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## Phenotypic responses to lifelong hypoxia in cichlids

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## REFERENCES

- Almeida-Val, V.M.F., Farias, I.P., Silva, M.N.P., Duncan, W.P., and Val, A.L. (1995) Biochemical adjustments to hypoxia by Amazon cichlids. *Brazilian Journal of Medical and Biological Research*, 28:1257-1263.
- Almeida-Val, V.M.F., Val, A.L., and Hochachka, P.W. (1993) Hypoxia tolerance in Amazon fishes: Status of an under-explored biological "goldmine". In: *Surviving hypoxia: Mechanisms of control and adaptation*. P.W.Hochachka, P.L.Lutz, T.Sick, M.Rosental, and G.Van den Thillart, eds. CRC press, pp. 435-445.
- Almeida-Val, V.M.F., Val, A.L., and Walker, I. (1999) Long- and short-term adaptation of Amazon fishes to varying O<sub>2</sub> levels: intra-specific phenotypic plasticity and interspecific variation. In: *Biology of tropical fishes*. A.L.Val, and V.M.F.Almeida-Val, eds. INPA, Manaus, pp. 185-206.
- Arunga, J.O. (1981) A case study of the Lake Victoria Nile perch *Lates niloticus* (Mbuta) fishery. *Nat.Ac.Adv.Arts Sci.*, 165-184.
- Babiker, M.M. (1985) The role of organophosphates in adaptation of an obligate water-breathing teleost (*Tilapia nilotica* L.) to hypoxia. *Hydrobiologia*, 121:59-64.
- Ballintijn, C.M. (1969) Movement pattern and efficiency of the respiratory pump of the carp (*Cyprinus carpio* L.). *J.Exp.Biol.*, 50:593-613.
- Barel, C.D.N. (1993) Concepts of an architectonic approach to transformation morphology. *Acta Biotheoretica*, 41:345-381.
- Barel, C.D.N., Dorit, R., Greenwood, P.H., Fryer, G., Hughes, N., Jackson, P.B.N., Kawanabe, H., Lowe-McConnel, R.H., Nagoshi, M., Ribbink, A.J., Trewavas, E., Witte, F., and Yamaoka, K. (1985) Destruction of fisheries in Africa's lakes. *Nature*, 315:19-20.
- Barel, C.D.N., Van Oijen, M.J.P., and Witte, F. (1977) An introduction to the taxonomy and morphology of the haplochromine Cichlidae from Lake Victoria. A manual to Greenwood's revision papers. *Neth.J.Zool.*, 27:333-389.
- Barel, C.D.N., Witte, F., and Van Oijen, M.J.P. (1976) The shape of the skeletal elements in the head of a generalised haplochromis species: *H. elegans* Trewavas 1933 (Pisces, Cichlidae). *Neth.J.Zool.*, 26:163-265.
- Basu, S.P. (1959) Active respiration of fish in relation to ambient concentrations of oxygen and carbon dioxide. *J.Fish.Res.Bd.Can.*, 16:175-212.

Beamish,F.W.H. (1963a) Respiration of fishes with special emphasis on standard oxygen consumption II. Influence of weight and temperature on respiration of several species. *Can.J.Zool.*, 42:187.

Beamish,F.W.H. (1963b) Respiration of fishes with special emphasis on standard oxygen consumption III. influence of oxygen. *Can.J.Zool.*, 42:355-366.

Beamish,F.W.H. (1964) Respiration of fishes with special emphasis on standard oxygen consumption III. influence of oxygen. *Can.J.Zool.*, 42:355-366.

Beauchamp,R.S.A. (1958) Utilising the natural resources of Lake Victoria for the benefit of fisheries and agriculture. *Nature*, 181:1634-1636.

Bendib,S., Français,O., Tabeling,P., and Willaime,H. (2001) Analytical study and characterisation of micro-channel and passive micro-diode. 12th micromechanics Europe workshop 16-18 September 2001 Corc, Ireland.

Bouton,N., De Visser,J., and Barel,C.D.N. (2002) Correlating head shape with ecological variables in rock-dwelling haplochromines (Teleostei: Cichlidae) from Lake Victoria. *Biological Journal of the Linnean Society*, 76:39-48.

Chabot,D., and Dutil,J.-D. (1999) Reduced growth of Atlantic cod in non-lethal hypoxic conditions. *Journal of Fish Biology*, 55:472-491.

Chapman,L.J., and Chapman,C.A. (2002) Tropical forest degradation and aquatic ecosystems: our current state of knowledge. In: *Conservation of Freshwater Fishes: Options for the Future*. M.J.Collares-Pereira, I.G.Cowx, and M.M.Coelho, eds. Fishing News Books, an imprint of Blackwell Science, pp. 237-249.

Chapman,L.J., Chapman,C.A., Nordlie,F.G., and Rosenberger,A.E. (2002) Physiological refugia: swamps, hypoxia tolerance and maintenance of fish diversity in the Lake Victoria region. *Comp.Biochem.Physiol.*, 133A:421-437.

Chapman,L.J., Galis,F., and Shin,J. (2000) Phenotypic plasticity and the possible role of genetic assimilation: Hypoxia-induced trade-offs in the morphological traits of an African cichlid. *Ecology Letters*, 3:387-393.

Chapman,L.J., Kaufman,L.S., Chapman,C.A., and McKenzie,F.E. (1995) Hypoxia tolerance in twelve species of East African cichlids: Potential for low oxygen refugia in Lake Victoria. *Conservation Biology*, 9:1274-1288.

Chapman,L.J., and Liem,K.F. (1995) Papyrus swamps and the respiratory ecology of *Barbus neumayri*. *Env.Biol.Fish.*, 44:183-197.

Chapman,L.J., Nordlie,F.G., and Seifert,A. (2002) Respiratory oxygen consumption among groups of *Pseudocrenilabrus multicolor victoriae* subjected to different oxygen concentrations during development. *Journal of Fish Biology*, 61:242-251.

De Jager,S., and Dekkers,W.J. (1975) Relations between gill structure and activity in fish. *Neth.J.Zool.*, 25:276-308.

De Jonge,V.N., Elliott,M., and Orive,E. (2002) Causes, historical development, effects and future challenge of a common environmental problem: eutrophication. *Hydrobiologia*, 475/476:1-19.

De Visser, J. and Barel, C. D. N. Transformation patterns and functional significance of headshape in cichlid fish (Cichlidae, Teleostei). 55-76. 2000. PhD-Dissertation University of Leiden, Netherlands

Diaz,R.J., and Rosenberg,R. (1995) Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: An Annual Review*, 33:245-303.

Duthie,G.G. (1982) The respiratory metabolism of temperature-adapted flatfish at rest and during swimming activity and the use of anaerobic metabolism at moderate swimming speeds. *J.Exp.Biol.*, 97:359-373.

Fernandez,M.N., and Rantin,F.T. (1989) Respiratory responses of *Oreochromis niloticus* (Pisces, Cichlidae) to environmental hypoxia under different thermal conditions. *Journal of Fish Biology*, 35:509-519.

Fernandez,M.N., and Rantin,F.T. (1994) Relationships between oxygen availability and metabolic cost of breathing in Nile tilapia (*O. niloticus*). *Aquaculture consequences*. *Aquaculture*, 127:346.

Frey,B.F., Weber,R.E., Van Aardt,W.J., and Fago,A. (1998) The haemoglobin system of the mudfish, *Labeo capensis*; adaptations to temperature and hypoxia. *Comp.Biochem.Physiol.*, 120B:735-742.

Fryer,G. (1997) Biological implications of a suggested Late Pleistocene desiccation of Lake Victoria. *Hydrobiologia*, 354:177-182.

Fryer,G. (2001) On the age and origin of the species flock of haplochromine cichlid fishes of Lake Victoria. *Proc.R.Soc.Lond.B.*, 268:1147-1152.

Fryer,G., and Iles,T.D. (1972) The cichlid fishes of the great lakes of Africa: Their Biology and evolution, Oliver and Boyd, Edinburgh.

Galis,F., and Barel,C.D.N. (1980) Comparative functional morphology of the gills of African lacustrine cichlidae (Pisces, Teleostei). *Neth.J.Zool.*, 30:392-430.

Goldschmidt,T., Witte,F., and De Visser,J. (1990) Ecological segregation in zooplanktivorous haplochromine species (Pisces: Cichlidae) from Lake Victoria. *Oikos*, 58:343-355.

Gracey,A.Y., Troll,J.V., and Somero,G.N. (2001) Hypoxia-induced gene expression profiling in the euryoxic fish *Gillichthys mirabilis*. *PNAS*, 98:1993-1998.

Gray,I.E. (1954) Comparative study of the gill area of marine fishes. *Biol.Bull.*, 107:219-225.

Greaney,G.S., Place,A.R., Cashon,R.E., Smith,G., and Powers,D.A. (1980) Time course of changes in enzyme activities and blood respiratory properties of killifish during long-term acclimation to hypoxia. *Physiol.Zool.*, 53:136-144.

Greenwood,P.H. (1959) The monotypic genera of cichlid fishes in Lake Victoria part II and a revision of the Lake Victoria *Haplochromis* species (Pisces Cichlidae) part III. *Bulletin of the British Museum of Natural History (Zoology)*, 5:164-177.

Greenwood,P.H. (1960) A revision of the Lake Victoria *Haplochromis* species (Pisces, Cichlidae) part IV. *Bulletin of the British Museum of Natural History (Zoology)*, 6:1-281.

Greenwood,P.H. (1965a) Environmental effects on the pharyngeal mill of a cichlid fish, *Astatoreochromis alluaudi*, and their taxonomic implications. *Proc.Linn.Soc.Lond.*, 176:1-10.

Greenwood,P.H. (1965b) The cichlid fishes of Lake Nabugabo, Uganda. *Bull.Br.Mus.Nat.Hist.(Zool.)*, 12:313-357.

Greenwood,P.H. (1973) A revision of the *Haplochromis* and related species (Pisces: Cichlidae) from Lake George, Uganda. *Bull.Br.Mus.Nat.Hist.(Zool.)*, 25:141-242.

Greenwood,P.H. (1974) The cichlid fishes of Lake Victoria, East Africa: the biology and evolution of a species flock. *Bull.Br.Mus.Nat.Hist.(Zool.)*, suppl.6:1-134.

Greenwood,P.H. (1981) The haplochromine cichlids of the East African Lakes: Collected papers on their taxonomy, biology and evolution, Kraus International Publications, Munich, Germany.

Harmsen,E., De Tombe,P.Ph., and De Jong,J.W. (1982) Simultaneous determination of myocardial adenine-nucleotides and creatine-phosphate by high-performance liquid-chromatography. *Journal of Chromatography*, 230:131-136.

Hattingh,J. (1976) Haemoglobins in *Labeo umbratus*: The influence of temperature and oxygen. *South African Journal of Science*, 72:27-28.

Hecky,R.E. (1993) Peter Kilham Memorial Lecture: The eutrophication of Lake Victoria. *Verh.Internat.Verein.Limnol.*, 25:39-48.

Hecky,R.E., and Bugeny,F.W.B. (1992) Hydrology and chemistry of the African Great Lakes and water quality issues: problems and solutions. *Mitt.Internat.Verein.Limnol.*, 23:45-54.

Hecky,R.E., Bugeny,F.W.B., Ochumba,P.B.O., Talling,J.F., Mugidde,R., Gophen,M., and Kaufman,L.S. (1994) Deoxygenation of the deep water of Lake Victoria, East Africa. *Limnol.Oceanogr.*, 39:1476-1481.

Hoogerhoud,R.J.C. (1984) A taxonomic reconsideration of the haplochromine genera *Gaurochromis* Greenwood, 1980 and *Labrochromis* Regan, 1920 (Pisces, Cichlidae). *Neth.J.Zool.*, 34:539-565.

Hoogerhoud, R. J. C. Ecological morphology of some cichlid fishes. PhD-Dissertation University of Leiden, Netherlands 1-133. 1986.

Hoogerhoud,R.J.C., Witte,F., and Barel,C.D.N. (1983) The ecological differentiation of two closely resembling Haplochromis species from Lake Victoria (*H. iris* and *H. hiatus*; pisces, Cichlidae). *Neth.J.Zool.*, 33:283-305.

Hoppeler,H., Vogt,M., Weibel,E.R., and Lück,M. (2003) Response of skeletal muscle mitochondria to hypoxia. *Exp.Physiol.*, 88:109-119.

Houston,A.H. (1980) Components of the haematological response of fishes to environmental temperature change. In: *Environmental physiology of fishes*. M.A.Ali, ed. Plenum, New York, pp. 241-298.

Houston,A.H., and Cyr,D. (1974) Thermoacclimatory variation in the haemoglobin systems of goldfish (*Carassius auratus*) and rainbow trout (*Salmo gairdneri*). *J.Exp.Biol.*, 61:455-461.

Houston,A.H., and Tun,N. (1986) Environmentally -related changes in red cell levels of ionic modulators of hemoglobin-O<sub>2</sub> affinity in rainbow trout, *Salmo gairdneri*. *Comp.Biochem.Physiol.*, 85A:779-783.

Hughes,G.M. (1966) The dimensions of fish gills in relation to their function. *Journal of Experimental Biology*, 45:177-195.

Hughes,G.M. (1972) Morphometrics of fish gills. *Respir.Physiol.*, 14:1-25.

Hughes,G.M., and Morgan,M. (1973) The structure of fish gills in relation to their respiratory function. *Biological Reviews*, 48:419-475.

Johnson,T.C., Scholz,C.A., Talbot,M.R., Kelts,K., Ricketts,R.D., Ngobi,G., Beuning,K., Ssemmanda,I., and McGlil,J.W. (1996) Late Pleistocene desiccation of Lake Victoria and rapid evolution of cichlid fishes. *Science* 273:1091-1093.

Johnston,I.A., and Bernard,L.M. (1982a) Routine oxygen consumption and characteristics of the myotomal muscle in tench: Effects of long-term acclimation to hypoxia. *Cell Tiss.Res.*, 227:161-177.

Johnston,I.A., and Bernard,L.M. (1982b) Ultrastructure and metabolism of skeletal muscle fibers in the tench: Effects of long-term acclimation to hypoxia. *Cell Tiss.Res.*, 227:179-199.

Jones,D.R., Randall,D.J., and Jarman,G.M. (1970) A graphical analysis of oxygen transfer in fish. *Resp.Physiol.*, 10:285-298.

Joyce,D.A., Lunt,D.H., Bills,R., Turner,G.F., Katongo,C., Duftner,N., Sturmbauer,C., and Seehausen,O. (2005) An extant cichlid fish radiation emerged in an extinct Pleistocene lake. *Nature*, 435:90-95.

Karlson,K., Rosenberg,R., and Bonsdorff,E. (2002) Temporal and spatial large-scale effects of eutrophication and oxygen deficiency on benthic fauna in Scandinavian and Baltic waters - a review. *Oceanography and Marine Biology*, 40:427-489.

Kaufman,L.S. (1992) Catastrophic change in species-rich freshwater ecosystems. The lessons of Lake Victoria. *Bioscience*, 42:846-858.

Keppler,D., and Decker,K. (1988) Glycogen. In: *Methods of enzymatic analysis*. Volume VI, *Metabolites 1: Carbohydrates*. H.A.Bergmeyer, J.Bergmeyer, and M.Graßl, eds. VHC Verlagsgesellschaft, Weinheim, pp. 11-18.

Lomholt,J.P., and Johansen,K. (1979) Hypoxia acclimation in carp- how it affects O<sub>2</sub> uptake, ventilation, and O<sub>2</sub> extraction from water. *Physiol.Zool.*, 52:38-49.

- Marinsky,C.A., Houston,A.H., and Murad,A. (1989) Effects of hypoxia on hemoglobin isomorph abundances in rainbow trout, *Salmo gairdneri*. *Can.J.Zool.*, 68:884-888.
- Matsuda,N., and Sakai,K. (1999) Technical evaluation of oxygen transfer rates of fish gills and artificial gills. *ASAIO J.*, 45:293-298.
- McNatt,R.A., and Rice,J.A. (2004) Hypoxia-induced growth rate reduction in two juvenile estuary-dependant fishes. *Journal of Experimental Marine Biology and Ecology*, 311:147-156.
- Meyer,A. (1990) Morphometric and allometry in the trophically cichlid fish, *Cichlasoma citrinellum*: Alternative adaptations and ontogenetic changes in shape. *J.Zool.Lond.*, 221: 237-260.
- Mortensen,N.A., Okkels,F., and Bruus,H. (2005) reexamination of Hagen-Poiseuille flow: Shap[e dependence of the hydraulic resistance in microchannels. *Physical Reviews E*, 71: 057301-1-057301-4.
- Muir,B.S., and Brown,C.E. (1971) Effects of blood pathway on the blood-pressure drop in fish gills, with special references to tunas. *J.Fish.Res.Bd.Can.*, 28:947-955.
- Muir,B.S., and Hughes,G.M. (1969) Gill dimensions for three species of tunny. *J.Exp.Biol.*, 51:271-285.
- Muusse,B., Marcon,J., Van den Thillart,G.J.E.E.M., and Val,A.L. (1998) Hypoxia tolerance of Amazon fish Respirometry and energy metabolism of the cichlid *Astronotus ocellatus*. *Comp.Biochem.Physiol.*, 120:151-156.
- Nagl,S., Tichy,H., Mayer,W.E., Takezaki,N., Takahata,N., and Klein,J. (2000) The origin and age of haplochromine fishes in Lake Victoria, East Africa. *Proc.R.Soc.Lond.B.*, 267:1049-1061.
- Nikinmaa,M., Cech Jr,J.J., Ryhanen,E.L., and Salama,A. (1987) Red cell function of carp (*Cyprinus carpio*) in acute hypoxia. *J.Exp.Biol.*, 47:53-58.
- Njuguna,S.G. (1991) Water hyacinth: The world's worst aquatic weed infests lakes Naivasha and Victoria. *Swara*, 14:8-10.
- Ochumba,P.B.O. (1990) Massive fish kills within the Nyanza Gulf of Lake Victoria, Kenya. *Hydrobiologia*, 208:93-99.



Ochumba, P. B. O., Gophen, M., and Kaufman, L. S. Changes in oxygen availability in the Kenyan portion of Lake Victoria: effects on fisheries and biodiversity. (Proceedings of the Lake Victoria Ecosystem Workshop held in Jinja, Uganda, Aug. 17 - 21, 1992), 33. 1993. New England, U.S.A., Edgerton Research Laboratory of the New England Aquarium, report 93-3. Kaufman, L. S., Ochumba, P. B. O., and Ogutu-Ohwayo, R.

Ochumba,P.B.O., and Kibaara,D.I. (1989) Observations on blue-green algal blooms in the open waters of Lake Victoria, Kenya. *Afr.J.Ecol.*, 27:23-34.

Ogutu-Ohwayo,R. (1990) The decline of the native fishes of lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile perch, *Lates niloticus*, and the Nile tilapia, *Oreochromis niloticus*. *Env.Biol.Fish.*, 27:81-96.

Ott,M.E., Heisler,N., and Ultsch,G.R. (1980) A re-evaluation of the relationship between temperature and the critical oxygen tension in freshwater fishes. *Comp.Biochem.Physiol.*, 67A:337-340.

Palzenberger,M., and Pohla,H. (1992) Gill surface area of water-breathing freshwater fish. *Reviews in Fish Biology and Fisheries*, 2:187-216.

Pearson,T.H., and Rosenberg,R. (1992) Energy flow through the Kattegat: A comparative examination of the eutrophication of a coastal marine ecosystem. *Netherlands Journal of Sea Research*, 28:317-334.

Petersen,J.K., and Petersen,G.I. (1990) Tolerance, behaviour consumption in the sand goby, *Pomatoschistus minutus* (Pallas), exposed to hypoxia. *Journal of Fish Biology*, 37:921-933.

Pihl,L., Baden,S.P., and Diaz,R.J. (1991) Effects of periodic hypoxia on distribution of demersal fish and crustaceans. *Marine Biology*, 108:349-360.

Pihl,L., Baden,S.P., Diaz,R.J., and Schaffner,L.C. (1992) Hypoxia-induced structural changes in the diet of bottom-feeding fish and Crustacea. *Marine Biology*, 112:349-361.

Randall,D.J. (1970) Gas exchange in fish. In: *Fish physiology*, Volume IV, The nervous system, circulation, and respiration. W.S.Hoar, and D.J.Randall, eds. Academic press, London, pp. 253-286.

Rantin,F.T., Kalinin,A.L., Lass,M.L., and Fernandez,M.N. (1992) Respiratory responses to hypoxia in relation to mode of life of two erythrinid species (*Hoplias malabaricus* and *Hoplias lacerdae*). *Journal of Fish Biology*, 41:805-812.

Reddy, M. (2005) Restoration and management of tropical eutrophic lakes, Science Publishers Inc. Enfield (NH) USA.

Roman, M.R., Gauzens, A.L., Rhinehart, W.K., and White, J.R. (1993) Effects of low oxygen waters on Chesapeake Bay zooplankton. *Limnol. Oceanogr.*, 38:1603-1614.

Ross, L.G. (2000) Environmental physiology and energetics. In: Tilapias: Biology and exploitation. C.M. Malcolm, Beveridge, J. Brendan, and e. McAndrews, eds. Kluwer academic publishers, Dordrecht/Boston/London, pp. 89-128.

Schlichting, C.D. and Pigliucci, M. (1998) Phenotypic evolution: a reaction norm perspective. Sinauer.

Schofield, P.J., and Chapman, L.J. (2000) Hypoxia tolerance of introduced Nile perch: implications for survival of indigenous fishes in the Lake Victoria basin. *African Zoology*, 35: 35-42.

Schumann, D., and Piiper, J. (1966) Der Sauerstoffbedarf der Atmung bei Fischen nach Messungen an der narkotisierten Schleie (*Tinca tinca*). *Pflugers Arch. Ges. Physiol.*, 288:15-26.

Schwantes, A.R., Bartlett, G.R., and Schwantes, M.L.B. (1991) The hemoglobin of *Geophagus brasiliensis* (cichlidae). *Comp. Biochem. Physiol.*, 99B:157-160.

Seehausen, O. (1996) Lake Victoria rock cichlids: Taxonomy, ecology, and distribution, Verduyn Cichlids, Zevenhuizen, Netherlands.

Seehausen, O. (2002) Patterns in fish radiation are compatible with pleistocene desiccation of Lake Victoria and 14600 year history for its cichlid species flock. *Proc. R. Soc. Lond. B.*, 269: 491-497.

Seehausen, O., Koertsier, E., Schneiden, M.V., Chapman, L.J., Chapman, C.A., Van Alphen, J.J.M., and Bills, R. (2003) Nuclear markers reveal unexpected genetic variation and a Congolese-Nilotic origin of the Lake Victoria cichlid species flock. *Proc. R. Soc. Lond.*, 270: 129-137.

Smith, D.G., and Johnson, D.W. (1977) Oxygen exchange in a simulated trout gill secondary lamella. *Am. J. Physiol. Reg. Int. Comp. Physiol.*, 2:R146-R161.

Smits, J.D., Anker, G.C., Witte, F., and Barel, C.D.N. (1997) Comparative functional anatomy of the pharyngeal jaw apparatus in two morphs of *Astatoreochromis alluaudi* (Pisces, Cichlidae). *Neth. J. Zool.*, 47:313-347.

Smits,J.D., Witte,F., and Povel,G.D.E. (1996a) Differences between inter- and intraspecific architectonic adaptations to pharyngeal mollusc crushing in cichlid fishes. *Biological Journal of the Linnean Society*, 59:367-387.

Smits,J.D., Witte,F., and Van Veen,F.G. (1996b) Functional changes in the anatomy of the pharyngeal jaw apparatus of *Astatoreochromis alluaudi* (Pisces, Cichlidae), and their effects on adjacent structures. *Biological Journal of the Linnean Society*, 59:389-409.

Sollid,J., De Angelis,P., Gundseren,K., and Nilsson,G. (2003) Hypoxia induces adaptive and reversible gross morphological changes in crusian carp gills. *The Journal of Experimental Biology*,3667-3673.

Sollid,J., Weber,R.E., and Nilsson,G.E. (2005) Temperature alters the respiratory surface area of crusian carp *Carassius carassius* and goldfish *Carassius auratus*. *Journal of Experimental Biology*, 208:1109-1116.

Stitt,M. (1984) Citrate synthase (Condensing enzyme). In: *Methods of enzymatic analysis*. Volume IV: Enzymes 2: Esterases, Glycosidases, Lyases, Ligases. H.A.Bergmeyer, H.A.Bergmeyer, and M.Graßl, eds. VCH Verlagsgesellschaft, Weinheim, pp. 353-358.

Thetmeyer,H., Waller,U., Black,K.D., Inselmann,S., and Rosenthal,H. (1999) Growth of european sea bass (*Dicentrarchus labrax* L.) under hypoxic conditions and oscillating oxygen conditions. *Aquaculture*, 174:355-367.

Trewavas,E. (1983) Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*, British Museum (Natural History).

Tun,N., and Houston,A.H. (1986) Temperature, oxygen, photoperiod, and the hemoglobin system of the rainbow trout *Salmo gairdneri*. *Can.J.Zool.*, 64:1883-1888.

Ultsch,G.R., Jackcon,D.C., and Moalli,R. (1981) Metabolic oxygen conformity among lower vertebrates: The toadfish revisited. *J.Comp.Physiol.*, 142:439-443.

Val,A.L. (2000) Organic phosphates in the red blood cells of fish. *Comp.Biochem.Physiol.*, 125A:417-435.

Val,A.L., Lessard,J., and Randall,D.J. (1995) Effects of hypoxia on rainbow trout (*Oncorhynchus mykiss*): intraerythrocytic phosphates. *J.Exp.Biol.*, 198:305-310.

Van Dam,A.A., and Pauly,D. (1995) Simulation of the effects of oxygen on food consumption and growth of Nile tilapia *Oreochromis niloticus* (L.). *Aquaculture Research*, 26:427-440.

Van Dam, L. On the utilisation of oxygen and regulation of breathing in some aquatic animals. 1938. PhD-Dissertation University of Groningen.

Van den Thillart, G., and Kesbeke, F. (1978) Anaerobic production of carbon dioxide and ammonia by goldfish, *Carassius auratus* (L.). *Comp. Biochem. Physiol.*, 59A:393-400.

Van den Thillart, G.J.E.E.M., Dalla via, J., Vitali, G., and Cortesi, P. (1994) Influence of long term hypoxia exposure on the energy metabolism of *Solea solea*. I. Critical O<sub>2</sub> levels for aerobic and anaerobic metabolism. *Mar. Ecol. Prog. Ser.*, 104:109-117.

Van den Thillart, G.J.E.E.M., Kesbeke, F., and Van Waarde, A. (1980) Anaerobic Energy Metabolism of Goldfish, *Carassius auratus* (L.). Influence of hypoxia and anoxia on phosphorylated compounds and glycogen. *J. Comp. Physiol.*, 136:45-52.

Van den Thillart, G.J.E.E.M., and Smit, H. (1984) Carbohydrate metabolism of goldfish (*Carassius auratus* (L.)). Effects of long-term hypoxia acclimation on enzyme patterns of red muscle, white muscle and liver. *J. Comp. Physiol. B.*, 154:477-786.

Van den Thillart, G.J.E.E.M., and Van Raaij, M.T.M. (1995) Endogenous fuels: Non-invasive versus invasive approaches. In: *Biochemistry and molecular biology of fishes*, vol. 4. P.W.Hochachka, and T.P.Mommsen, eds. Elsevier Science B.V.

Van den Thillart, G.J.E.E.M., and Van Waarde, A. (1985) Teleosts in hypoxia: Aspects of anaerobic metabolism. *Molecular Physiology*, 8:393-409.

Van den Thillart, G.J.E.E.M., and Verbeek, R. (1991) Anoxia-induced oxygen debt of Goldfish (*Carassius auratus* L.). *Physiol. Zool.*, 64:525-540.

Van Ginneken, V.J.T., Addink, A., Van den Thillart, G.J.E.E.M., Körner, F., Noldus, L., and Buma, M. (1997) Metabolic rate and level of activity determined in tilapia (*Oreochromis mossambiques*) by direct and indirect calorimetry and videomonitoring. *Thermochimica Acta*, 291:1-13.

Van Ginneken, V.J.T., Vanderschoot, J., and Addink, A.D.F. (1995) Direct calorimetry of aquatic animals: Dynamic response of biological processes. *Thermochimica Acta*, 249:143-159.

Van Leeuwen, J.L., and Spoor, C.W. (1987) Biting force in cichlids: a discussion of the planar model of Barel (1983). *Neth. J. Zool.*, 37:307-314.

Van Oijen, M.J.P., Witte, F., and Witte-Maas, E.L.M. (1981) An introduction to ecological and taxonomical investigations on the haplochromine cichlids from the Mwanza Gulf of Lake Victoria. *Neth. J. Zool.*, 31:149-174.

Van Raaij, M.T.M., Djemila, S.S.P., Balm, H.M., Steffens, A.B., and Van den Thillart, G.J.E.E.M. (1996) Behavioural strategy and the physiological stress response in rainbow trout exposed to severe hypoxia. *Hormones and Behaviour*, 30:85-92.

Van Velzen, J., Bouton, N., and Zandee, R. (1998) A procedure to extract phylogenetic information from morphometric data. *Neth.J.Zool.*, 48:305-322.

Vassault, A. (1987) Lactate dehydrogenase, Uv-method with pyruvate and NADH. In: *Methods of enzymatic analysis. Volume III: Oxireductases, Transferases*. H.A. Bergmeyer, J. Bergmeyer, and M. Graßl, eds. VCH Verlagsgesellschaft, Weinheim, pp. 118-133.

Verheijen, E., Blust, R., and Declair, W. (1994) Metabolic rate, hypoxia tolerance and aquatic surface respiration of some lacustrine and riverine African cichlid fishes (Pisces: Cichlidae). *107A*, 2:411.

Verheyen, E., Blust, R., and Doumen, C. (1985) The oxygen uptake of *Sarotherodon niloticus* L. and the oxygen binding properties of its blood and hemolysate (Pisces: Cichlidae). *Comp.Biochem.Physiol.*, 81A:423-426.

Verheyen, E., Salzburger, W., Snoeks, J., and Meyer, A. (2003) Origin of the superflock of cichlid fishes from Lake Victoria, East Africa. *Science*, 300:325-329.

Verschuren, D., Edgington, D.N., Kling, H.J., and Johnson, T.C. (1998) Silica depletion in Lake Victoria: Sedimentary signals at offshore stations. *J.Great Lakes Res.*, 24:118-130.

Verschuren, D., Johnson, T.C., Kling, H.J., Edgington, D.N., Leavitt, P.R., Brown, E.T., Talbot, M.R., and Hecky, R.E. (2002) History and timing of human impact on Lake Victoria, East Africa. *Proc.R.Soc.Lond.B.*, 269:289-294.

Vianen, G.J., Obels, P.P., Van den Thillart, G.J.E.E.M., and Zaagsma, J. (2002) B-Adrenoceptors mediate inhibition of lipolysis in adipocytes of tilapia (*Oreochromis mossambicus*). *Am.J.Physiol.Endocrinol.Metab.*, 282:E325.

Vianen, G.J., Van den Thillart, G.J.E.E.M., Van Kampen, M., Van Heel, T.I., and Steffens, A.B. (2001) Plasma lactate and stress hormones in common carp (*Cyprinus carpio*) and rainbow trout (*Oncorhynchus mykiss*) during stepwise decreasing oxygen levels. *Neth.J.Zool.*, 51:33-50.

Virani, N.A., and Rees, B. (2000) Oxygen consumption, blood lactate and inter-individual variation in the gulf kilifish, *Fundulus grandis*, during hypoxia and recovery. *Comp.Biochem.Physiol.*, 126:397-405.

Wahlefeld, A., and Siedel, J. (1985) Creatine and creatinine. In: Methods of enzymatic analysis, Volume VIII, Metabolites 3: Lipids, amino acids and related compounds. H.A. Bergmeyer, J. Bergmeyer, and M. Graßl, eds. VCH Verlagsgesellschaft, Weinheim, pp. 488-507.

Wanink, J.H. (1991) Survival in a perturbed environment: The effects of Nile perch introduction on the zooplanktivorous fish community of Lake Victoria. In: Terrestrial and Aquatic ecosystems: Perturbation and Recovery. O. Ravera, ed. Ellis Horwood Ltd., Chichester, UK, pp. 269-275.

Wanink, J.H., Kashindye, J.J., Goudswaard, K.P.C., and Witte, F. (2001) Dwelling at the oxycline: does increased stratification provide a predation refugium for the Lake Victoria sardine *Rastrineobola argentea*? *Freshw. Biol.*, 46:75-85.

Wanink, J.H., and Witte, F. (2000a) Rapid morphological changes following niche shift in the zooplanktivorous cyprinid *Rastrineobola argentea* from Lake Victoria. *Neth. J. Zool.*, 50:365-372.

Wanink, J.H., and Witte, F. (2000b) The use of perturbation as a natural experiment: effects of predator introduction on the community structure of zooplanktivorous fish in Lake Victoria. *Advances In Ecol. Res.*, 31:553-570.

Wannamaker, C.M., and Rice, J.A. (2000) Effects of hypoxia on movements and behavior of selected estuarine organisms from the southeastern United States. *J. Exp. M. Biol. Ecol.*, 249: 145-163.

Weber, R.E. (1990) Functional significance and structural basis of multiple hemoglobins with special reference to ectothermic vertebrates. In: Comparative physiology. R.K.H. Kinne, and E. Kinne-Saffran, eds. Karger S., Basel, pp. 57-75.

Weber, R.E. (1994) Hemoglobin-based O<sub>2</sub> transfer in viviparous animals. *Israel Journal of Zoology*, 40:541-550.

Weber, R.E. (1996) Hemoglobin adaptations in Amazonian and temperate fish with special references to hypoxia, allosteric effectors and functional heterogeneity. In: Physiology and biochemistry of the fishes of the amazon. A.L. Val, V.M.F. Almeida-Val, and D.J. Randall, eds. INPA Manaus, pp. 75-90.

Weber, R.E. (2000) Adaptations for oxygen transport: Lessons from fish hemoglobins. In: Hemoglobin function in vertebrates. Molecular adaptation in extreme and temperate environments. G.d. Prisco, B. Giardina, and R.E. Weber, eds. Springer-Verlag Italia.

Weber,R.E., and Jensen,F.B. (1988) Functional adaptations in hemoglobins from ectothermic vertebrates. *Ann.Rev.Physiol.*, 50:161-179.

Weber,R.E., and Wells,R.M.G. (1989) Hemoglobin structure and function. In: *Comparative pulmonary physiology*. S.C.Wood, ed. Marcel Dekker Inc., pp. 279-309.

Welcomme,R.L. (1967) Observations on the biology of the introduced species of tilapia in Lake Victoria. *Rev.Zool.Bot.Afr.*, 76:249-279.

Welcomme,R.L. (1988) International introductions of inland fish species. *FAO Fish Tech.Pap.*, 294:1-318.

Wendelaar Bonga,S.E. (1997) The stress response in fish. *Physiological Reviews*, 77:591-625.

Wilhelm,D.F., and Weber,R.E. (1983) Functional characterisation of hemoglobins from South Brazilian fresh water teleosts-II. Three cichlids (*Crenicichla lepidot A*, *Aequidens port aleggrensis* and *Geophagus brasiliensis*). *Comp.Biochem.Physiol.*, 75A:483-489.

Witte,F. (1981) Initial results of the ecological survey of the haplochromine cichlid fishes from the Mwanza Gulf of Lake Victoria: Breeding patterns, trophic and species distribution. *Neth.J.Zool.*, 31:175-202.

Witte,F. (2002) On research on tilapiine and haplochromine cichlids. *Hydrobiologica*, 470: 1-3.

Witte,F., Barel,C.D.N., and Hoogerhoud,R.J.C. (1990) Phenotypic plasticity of anatomical structures and its ecomorphological significance. *Neth.J.Zool.*, 40:278-298.

Witte,F., Goldschmidt,T., Wanink,J.H., Van Oijen,M.J.P., Goudswaard,K.P.C., Witte-Maas,E.L.M., and Bouton,N. (1992) The destruction of an endemic species flock: quantitative data on the decline of the haplochromine cichlids of Lake Victoria. *Environmental Biology of Fishes*, 34:1-28.

Witte,F., Goudswaard,K.P.C., Katunzi,E.F.B., Mkumbo,O.C., Seehausen,O., and Wanink,J.H. (1999) Lake Victoria's ecological changes and their relationships with the riparian societies. In: *Ancient Lakes: Their Cultural and Biological diversity*. H.Kawanabe, G.W.Coulter and A.C.Roosevelt ed. Kenobi Productions. Printed in Belgium, pp. 189-202.

Witte,F., Msuku,B.S., Wanink,J.H., Seehausen,O., Katunzi,E.F.B., Goudswaard,K.P.C., and Goldschmidt,T. (2000) Recovery of cichlid species in Lake Victoria: an examination of factors leading to differential extinction. *Reviews in Fish Biology and Fisheries*, 10:233-241.

Witte,F., and Van Oijen,M.J.P. (1995) Biology of haplochromine trophic groups. In: Fish stocks and fisheries of Lake Victoria: A handbook for field observations. F.Witte, and W.L.T.van Densen, eds. Samara Publishing, Cardigan, UK, pp. 321-335.

Witte,F., Wanink,J.H., Rutjes,H.A., Van der Meer,H.J., and Van den Thillart,G.J.E.E.M. (2005) Eutrophication and its influences on the fish fauna of Lake Victoria. In: Restoration and management of tropical eutrophic lakes. M.Reddy, ed. Science Publishers Inc. Enfield (NH) USA.

Witte,F., and Witte-Maas,E.L.M. (1981) Haplochromine cleaner fishes: a taxonomic and eco-morphological description of two new species. Revision of the haplochromine species (Teleostei, Cichlidae) from Lake Victoria. Part I. Neth.J.Zool., 31:203-231.

Witte,F., and Witte-Maas,E.L.M. (1987) Implications for taxonomy and functional morphology of intraspecific variation in haplochromine cichlids of Lake Victoria. In: From form to fishery. PhD-Dissertation University of Leiden.

Wu,R.S. (2002) Hypoxia: from molecular responses to ecosystem responses. Marine Pollution Bulletin, 45:35-45.

Wu,R.S., Zhou,B.S., Randall,D.J., Woo,N.Y., and Lam,P.K.S. (2003) Aquatic hypoxia is a disruptor and impairs reproduction. Environ.Sci.Technol., 15:1137-1141.

Yamamoto,K.-I. (1991) Relationship of respiration to body weight in the carp *Cyprinus carpio* under resting and normoxic conditions. Comp.Biochem.Physiol., 100A:113-116.

Yamamoto,K.-I. (1992) Relationship of respiration to body weight in the tilapia *Oreochromis niloticus* under resting and normoxic conditions. Comp.Biochem.Physiol., 103A:81-83.

Zhou,B.S., Wu,R.S.S., Randall,D.J., and Lam,P.K.S. (2001) Bioenergetics and RNA/DNA ratios in the common carp (*Cyprinus carpio*) under hypoxia. J.Comp.Physiol.B., 171:49-57.

Zhou,B.S., Wu,R.S.S., Randall,D.J., Lam,P.K.S., Ip,Y.K., and Chew,S.F. (2000) Metabolic adjustments in the common carp during prolonged hypoxia. Journal of Fish Biology, 57:1160-1171.