1. INTRODUCTION AND LITERATURE REVIEW

1.1 SYNOPSIS, PROBLEM STATEMENT AND SUBSTANTIATION

The functional design of an organism relates to its ecology by limiting the ability of the individual to perform key tasks in its daily life (Wainwright, 1991). It often seems that larvae receive less attention than the adult; this is true for many animal groups, as well as Amphibia. While an abundance of morphological data is available for anuran adults, tadpoles may well illustrate more distinct morphological characteristics. In spite of this, tadpoles have often been overlooked (Altig et al., 2007). Tadpoles should not be downgraded to frog add-ons: they represent an important phase in anuran life history (Randrianiaina et al., 2009).

Van Dijk (1972) divided South Africa’s tadpoles into six behavioural ecomorphological guilds making use of previous informal concepts of ecomorphological types (Figure 1). Using a fair amount of bias the tadpoles of South African’s frog species have been classified into six guilds according to their behavioural and some morphological characteristics (Van Dijk, 1972) (Figure 1). Altig and Johnston (1989) conducted a global survey of the morphology of exotrophic tadpoles. Focusing on oral structures, the authors offered various speculative scenarios and hypotheses regarding the functions of such structures. By taking tadpole morphology and behaviour into account, they characterized 18 ecomorphological guilds. However, only a few anuran species from South Africa formed part of this study. McDiarmid and Altig (1999) revised these ecomorphological guilds and recognized 15 guilds of exotrophic tadpoles. For this study morphology, ecology and known/ presumed feeding behaviour was considered. More species from southern Africa were also included. These guild delineations were however performed based on genus level and McDiarmid and Altig stated that “most of these ecomorphological classifications are based on similarity of appearance”. New amphibian species have since been discovered in South Africa, and a number of old species have been re-described/revised. Understanding of the oral morphology of the tadpoles in southern Africa has also expanded (Channing, 2001; du Preez et al., 2009). There is thus a need to revise South Africa’s ecomorphological tadpole guilds against the backdrop of recent advances in anuran taxonomy using a strong analytical approach.

Anuran species that have declined over time might share significant ecological characteristics, allowing one to differentiate between these species and other species that have not suffered decline (Williams & Hero, 1998). Certain threats to anurans might pose a greater risk to species that share a particular set of morphological characteristics. Assigning southern Africa’s tadpoles to specific ecomorphological guilds
will allow us to study the relationship between species found in the same ecomorphological guilds and their conservation status. Declining species may also be the indicators of an extensive deterioration in global environmental quality, seeing as both frogs and tadpoles are recognized as sensitive indicators of environmental health (Channing, 1999).

Tadpole diet characteristics and feeding behaviour is frequently associated to functional roles, and thus often play an important part in guild analyses (Williams & Hero, 1998; McDiarmid & Altig, 1999; Saidapur, 2001; Hall et al., 2002; Altig et al., 2007). The only easily quantifiable matter in the intestines of tadpoles, which are most probably purposely ingested are diatoms (Altig & Johnston, 1989). Diatoms are known for being good water quality indicators and diatom species’ position within a diatom community is specific (e.g. adnate, apically attached, short stalked or tall stalked) (Rimet & Bouchez, 2012; Wetzel et al., 2012). Diatoms could therefore also be indicative of tadpole mouthpart functionality, since some species are almost resistant to grazing yet are found in certain tadpoles’ gut contents (Stevenson et al., 1996; Botha et al., 2011).

1.2 Anuran Tadpole Ecomorphology and Phylogeny

Investigating tadpole ecomorphology is a valuable field of research, especially in light of the rapid worldwide decline of amphibians from even pristine environments (Hero, 1996; Kouba et al., 2013). Indeed, tadpoles are important for monitoring and conservation, as tadpoles are reasonably common and often easier to find than adult frogs and toads (Channing et al., 2012). Despite this, tadpoles are often overlooked, and have not been studied as much as other groups found in freshwater ecosystems, like fishes and macro-invertebrates (Altig et al., 2007). Knowing more about the morphology and ecology of tadpoles is also crucial in order to better grasp the ecological requirements of the adult frogs and toads (Raharivololoniaina et al., 2006).

Ecomorphology deals with the covariation of ecology and morphology, with behavioural studies being an important link between functional morphology and ecological research (Winkler, 1988; Bock, 1994). Ecomorphological tadpole guilds can be used to infer information related to guilds that were not directly examined. As an illustration Peltzer & Lajmanovich (2003) were able to address the differences in microhabitat use and feeding preferences of tadpole species based solely on their categorization of ecomorphological guilds. Assigning species into ecomorphological guilds provides insight into complex biogeographical patterns, spatial patterns of species richness as well the ecological diversity of species within a community structure (Williams & Hero, 1998; Alford, 1999).
Amphibians significantly contribute to the rich biodiversity of southern Africa, serving as additional motivation to protect various areas. Due to anuran species permeable skins and the requirement of both aquatic and terrestrial habitats to complete their life cycle, they tend to be the more sensitive species present in most ecosystems. For example Williams and Hero (1998) found that nearly all of the specialist frog species endemic to the Wet Tropics of Australia (three ecological guilds) have declined or are absent. This is not due to a single characteristic, but a combination of characteristics (Williams & Hero, 1998). These results have serious implications for the long-term preservation of biodiversity and assigning tadpoles to ecomorphological guild might provide insight to which combination of characteristics might result in future declines (Williams & Hero, 1998).

A number of tadpole characters, particularly the external characters (e.g. mouthparts, etc.) have been an important part of anuran systematics for over 60 years now (Orton, 1953; Orton, 1957; Duellman & Trueb, 1986; Ford & Cannatella, 1993). Orton (1953 & 1957) first anticipated that various tadpole morphological characteristics could be used to recognize phylogenetic patterns in amphibians. In 1999, Channing performed a historic overview of anuran systematics in southern Africa. From his study the following was evident: From 1800 to 1912 operatives were mainly based in European museums, working with specimens submitted by non-scientists (missionaries, government officials, etc.). Systematic efforts for the most part were checklists, with the various taxa prearranged according to other major lists. From 1913 to 1944 the significance of field data in systematics was acknowledged, and groupings were made based on similarity (many puzzling anomalies). The interpretation of data was however still seen as merely the experts’ opinion. Only after cladistic methodology was published in 1966 in English (Hennig, 1966), did a range of new computer software using this ground-breaking approach to phylogenetic systematics follow. This discovery allowed data-rich analyses to be used, instead of arrangements centred on the experts’ opinions. One analysis nevertheless meant many hours of calculation on mainframe computers. During the 1972 to 1999 period, simplified biochemical techniques became available. Such techniques enabled more laboratories to use protein, chromosome and DNA sequences to distinguish between taxa.

When investigation of southern African tadpoles began, a considerable amount of comparative morphological preconceptions existed, and as investigation continued they were further accompanied by an array of systematic preconceptions (Van Dijk, 1972). Van Dijk published two papers (1966 and 1971) in which he reviewed various morphological traits of southern African tadpoles. This led to subsequent publications including more information on tadpole morphology, as opposed to previous publications that were dominated by the morphology of adult frogs and toads (Channing, 1999). Channing (1999) noted that “many of the genera that had previously been lumped were easily separated using tadpoles”.

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In 1972 Van Dijk distinguished between different modes of behaviour of southern African tadpoles, using informal concepts of ecomorphological kinds recognized by Orton (1953), and an extensive body of observations on the ecology and behaviour of these tadpoles (Van Dijk, 1972). Only the anuran genus level (with the exception of 15 species) was noted and genera were assigned to different guilds based on behavioural traits. Species levels were used when a range of behaviours was distinguished and all the species in a genus were regarded as having similar behaviour, unless otherwise stated.

Most of the genera were however assigned to more than one of these behavioural modes without specifying which species were being referred to (Figure 1). When sorting species into eco-morphological guilds, it is important to bear in mind that the scheme is a continuum, which is clear from Van Dijk’s delineation in Figure 1. It should also be kept in mind that no clear analytical approach was identified for this distinction (Orton, 1957). Given that technology and software advanced considerably since 1970, the methods of systematics improved, allowing data-rich analyses to be used instead of arrangements based mainly on the researchers’ bias (Channing, 1999).

In Altig and Johnston (1989) a global survey of tadpole morphology, emphasising exotrophic tadpole oral structures was performed. Although this study also contained bias, they applied a more analytical approach than Van Dijk (1972) did. During the Altig and Johnston (1989) study, both morphology and behaviour were taken into account. This permitted the recognition of 18 fully characterised ecomorphological guilds. Altig and Johnston incorporated Van Dijk’s findings into their study, and included species from 12 of southern Africa’s anuran genera (Altig & Johnston, 1989). This study further stimulated investigation regarding the interactions between functional morphology and ecology. McDiarmid and Altig (1999) revised Altig and Johnston’s (1989) ecomorphological guilds and recognized 15 guilds of exotrophic tadpoles. For this study morphology, ecology and known/presumed feeding behaviour was considered. More species from southern Africa were also included. These guild
delineations were however performed based on genus level data and McDiarmid and Altig (1999) stated that “most of these ecomorphological classifications are based on similarity of appearance”. In 2011 Both et al. conducted a study to classify tadpoles from southern Brazil into ecomorphological guilds. This study was based on criteria suggested by McDiarmid and Altig (1999). The southern Brazilian species were classified into six guilds; none of these occur in southern Africa.

Haas (2003) presented a phylogenetic analysis based mainly on external tadpole features to analyse the contribution of such a data set to the discussion of anuran phylogeny. The findings confirmed a range of recognised clades, and included, among others, the Bufonidae, Dendrobatidae, Hyperoliidae, Microhylidae, and Pipidae.

1.3 TADPOLE MORPHOLOGY AND KNOWN FUNCTIONALITY

Exotrophic tadpoles are essentially free-living embryos that orally consume a number of sources of energy, which are not derived from the parent. They reach a developmental climax (majority of features) at Gosner (1960) stages between 32 and 40 (Altig, 2007; Grosjean, 2005). The majority of the characters mentioned below are used for tadpole identification (Lambiris, 1988; McDiarmid & Altig 1999; Dorcas & Gibbons, 2008; du Preez et al., 2009; Channing et al., 2012).

1.3.1 TADPOLE ORAL STRUCTURES

Initially tadpole guilds were characterized based on microhabitat, kind of development and external morphology, until Altig and Johnston (1989) brought internal oral structures into consideration (Vera Candioti et al., 2010). The oral disc consists of anterior (upper) and posterior (lower) lips (labia); these are free at the outer margins (Figure 3) (Altig, 1999; Channing et al., 2012). Depending on the taxa, the oral disc is orientated anywhere from anterior to ventral, reflecting ecological differences (Figure 2) (Altig & Johnston, 1989; Altig, 1999; du Preez et al., 2009).

![Figure 2: Tadpole oral disc orientation, body form and tail fin variation. From left to right: Leptopelis natalensis, Pyxicephalus edulis (lentic), Heleophryne hewitti (lotic).](image)
Papillae (Figure 3) vary greatly in density and distribution in tadpoles (Altig, 1999). The oral discs have two regions of papillae, namely marginal papillae and submarginal papillae; the first being situated on the rim of the oral disc and the later the face of the oral disc (Altig, 1999; Channing et al., 2012). The papillae are believed to serve as tactile and chemosensory receptors, while also assisting in attachment to substrates, control of water flow and accumulation of food (Altig & Johnston, 1989; Altig, 1999; Saidapur, 2001; Altig, 2010).

![Figure 3: Illustration of tadpole oral structures, using *Amietia umbraculata.*](image)

Keratin (dark protein) is a strong light weight compound that is deposited on single epidermal cells of the labia to form small, complex keratinized labial teeth (Figure 3) (Vera Candiotti et al., 2010; Channing et al., 2012). The labial teeth, also known as keratodonts, are arranged in rows on tooth ridges and can grow and be replaced (Channing et al., 2012). Vera Candiotti et al. (2010) examined the interspecific shape variations in the labial teeth in order to determine whether a correlation exists between the varying structures, ecomorphological guilds and phylogeny. Their results indicated that there was no significant correlation between ecomorphological guild and labial tooth shape ordination, implying that harvesting ability may for the most part only be functional under certain circumstances (Vera Candiotti et al., 2010). Ecomorphological effects independent of phylogenetics, were found to be significant for gastromyzophorous and lotic suckorial guilds only (Vera Candiotti et al., 2010).

Keratinized jaw sheaths (Figure 3) often have serrated cutting edges, cover the anterior and posterior cartilages found in tadpole mouths, and are formed by the fusion of cellular arrays (Luckenbill, 1965; Altig, 1999; Channing et al., 2012). Jaw sheaths, also known as rostroodonts (Figure 4), vary across taxa.
and can be absent, delicate, moderate, or massive indicating numerous performance abilities (Saidapur, 2001; du Preez et al., 2009).

![Image](image.png)

**Figure 4:** Keratinized tadpole mouth parts. From left to right: *Heleophryne hewitti*, *Schismaderma carens*, *Amietia umbraculata* and *Semnodactulus wealii.*

### 1.3.2 TADPOLE BODY MORPHOLOGY IN RELATION TO HABITAT AND BEHAVIOUR

Correlations between the phenotypes of organisms and the habitats they occupy have been noted for some time now. This is also true for tadpoles concerning their body forms, oral morphology and the habitats they reside in (Orton, 1953; Orton, 1957; Altig & Johnston, 1989; Strauss & Altig, 1992; Altig, 1999; Van Buskirk, 2009). Tadpoles do not have much control over the general habitat type they occupy, since this is determined by the adults’ choice of spawning site (Alford, 1999). Tadpoles have a rather simple body form, consisting of a head and a tail that can be anything from streamlined to bulbous; and many features that make it possible for them to be very successful (Altig, 1999; Alford, 1999; Channing et al., 2012). When the frog morphotype begins to appear in the form of the front legs erupting through the opercular wall, the atrophy of the oral apparatus follows immediately in most tadpoles (Altig, 1999).

Tadpole feeding behaviour is frequently associated with functional roles (McDiarmid & Altig, 1999; Altig et al., 2007). It is therefore important to obtain information on feeding behaviours in order to understand the tadpoles’ ecological roles. Once tadpole behavioural ecology is known it will also be possible to better understand the morphological variations and the ecological importance of these features (McDiarmid & Altig, 1999; Saidapur, 2001). Van Buskirk (2009) set out to determine the associations between tadpole morphology and habitat. He found that the majority of variation in shape is related to the time area in which a soil area/wetland is waterlogged and the tadpoles foraging position within the water column. He also found that the shape of the mouth did not directly relate to the habitat. The only significant correlation when taking the oral disc into account, was that pond dwelling species had more robust jaw sheaths than that of stream dwelling species.

The tadpoles of many frog species have been observed to choose a diversity of microhabitats within the same water body; this selection correlates with their morphological characteristics and is a vital strategy in ensuring their survival and growth (Alford, 1999; Saidapur, 2001). Tadpole tail characters influence
microhabitat choice and swimming capabilities. For example, the musculature of pond dwelling or lentic tadpoles are generally weak with larger fins (for fast acceleration) that are attached high on the head. In contrast, lotic or stream-dwelling tadpoles have stronger musculature and reduced fins which are longer and attached lower (shallow) on the head (Figure 2) (Altig & Johnston, 1989; Saidapur, 2001; Van Buskirk, 2009; Channing et al., 2012). The longer shallow tails are also seen in benthic tadpoles (Van Buskirk, 2009). Tadpoles’ eye position is also related to the microhabitat. Tadpole eyes may be located anywhere from the lateral side of the head to dorsally positioned (Altig & Johnston, 1989; du Preez et al., 2009; Channing et al., 2012). For example, bottom-dwelling tadpoles have dorsal eyes, while pelagic and stream-dwelling tadpoles have lateral eyes (Van Buskirk, 2009; Channing et al., 2012). Various morphological characteristics equip tadpoles to occupy specific microhabitats; these morphological characteristics and microhabitat selection correlate with the behavioural patterns expressed by tadpoles.

Tadpoles exhibit behavioural patterns such as aggregation. Similarities in aggregation behaviour may however occur in species that are not closely related (Caldwell, 1989; McDiarmid & Altig, 1999). Three types of aggregation behaviour has been identified: Type I includes species that form schools at the bottom of shallow waters, where they are polarized (tadpoles orientated in the same direction)/not polarized (not all orientated in the same direction) and loosely aggregated; Type II contains species that are strongly polarized in midwater and do not come in contact with one another; Type III include species that are always in contact with one another, although well-organized into polarized schools that are found throughout the water column (Caldwell, 1989; Hoff et al., 1999).

Tadpoles exhibit a wide range of behavioural patterns, these patterns may however be influenced when optimal conditions drastically change. The following speculative scenario was suggested in the absence of more information on a typical pond tadpoles’ feeding biology (Schesari, 2004; Altig, 2006): The pond tadpole performs mainly as a carnivore and under specific circumstances may employ three different feeding modes. Scenario one; the jaws function most effectively and the labial teeth are used primarily for stabilization when a reasonably tall over-story (e.g. fibrous periphyton) is harvested without creating a particulate suspension. Scenario two; the labial teeth work most effectively when feeding on very thin layers (e.g. diatom films) and a partial particulate suspension is created (captured by buccopharyngeal structures). Scenario three; naturally suspended particles are captured mainly by using food traps.
Alternative tadpole feeding behaviour, most probably caused by a lack of preferred food items, has also been observed (Altig et al., 2007). These include, feeding on the surface film while overturned (ventral side up), digging of feeding pits, as well as switching from rasping to suspension feeding (Altig et al., 2007). Altig (2006) suggested that a range of functions might be exhibited when crucial/extreme conditions (e.g. competition due to differential feeding abilities) demand interspecific alterations in feeding ecology.

1.4 Exotrophic Tadpole Diet

Tadpole diet characteristics and feeding behaviour is frequently associated to functional roles, and thus often play an important part in guild analyses (Williams & Hero, 1998; Saidapur, 2001; Hall et al., 2002; Altig et al., 2007). Ecologists generally viewed tadpoles as herbivores, occupying only the lower trophic levels in aquatic communities, with the exception of certain tadpoles exhibiting phenotypic, nutritional, and niche specializations (Alförd, 1989; Petranka & Kennedy, 1999). Since tadpoles possess keratinized labial teeth and jaw sheaths, structures associated with suspension feeding, and protracted guts, trophic specialists labelled the majority of tadpoles as omnivorous, microphagous suspension feeders (Petranka & Kennedy, 1999). Strong evidence of opportunistic feeding, carnivory and differentiation within feeding niches among phenotypically generalized tadpoles have since been observed, providing evidence for ontogenetic niche shifts and much diversity in feeding niches and tadpole diets (Petranka & Kennedy, 1999; Schiesari, et al, 2009). The true trophic status of many tadpoles species is still unknown and tadpoles may well affect various trophic levels as they age (Altig et al., 2007; Ghioca-Robrecht & Smith, 2011).

Similarity in tadpole diet is related to the interaction of several parameters. These parameters include feeding behaviour, microhabitat and the taxonomic relationship between tadpole species. However, ecological separation of different tadpole species does occur (Gosner, 1959; Rossa-Feres et al., 2004). Tadpole diet selection may reveal responses to ecological changes, responses which would increase development, growth and survival (Richter-Boix et al., 2007). The majority of tadpole species may however, not be specialized feeders, instead their feeding emphasis may shift in relation to certain foods in their environment being more abundant (Altig & McDearman, 1975). Though occupying the same or similar habitats, different tadpole species might make use of different feeding methods and even choose various materials to feed on (Gosner, 1959).

In most tadpole species, there is no clear relationship between the shape of the labial teeth and the food they favour (Vera Candioti et al., 2010). However, labial tooth shape will affect the way and the extent to which the tadpole can come into contact with the substrate, as well as the pressure the tadpole will be able
to exert to keep the tooth implanted and aligned (Altig & Johnston, 1989; Vera Candioti et al., 2010). It has been observed that the same sized tadpoles from different species are influenced by various physical and biological factors, for example one species could consistently penetrate and remove pieces from an agar-based food source, while the other was not able to (Altig & Johnston, 1989). Thus even though there is no clear relationship between the shape of the labial teeth and the food most tadpole species favour, the tadpoles’ ability to consume certain foods is still affected by the keratinized mouth parts.

Tadpoles have lengthy guts with weak peristalsis and an alkaline pH (Altig and McDearman, 1975, Ghioca-Robrecht & Smith, 2011). The foregut increases with increase in body size, and the surface area (for absorption of nutrients) is increased by length (Altig and McDearman, 1975, Ghioca-Robrecht & Smith, 2011). Despite the long gut, and tadpoles eating large quantities of food in relation to their body size, their digestive efficiency is rather poor (Altig and Kelly, 1974). Food is rapidly passed through the gut – tadpoles have short clearance time in comparison to other trophic groups. However, this may change in reaction to a number of factors (e.g. food quality, population density, temperature, etc.) (Altig & McDearman, 1975; Altig & Johnston, 1989). Altig and Kelly (1974) found that carnivorous tadpoles have less voluminous, undersized guts compared to herbivorous tadpoles. The gut of a tadpole also has the ability to change in structure (from less voluminous to more) relating to diet, indicating that suitable diets can vary significantly (Altig et al., 2007). Gut content analysis has also indicated interspecific differences in tadpole diets and non-selective feeding in terms of spatial and temporal position as well as composition of gut content (Altig & Johnston, 1989).

A rather extensive list of material ingested by tadpoles has been reported, which include: higher plant tissue (e.g. Macrophyta) and products (e.g. pollen); algae (benthic, phytoplankton, filamentous) as well as their extracellular products; zooplankton; arthropods (mainly crustaceans); organic debris or detritus (unidentified organic particles) and associated microorganisms (bacteria and meiofauna); and inorganic material (e.g. minerals, sediments) (Gosner, 1959; Altig & Kelly, 1974; Altig & Johnston, 1989; Petranka & Kennedy, 1999; Ranvestel et al., 2004; Ghioca-Robrecht & Smith, 2011). Of these ingested items, detritus and diatoms are found most frequently (Altig & Johnston, 1989; Ghioca-Robrecht & Smith, 2011). Diatoms are the only easily enumerated items in tadpole guts (Altig & Johnston, 1989). The majority of the plant materials mentioned could remain undigested (with only some nutrients removed) during gut passage, because it is protected by thick cell walls. Detritus’ nutritional value has been suggested to lie in the associated microbes and not the particles themselves (Altig & Johnston, 1989). Although tadpoles do not seem to fully digest and retain the majority of the nutrients they ingest, it is assumed that they are able to obtain nutrients from a large range of materials.
1.5 ENVIRONMENTAL APPLICATIONS OF DIATOMS

Diatoms are unicellular, microscopic algae, with uniquely ornamented siliceous cell walls (frustules) (Figure 5). These primary producers are widely distributed in many, if not all aquatic environments, and compose approximately 40% of any given algal community. Thus a change in this fundamental part of the aquatic community could disrupt the balance of the whole ecosystem (Round et al., 1990; Stoermer & Smol, 2004). Benthic diatoms grow attached to submerged substrata such as sediment, woody and herbaceous plants and rocky substrata.

Figure 5: Achnanthes subaffinus as example of a diatom cell, as seen from (a) girdle view and (b) valve view.

Diatom communities react rapidly and with specificity to changes in environmental conditions such as eutrophication, organic enrichment, salinization and changes in pH (Van Dam et al., 1994). Due to their high dispersal rates, rapid growth rate, and direct response to environmental changes, algae provide the first indication of changes and are thus one of the most widely used indicators of biological integrity and physico-chemical conditions in aquatic ecosystems.

Diatoms’ potential as water quality indicators in South Africa was initially realized by Cholnoky, who found a good correlation between the diatom communities’ species composition and the water quality (Taylor et al., 2007a). This potential was only thoroughly investigated several years later, where after it was concluded that benthic diatoms might be a useful addition to the National Biomonitoring Program for Riverine Ecosystems (NBPAE), since benthic diatoms provide a time-integrated indication of certain water quality constituents (Hohls, 1996; Bate et al., 2002). Efficient and cost-effective techniques for routine river monitoring include diatom-based pollution indices, as opposed to conventional chemical monitoring techniques and the measuring of algal biomass (Belton et al., 2005; Talyor et al., 2007a). Diatoms are relatively easy to sample and permanent records can be made from each sample collected. They differ from fish and macro-invertebrates in that (in general) they do not need any specialized food, habitat, depth or velocity of water, and they occur anywhere where there is water. For these reasons, the use of diatoms for bioassessment may provide a valuable tool for inferring water quality.
The cumulative response of diatoms to environmental stressors can be reflected as an index score. Diatom indices function in the following manner: in a sample from a body of water with a particular level or concentration of determinant (e.g. phosphorus), diatom taxa with their optimum close to that level will be most abundant. Therefore an estimate of the level of that determinant in the sample can be made from the average of the pollution sensitivity of all the taxa in that sample, each weighted by its abundance. This means that taxa that are found frequently in a sample have more influence on the result than taxa that are rare. A further refinement is the provision of an ‘indicator value’ which is included to give greater weight to those taxa which are good indicators of particular environmental conditions. In practice, use of diatom indices involves making a list of the taxa present in a sample, along with a measure of their abundance. The index is expressed as the mean of the pollution sensitivity of the taxa in the sample, weighted by the abundance of each taxon. The indicator value acts to further increase the influence of certain species (Harding & Taylor, 2011).

Examples of these autecological indices include: Descy’s index or DES (Descy, 1979) is one of the first true diatom indices and deduces the average pollution level. The application of this index would however be futile in South Africa, seeing as the index takes only a few (±20) species into account. Schiefele and Schreiner’s index or SHE (Schiefele and Schreiner, 1991) has been applied to the monitoring of nutrient enrichment, acidification and impact salts, among others. The Specific Pollution Sensitivity Index was developed and refined over a period of 20 years in France. This index has been tested in South Africa for 9 years and was found to accurately reflect water quality (Coste & Ayphassorho, 1991; de la Rey et al., 2004). The Biological Diatom Index or BDI (Lenoir & Coste, 1996) is also applicable in South Africa, as past studies indicated a strong relationship to general water quality (Taylor, 2007a). The Generic Diatom Index or GDI (Coste & Ayphassorho, 1991) is a pollution index, which only requires identification up to genus level, making it one of the simplest indices to use. The Percentage Pollution Tolerance Valves or %PTV (Kelly & Whitten, 1995) makes use of the percentage pollution-tolerant taxa present to illustrate the level of organic pollution within a river, and was designed to apply if the %PTV present influences the ability of other indices to make accurate assessments.
1.6  RESEARCH AIM AND OBJECTIVES

The aim of this study was to test the applicability of anuran tadpole functional ecology with regards to diet as a tool for determining ecosystem function in aquatic habitats.

Specific objectives include:

- All the presently known southern African anuran species’ tadpoles assigned to ecomorphological guilds, using multivariate statistical analysis and applying more resent terminology and concepts.
- Determine if there is a link between species found in the same ecomorphological guilds and those species’ conservation status.
- Quantify tadpole gut contents (diet in percentage values) and use data obtained from gut content analysis to verify/support the ecomorphological guilds.

Furthermore, 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, this study will also aim to supplement the assessment of ecosystem functioning, and management of aquatic resources of the Lower Phongolo River and floodplain, by meeting the following objective.

- Provide information regarding the health of the Lower Phongolo River and floodplain, as portrayed by diatom analyses of the current diatom communities as sampled from riverine substratum.