. 1978. Oxygen consumption rates of midwater fishes as a function of depth of occurrence. - Deep Sea Res Part Oceanogr Res Pap 26: 185–197.