

Ecomorphological guilds and diet of exotrophic anuran tadpoles

V Botha
21101086

Dissertation submitted in fulfilment of the requirements for the
degree *Magister Scientiae* in *Environmental Sciences* at the
Potchefstroom Campus of the North-West University

Supervisor: Prof C Weldon

Co-supervisor: Dr J Taylor

May 2014



ABSTRACT

To test the applicability of anuran tadpole functional ecology with regards to diet as a tool to determine ecosystem function of aquatic habitats, all the presently known southern African anuran species' tadpoles were assigned to ecomorphological guilds. The data set included 106 anuran tadpole species and 84 variables, which included: 23 habitat; 49 morphological; 9 behavioural; and 3 development (time to metamorphosis) related variables. Although the data set for the guild delineation did not include genetic data, a phylogeny (evolutionary approach) was used to obtain a tree where species are grouped together based on shared characteristics, similar to that of a cluster analysis where each cluster or group is a guild. Maximum parsimony was employed with PAUP 4.0b10 to construct consensus trees using heuristic search settings. The phylogenetic/taxonomic affiliation of the species in each ecomorphological guilds' was also observed by constructing a phylogenetic tree. The 12S and 16S mitochondrial gene sequences were retrieved from Genbank, to represent the major lineages documented in the anurans of southern Africa thus far. The ecomorphological guild delineation was further supported by quantify tadpole gut contents to determine their trophic status. Information on the feeding behaviour of four guilds was obtained by analysing a representative anuran tadpole species from each. The IUCN red list of threatened species was consulted to obtain the conservation status of the 106 anuran species used for this study, which made it possible to determine whether there is a link between species found in the same ecomorphological guilds and those species' conservation status. Considering the high diversity of anuran species in the Phongolo region (offering access to a variety of tadpole guilds), and the ability to analyse the diatom communities found in the gut contents of tadpoles. A portion of this study supplemented the assessment of ecosystem functioning and management of aquatic resources of the lower Phongolo River and floodplain, by providing information regarding the health. Diatom bioassessment was applied as a tool for inferring water quality.

The phylogenetic approach proved to be very effective for the guild delineation, permitting the recognition of 10 fully characterised ecomorphological guilds, a number of which corresponded with previously characterized guilds. Terminology had to be produced for three new guilds, based on the guild defining criteria. The phylogeny of the anuran species coincides with guild delineation to some extent in terms of phylogenetic clades. The majority of species within one guild, although belonging to different genera and families belonged to the same phylogenetic clade. The trophic analysis supports the guild delineation, since a clear distinction could be made between the percentage and combination of materials from each trophic category ingested by tadpoles from different ecomorphological guilds.

Even though some similarity can be seen between species, based on the criteria for the endangered status, there was still no true correlation between IUCN status and ecomorphological guild. The fact that the critically endangered, endangered and vulnerable species are distributed over so many guilds further emphasises the extent of amphibian decline. The majority of the diatom species found in the Phongolo River and floodplain favour brackish water, with a moderate to high electrolyte content. Indicating that the Phongolo River and the section of the floodplain considered for this study had a high salinity. This might be due to the water bodies' close proximity to the coast. The diatom index scores indicated the presence of organic pollutants and labelled these water bodies as mesotrophic to eutrophic.

Keywords: Tadpole; Ecomorphological guild, Phylogeny, Conservation status, Diet, Diatom.

ACKNOWLEDGEMENTS

Psalms 124:8 “Our help is in the name of the LORD, who made heaven and earth.” (KJV)

Above all I thank my best Friend, Father and Loving King, the God above all; through whom and for who all things were created. Without You none of this would have been possible. All the honour is Yours.

Revelation 4:11 "You are worthy, our Lord and God, to receive glory and honour and power, for you created all things, and by your will they existed and were created." (NKJV)

I sincerely thank my promoters Prof. Ché Weldon and Dr. Jonathan C. Taylor for their encouragement, guidance and support.

I will always be thankful to my wonderful parents and loving sister for believing in and supporting me in everything I set out to do.

I gratefully acknowledge the assistance and encouragement of Mathieu Badets who always challenged me to try harder and go further. Thank you for always expressing your belief in my potential to be a good scientist.

I thank the following people and organizations without whom many aspects of this research would not have been realised.

The African Amphibian Conservation and Research Group (AACRG), for their support of this study and for allowing me full access to their extensive collection.

The Water Research Commission of South Africa for their financial support and allowing this study to supplement their large scale assessment of the ecosystem functioning, sustainable utilization and management of aquatic resources of the Lower Phongolo River and floodplain.

Stefan Barnard for his time and assistance in composing a geographic map of the study area.

I am thankful to Prof. Louis H. du Preez for sharing his knowledge of the anurans of southern Africa with me. Photo credits of all tadpoles go to Prof. Louis H. du Preez.

TABLE OF CONTENTS

Abstract.....	i
Acknowledgements	iii
Table of contents	iv
List of tables and figures	vi
Tables.....	vi
Figures	vi
Equation.....	vii
Annexures (see attached compact disc)	vii
1. Introduction and Literature Review	9
1.1 Synopsis, problem statement and substantiation.....	9
1.2 Anuran tadpole ecomorphology and phylogeny	10
1.3 Tadpole morphology and known functionality	13
1.3.1 Tadpole oral structures.....	13
1.3.2 Tadpole body morphology in relation to habitat and behaviour	15
1.4 Exotrophic tadpole diet	17
1.5 Environmental applications of diatoms.....	19
1.6 Research aim and objectives	21
2. Methods.....	22
2.1 Systematic assessment of ecomorphological tadpole guilds.....	22
2.1.1 Matrix data	22
2.1.2 Matrix analysis.....	23
2.2 Phylogeny of the anuran species of southern Africa.....	23
2.3 Field site selection.....	25
2.4 Field procedures.....	27
2.4.1 Tadpole and diatom sampling and preservation.....	27

2.4.2	Water samples and multi parameter measurements for chemical analysis	28
2.5	Laboratory procedures	28
2.5.1	Tadpole identification and trophic analysis	28
2.5.2	Diatom isolation, slide preparation and quantification	29
2.6	Statistical analysis	31
2.6.1	Relation between anuran endangered status and ecomorphological tadpole guilds	31
2.6.2	Correlation between tadpole diet and ecomorphological guilds	32
2.6.3	Diatom indices for the biological monitoring of water quality in the Phongolo River and floodplain	32
3.	Results	34
3.1	Systematic assessment of ecomorphological tadpole guilds	34
3.2	Phylogeny of the anuran species of southern Africa	37
3.3	Relation between anuran conservation status and ecomorphological guilds	40
3.4	Tadpole trophic analysis	42
3.5	Dominant diatom species and diatom index scores for the Ndumo Game Reserve	43
4.	Discussion	49
4.1	Anuran tadpole ecomorphological characterization and phylogeny	49
4.2	Relation between anuran conservation status and ecomorphological guilds	59
4.3	Tadpole trophic analysis in relation to ecomorphological guilds	61
4.3.1	Trophic categories of materials ingested by tadpoles	62
4.3.2	Ecomorphological guilds dietary preferences	63
4.4	Diatom bioassessment for the biological monitoring of water quality in the Phongolo River and floodplain	66
4.4.1	Water quality as inferred by the diatom indices and dominant diatom species	67
4.4.2	Environmental variables in relation to diatom indices and dominant diatom species	68
5.	Conclusions	69
6.	References	71

LIST OF TABLES AND FIGURES

TABLES

Table 1: Tadpole sampling sites in the Ndumo Nature Reserve	26
Table 2: Diatom sampling sites in the Ndumo Nature Reserve.	27
Table 3: Main criteria in common and previous recognition in guild delineation of the 106 southern African anuran tadpoles	36
Table 4: The conservation status criteria for critically endangered, endangered and vulnerable anuran species of southern Africa (IUCN, 2013)	41
Table 5: Ecomorphological guild representatives for tadpole trophic analysis	42
Table 6: The relative abundance of the dominant diatom species (in bold) encountered in the diatom sites sampled in the Ndumo Nature Reserve.....	44
Table 7: Diatom indices calculated using Omnidia 5.3	47
Table 8: Class limit values for diatom indices (Prygiel & Coste, 2000).....	47
Table 9: Physico-chemical water quality parameters as measured at all the diatom sampling sites in the Ndumo Nature Reserve	48
Table 10: Pearson correlation between diatom index scores and environmental variables	48

FIGURES

Figure 1: Van Dijk's (1972) illustration of various modes of behaviour and related ecological positions of southern African anuran tadpoles.	12
Figure 2: Tadpole oral disc orientation, body form and tail fin variation. From left to right: <i>Leptopelis natalensis</i> , <i>Pyxicephalus edulis</i> (lentic), <i>Heleophryne hewitti</i> (lotic).....	13
Figure 3: Illustration of tadpole oral structures, using <i>Amietia umbraculata</i>	14
Figure 4: Keratinized tadpole mouth parts. From left to right: <i>Heleophryne hewitti</i> , <i>Schismaderma carens</i> , <i>Amietia umbraculata</i> and <i>Semnodactulus wealii</i>	15
Figure 5: <i>Achnanthes subaffinus</i> as example of a diatom cell, as seen from (a) girdle view and (b) valve view.....	19
Figure 6: Map of Ndumo Game Reserve indicating the study location and sampling points (map compiled using GIS information)	25
Figure 7: Phylogenetic assessment of ecomorphological tadpole guilds using Parsimony criteria.....	35

Figure 8: Molecular Phylogenetic analysis of the anuran species of southern Africa, using Maximum Likelihood method on the data specific model (Nei, & Kumar, 2000).....	38
Figure 9: Percentage of anuran tadpole species from each ecomorphological guild, within each IUCN category.....	40
Figure 10: Ratios of food items in gut contents of tadpoles from four guilds; values represent averages from three specimens	43
Figure 11: <i>Halamphora turgida</i> (left) and <i>Navicula erifuga</i> (right).....	45
Figure 12: <i>Cymbella turgidula</i>	45
Figure 13: <i>Gomphonema pumilum</i> (left) and <i>Nitzschia amphibia</i> (right).....	46
Figure 14: Representative body forms of tadpoles from each ecomorphological guilds.....	58
Figure 15: Representation of Lentic-nektonic tadpoles' oral discs (<i>Kassina senegalensis</i>).....	64
Figure 16: Representation of Benthic-profundal tadpoles' oral discs (<i>Ptychadena anchietae</i>).....	65
Figure 17: Representation of Lentophytophilic tadpoles' oral discs (<i>Phrynomantis natalensis</i>).....	65

EQUATION

Equation 1: The Zelinka and Marvan (1961) formula most diatom indices are based on.....	32
--	----

ANNEXURES

Annexure A – Anuran acronyms

Table 1: Anuran species list and acronyms

Annexure B – Ecomorphological guild criteria

Table 1: Habitat variables considered for the delineation of ecomorphological guilds for the anuran tadpoles of southern African.

Table 2: Morphological variables considered for the delineation of ecomorphological guilds for the anuran tadpoles of southern African.

Table 3: Behavioural variables considered for the delineation of ecomorphological guilds for the anuran tadpoles of southern African.

Table 4: Anuran tadpoles of southern Africa's time to metamorphosis.

Annexure C – Genbank information

Table 1: Information on the genetic sequences obtained from Genbank for the anuran species of southern Africa.

Table 2: Genes available on Genbank for the anuran species used in this study

Annexure D – Anuran conservation status

Table 1: Conservation status of the anurans of southern Africa as given by the International Union for Conservation of Nature (IUCN) red list (IUCN, 2013).

Annexure E – Trophic data

Table 1: Relative abundance of components found in the gut content of representatives from four ecomorphological guilds.

Annexure F – Diatom data

Table 1: Relative abundance of diatoms quantified for samples taken in the Ndumo Nature Reserve.

Annexure G – Project exposure

11th Symposium of the Herpetological Association of Africa. Pretoria, South Africa, 2013.

Water Research Commission Project K5-2185