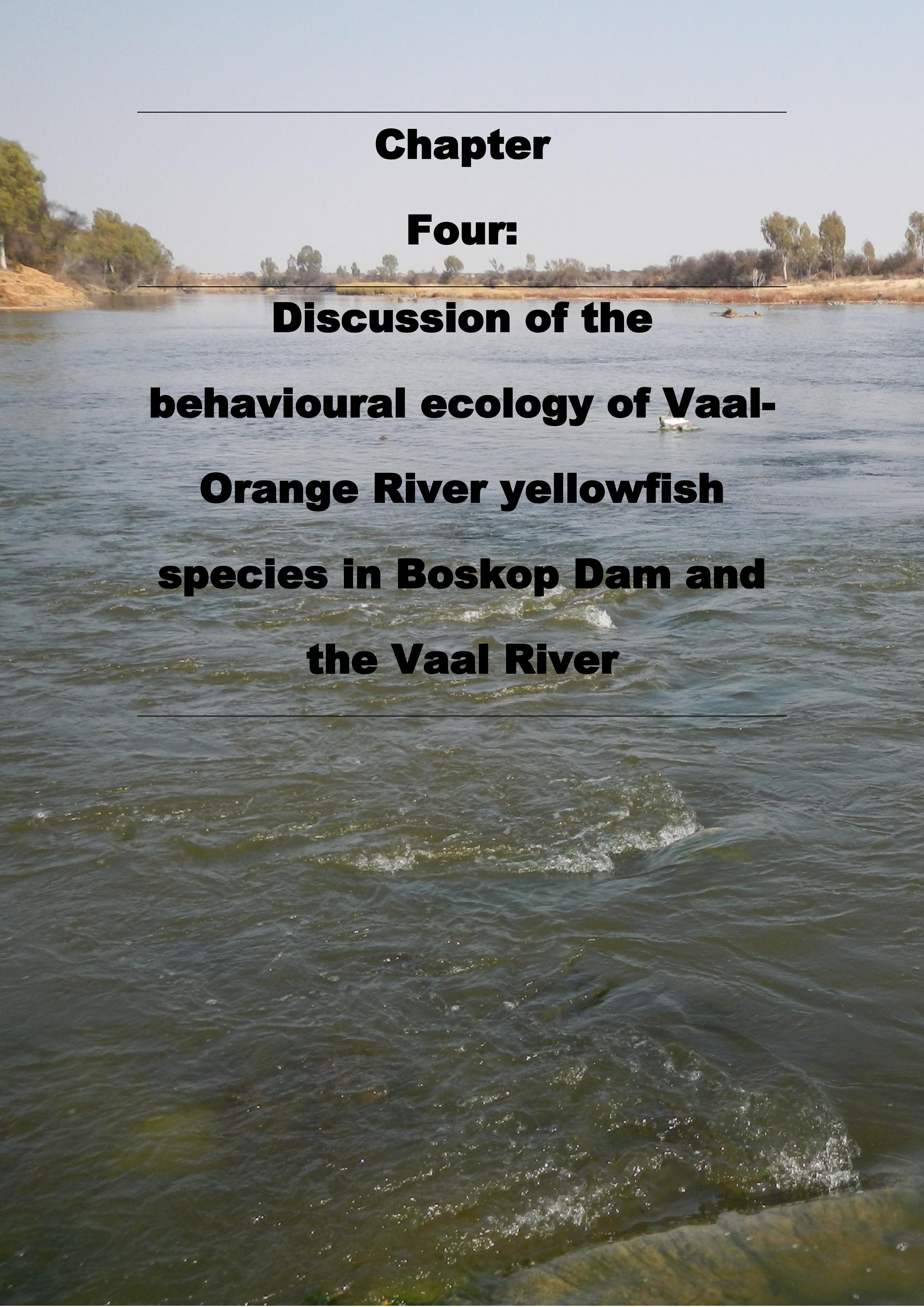
Chapter Four:

Discussion of the behavioural ecology of Vaal-Orange River yellowfish species in Boskop Dam and the Vaal River



4 Discussion of the behavioural ecology of Vaal-Orange River yellowfish species in Boskop Dam and the Vaal River

4.1 Behavioural ecology of *Labeobarbus aeneus* in Boskop Dam

From the results of the radio telemetry methods applied in the lentic system (Boskop Dam) for one year, it is possible to successfully identify movement, habitat use and activity of *L. aeneus* in Boskop Dam.

Labeobarbus aeneus in Boskop Dam shows higher movement activity during daylight hours (04:00-08:00, 12:00-16:00) with lower movement activity during nocturnal periods of the day (20:00-24:00, 00:00-04:00). This trait can be expected in *L. aeneus* as it is well documented that when a predator's prey is relatively smaller than itself, searching for prey items forms the greater part of the foraging time occupied (Godin, 1997). Furthermore one of the most important food sources for *L. aeneus* is benthic prey which requires a more mobile foraging tactic in lentic systems (Gaigher and Fourie, 1984; Godin, 1997; Skelton, 2001). Higher light intensity during daytime may be the trigger for *L. aeneus* to actively start searching for prey, as movement activity increases with higher light intensity. When light intensity decreases during night time, movement activity also decreases, suggesting that *L. aeneus* change the foraging tactic that they use during daytime. Studies on the blacksmith (*Chromis punctipinnis*) on a reef off Santa Barbara in California have shown the same behaviour. This species spends the night time in crevices and start actively foraging and searching for prey during daylight hours (Bray, 1981; Godin, 1997). These findings are further supported by notes from Joubert (1970) who commented on the best methods of targeting *L. aeneus.* He suggested that the best time to fish for them was during midday (12:00-16:00), because they 'seem to be more actively feeding during these times than any other time of the day'.

This behaviour by tagged individuals is correlated with the use of deeper water during periods of high light intensity periods during the day (04:00-08:00, 12:00-16:00) whereas they moved to shallow areas during periods of low light intensity during the night (20:00-24:00, 00:00-04:00). Fish preferring deeper habitats when light intensity is highest (04:00-08:00, 12:00-16:00) could be a defensive reaction to avoid predators (Cerri, 1983). The risk of becoming prey while foraging can influence diet selection to such an extent that individuals may prefer less profitable prey in safer areas (Godin, 1990; Sih, 1993). Studies on coho and Atlantic salmon (*Salmo salar)* show that when individuals are simulated with a threat of predation, they become reluctant to move away from their refuge areas (Dill and Fraser, 1984). This, however, implies that prey items which were more profitable far away are traded for prey items that are closer but less profitable (Godin, 1990). Hugie and Dill (1994) further suggest that when predators (*L. aeneus*) become prey (*L. aeneus*) individuals are sometimes forced to avoid habitats (shallow water) at certain times of the day, therefore avoiding humans, otters and avian predators that were observed in the area (Cerri, 1983; Godin, 1990; Sih, 1993). *Labeobarbus aeneus* moving to deeper (safer) water during these periods may incur certain costs (Werner *et al.,* 1983). The increased movement activity during these periods might be a cost that is needed to make foraging in deeper water profitable (Schlosser, 1988; Harvey and Stewart, 1991; Godin, 1997). Studies on other cyprinid species have found that forager show higher movement activity due to higher light intensity, as prey items are more difficult to catch because of higher light intensity and therefore better visibility (Cerri, 1983). Another possibility for *L. aeneus* moving to deeper water during high light intensity might be that better light penetration and increased visibility allow individuals to forage more effectively in deeper water (Gaigher and Fourie, 1984; Skelton, 2001).

This reaction to light intensity is also prominent during full and new moon phases. During the full moon (higher light intensity) *L. aeneus* in Boskop Dam showed higher movement counts than during new moon phases. This is the same reaction they exhibited during daylight and night periods of a day. Individuals preferred deeper water during full moon phases than they did during new moon phases, possibly for the same reasons as higher light intensity during day time.

Results from movement counts during seasonal variations are inconclusive as seasonal data from each individual were not recorded through all four seasons. Limitations of the radio tags may have caused these gaps in data through some of the seasons. Movement activities during spring and summer are significantly ($P<0.05$) higher than during autumn and winter. Movement counts were significantly higher ($P<0.05$) with increased temperatures and shallower water in summer whereas movement significantly decreased ($P<0.05$) with decreased temperatures and increased depth in autumn and winter. This decrease in movement from spring and summer to autumn and winter has also been documented for *L. aeneus* in the Vaal River (O'Brien *et al*., 2013). Lower movement suggest that *L. aeneus* spend less energy moving around. It may be that movement during these seasons becomes metabolically costly when water temperatures reach a certain point (Brett and Groves, 1979). Studies on another large cyprinid the mahseer (*Tor putitora*) a relative of the *L. aeneus* species, showed that they do not feed below 16°C and show very little movement during these temperatures (Akhtar, 2002). This has also been documented in other Cyprinidae species including *Cyprinus carpio* where feeding stops completely at temperatures of 10°C and movement activity decreases notably (Eccles, 1985; Akhtar, 2002). This might be the case for *L. aeneus,* that when water temperatures reach a certain point they stop feeding or change foraging tactics (Godin, 1997).

The low movement activity during autumn and winter is correlated with *L. aeneus* moving to deeper water. This reaction to changing seasons is associated with higher atmospheric pressure and lower temperatures; however, no significant ($P>0.05$) relationship between movement and atmospheric pressure could be identified. *Labeobarbus aeneus* in Boskop Dam may avoid high movement activity during these seasons as the specific oxygen consumption will be lower in colder temperatures as a result of a reduction in metabolism (Eccles, 1985). *Labeobarbus aeneus* can therefore survive certain periods within these seasons being relatively stationary and immobile. Cold water can carry more oxygen than hot water; therefore the oxygen percentage in colder water is sufficient to allow *L. aeneus* to exert minimum movement activity during certain periods (Eccles, 1985).

The movement of *Labeobarbus aeneus* is significantly ($P<0.05$) higher during spring and summer than during autumn and winter. *Labeobarbus aeneus* is an omnivorous feeder which relies mainly on plankton, algae, insects and insect larvae, which greatly increase during spring and summer (Mulder, 1973; Skelton, 2001). Therefore *L. aeneus* has higher movement during this 'fertile' period of the year and show increased movement activities possibly due to increased foraging. The depth parameters during these two seasons also suggest that *L. aeneus* spend generally more time in shallower water even sometimes feeding on the surface than they do during autumn and winter. Another possibility of the increased movement during spring in summer is spawning activities. Ripe and running males can already be found late in August (winter), but the main spawning event is in October (spring) with a possible second spawning event in January (summer) (Mulder, 1973; Skelton, 2001, De Villiers and Ellender, 2007; Skelton and Bills, 2007). Males and females were found ripe and running in Boskop Dam during various monitoring surveys, suggesting that they also spawn during this time period. Some of the data collected during spring and summer (spawning period) by remote monitoring station one were definitely not spawning activity, as individuals never stayed in that specific area, and had to swim past this station to reach the inlet of the dam (Mooi River). This area around remote monitoring station one also lacks the spawning habitat for *L. aeneus*. *Labeobarbus aeneus* in reservoirs are known to spawn in inflowing rivers and shallow rocky bays were wind-driven currents are created (Tomasson *et al*., 1984; Impson, 2007). This study has identified two possible spawning areas. One spawning area is on gravel beds within the Mooi River at the inlet of Boskop Dam and the other is in a manmade rocky bay near the Department of Water Affairs (DWA) Regional Office on the southern bank. The manmade rocky bay at Water Affairs is built at an angle were wind creates the necessary current that yellowfish prefer for spawning (De Villiers and Ellender, 2007). None of the tagged individuals were recorded using these spawning areas, but *L. aeneus* was seen on numerous occasions spawning in these areas.

Labeobarbus aeneus in Boskop Dam move around in shoals that can be seen around the entire study area. This behaviour was also observed in the suitability assessment where shoals of *L. aeneus* were always captured as opposed to single individuals. From the amount of data obtained by remote monitoring station five (n=4 895) which formed the bulk of the data, it is possible that *L. aeneus* chose this as a refuge area during autumn and winter. This area had a depth of up to 8 000 mm and consisted of various habitat types including rocky substrates, weeds, grass beds and reeds. *Labeobarbus aeneus* were also sampled in this area during the suitability assessment of Boskop Dam in winter, which further supports the notion that this area may possibly be an important refuge area during autumn and winter. Furthermore, this area is situated inside a small protected area within the nature reserve, and is closed to the public for fishing and other water-related activities. This area is already classified as a management area in the Boskop Dam Nature Reserve and it is thus further emphasised to be a very important refuge area for *L. aeneus* in Boskop Dam. It is suggested that stricter rules and regulations be applied to this specific area, to increase conservation and protection of this highly utilised species in Boskop Dam.

Observation notes on possible predatory behaviour of *Labeobarbus aeneus* in Boskop Dam

Species within the Cyprinidae family are known to change their feeding habits to adapt to changing environmental conditions. Individuals of the same species have often been described as a herbi-omnivore and carnivorous feeders that feed mainly on algae, molluscs, micro vegetation and insects, but also hunt small fishes if conditions permit (McDonald, 1948; Kaushal *et al.,* 1980; Dubey, 1985; Shrestha, 1997). Individuals within the same species may also have different morphological variations in their jaws. Variation in jaw morphology is usually associated with different feeding behaviours, which may change in different environments (Jubb, 1967; Bloomer *et al.,* 2007). *Labeobarbus aeneus* in Boskop Dam is possibly using different foraging tactics where fish could forage on invertebrates and then change to hunting small fishes (Gaigher and Fourie, 1984; Wootton, 1984; Hart, 1996). The clarity of Boskop Dam should allow for predatory behaviour of *L. aeneus* on smaller fish species. This phenomenon has been witnessed on numerous occasions were *L. aeneus* would actively hunt small fishes on the water surface. The jaw morphology of *L. aeneus* in Boskop Dam (Figure 61A-B) furthermore resembles that of more predatory fish like *L. kimberleyensis* (Figure 61C-D) whose jaw morphology differs from fishes only foraging on invertebrates (Figure 61E-G). *Labeobarbus aeneus* in Boskop Dam may possibly be more predatory compared to *L. aeneus* in rivers. This is furthered supported by numerous *L. aeneus* specimens caught on artificial lures by anglers targeting *M. salmoides* around the dam.

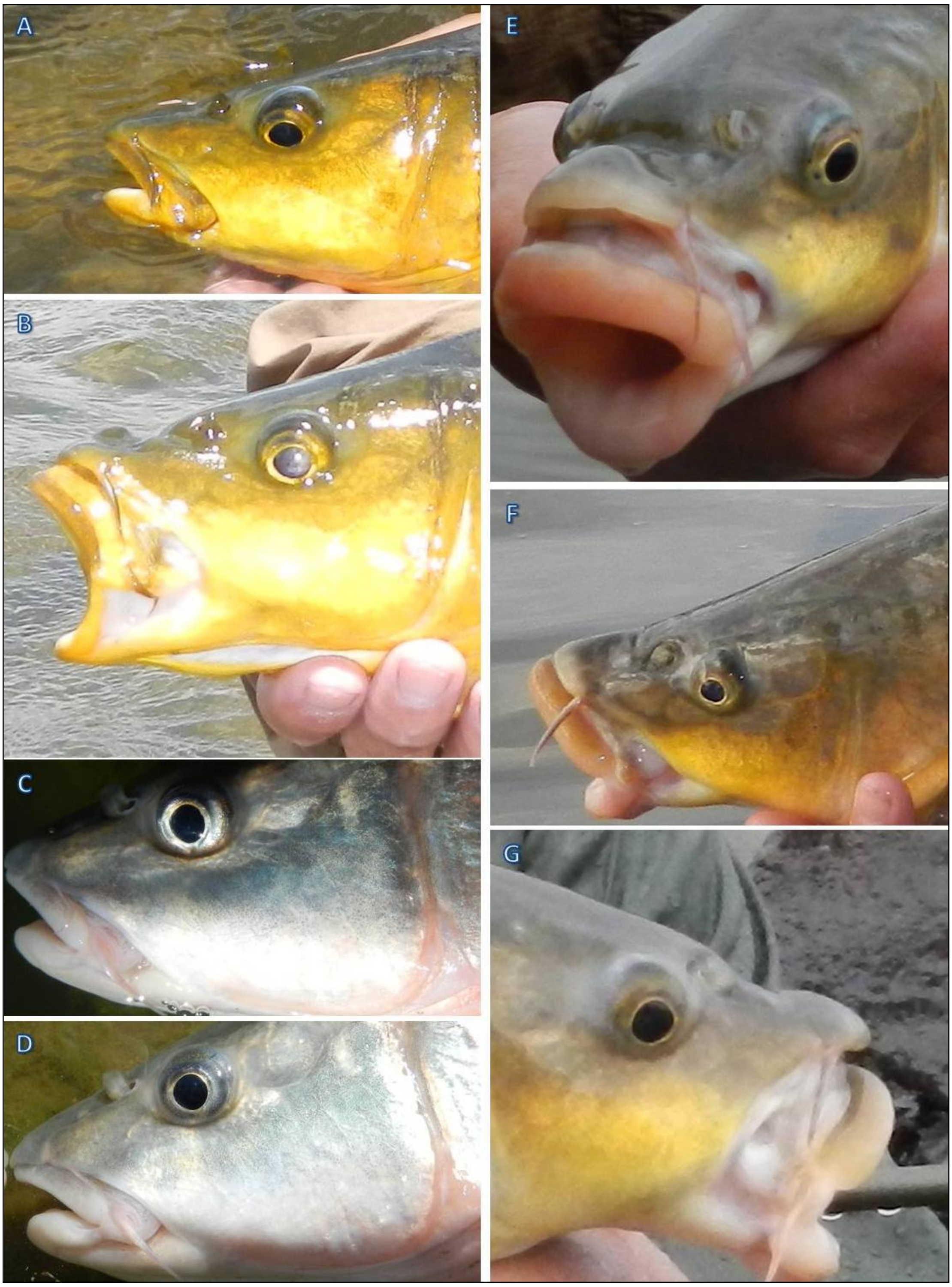


Figure 61: Different jaw morphologies developing with various feeding habits, including (A-B) *L. aeneus* from Boskop Dam with very distinct hard bony jaws situated in a similar position as jaws of *L. kimberleyensis* (C-D). Common jaw morphology (rubber lips) of *L. aeneus* in the Vaal River (E-G), resembling those of fish that feed on invertebrates between rocks.

4.2 Behavioural ecology of *Labeobarbus aeneus* in the Vaal River

Labeobarbus aeneus tagged in the Vaal River show that there is a high variation in individual movement behaviour and habitat selection. The majority of fishes, however, seemed to adopt a general movement pattern. *Labeobarbus aeneus* in the Vaal River exhibit the same movement behaviour patterns, during day and night periods as in Boskop Dam. *Labeobarbus aeneus* in the Vaal River showed the same trend for deeper habitats during high movement activity; however, this trend is not distinct. The reason for this might be the topographic layout of the study area where the water column is fairly similar in most habitats or that turbidity might influence this behaviour. The Vaal River being a naturally turbid river may be the reason for an individual's behaviour being different from that of an individual in the clear water in Boskop Dam. Studies have shown that turbidity affects the feeding and movement behaviour of certain Cyprinids (Bruton, 1985; Clough *et al.,* 1998). Turbidity may act as a cover feature in this case where individuals are sometimes forced to avoid habitats (shallow water) in clear water during certain periods of the day, therefore avoiding humans, otters and avian predators might be regarded as being less of a threat in the turbid Vaal River water (Godin, 1990; Sih, 1993). *Labeobarbus aeneus* show higher movement activity during new moon phases than full moon phases. This higher activity during new moon phases is associated with shallower habitats, which implies that predator avoidance is a possible reason for selecting deeper habitats during full moon phases (Godin, 1990; Sih, 1993). Fishes, including omnivores that have to extensively search for prey, need to explore their habitats more than, for example, ambush predators, to find the most productive food sources (Godin, 1990). This might possibly be why *L. aeneus* uses the entire water column to find prey items throughout a day.

Movement counts of *L. aeneus* varied during the different seasons monitored. Seasons are one of the driving forces that influence the distribution and habitat preference of certain cyprinids (Penne and Pierce, 2008). *Labeobarbus aeneus* in the Vaal River displayed similar movement behaviour as in Boskop Dam; however, reasons for the same behaviour might be different. This decrease in movement activity during winter and increased movement during summer has been documented for *L. aeneus* in the Vaal River (O'Brien *et al*., 2013). The decrease in movement is usually associated with changes in environmental variables such as flow, pressure and temperatures (O'Brien *et al*., 2013). Autumn and winter are generally associated with low flows were *L. aeneus* prefer deeper water >1 000 mm as a result of tradeoffs between swimming costs, and the supply rate of capturing food items (Hughes and Dill, 1990). Rapids and riffles which are generally shallower habitats might be avoided during low-flow periods because of the increased effort to catch prey successfully in shallower habitats (Hughes and Dill, 1990). During spring and summer *L. aeneus* used shallower habitats that might suggest that individuals preferred habitats such as glides, runs and riffles whereas in autumn and winter *L. aeneus* preferred deeper water suggesting pool habitats (O'Brien et al., 2013). *Labeobarbus aeneus* are known summer riffle dwellers and have therefore adapted specific foraging strategies that further support *L. aeneus* moving from shallower <1 000 mm water in summer to deeper >1 000 mm water in winters (Wootton, 1984; Hart, 1996). The preferred habitats were relatively shallow (<1 000 mm) with only a few pools deeper than >1 000 mm. These habitat preferences are further supported by O'Brien *et al.* (2013) where *L. aeneus* preferred fast-flowing to moderately shallow (<1 000 mm) habitats throughout the year. Being an omnivorous feeder *Labeobarbus aeneus* seems to prefer these fast-flowing habitats where the majority of their diet can be found (Dörgeloh, 1994; 1996; Stadtlander *et al.,* 2011). Feeding behaviour of *L. aeneus* that was identified in this study showed that *L. aeneus* will occupy an area behind a suitable rock, while facing upstream. Drifting food is then brought in the current like a conveyer belt, where *L. aeneus* would then dart up and down or from side to side to capture prey. *Labeobarbus aeneus,* like other Cyprinidae species, also have the ability to change their foraging tactics to suit environmental changes (Wootton, 1984; Hart, 1996). It is a well-known fact that *L. aeneus* can change from feeding in riffles and rapids in summer to avoiding riffles and rapids in winter, and then change to feeding on other prey found in deeper habitats. Further studies are needed to identify the movement activity signatures from radio tags to identify different foraging tactics.

Cyprinids are highly mobile and are therefore capable of using areas ranging from a few metres to hundreds of kilometres (Crook, 2004; Stuart and Jones, 2006; Penne and Pierce, 2008). Individuals monitored in this study exhibited area usage of up to 9 km^2 (n=3) whereas some individuals preferred to remain in focus areas of up to 2 km^2. This contradicts findings in a previously published report stating that *L. aeneus* is believed to use home ranges of maximum 2 km (O'Brien *et al*., 2013). *Labeobarbus aeneus* in the Vaal River are known to migrate during spawning periods in summer and spring (Tomasson, 1983). These spawning events are triggered in late September and October when water temperatures reach 18.5°C in conjunction with the rainy season that create suitable flows over spawning habitats which are dominated by gravel, cobbles and boulders (Tómasson et al., 1984; Bruton, 1985; De Moor and Bruton, 1998; O'Brien *et al*., 2013). Five of the tagged individuals possibly partook in a spawning migration. These individuals all migrated upstream to the vicinity of remote monitoring station two in spring and summer.

4.3 Behavioural ecology of *Labeobarbus kimberleyensis* in the Vaal River

Labeobarbus kimberleyensis in the Vaal River exhibited the same daily movement as *L. aeneus* in the Vaal River. The high movement activity of *L. kimberleyensis* is associated with deeper water during daytime periods and vice versa. These movement patterns are identical to the movement patterns of *L. aeneus* during daytime periods in Boskop Dam. It is possible that the predatory behaviour of *L. aeneus* in Boskop Dam is similar to that of *L. kimberleyensis* in the Vaal River which are known predators that hunt in shallow habitats during low light conditions of the day (Skelton, 2000). Movement activity of *L. kimberleyensis* during full moon phases was observed to be higher than during new moon phases; individuals also generally kept to shallower water (<500 mm) during new moon phases possibly avoiding predators the same way *L. aeneus* does (Godin, 1990; Sih, 1993). *Labeobarbus kimberleyensis* may also use the increased light intensity during full moon to ambush fodder fish species that tend to stay in shallower water during nocturnal periods. Like other piscivorous fish species like perch *Perca fluviatilis* (Scott and Crossman, 1973) and pike *Esox lucius* studied in North America, it is possible that *L. kimberleyensis* may use some of the same foraging strategies (Webb and Skadsen, 1980; Hart and Hamrin, 1988; Eklöv and Diehl, 1994). These strategies include *L. kimberleyensis* using a sit-and-wait search tactic. This tactic implies that *L. kimberleyensis*, especially the dominant (large) individuals, will select the best structure from where it can ambush fodder fish (Webb and Skadsen, 1980; Hart and Hamrin, 1988; Eklöv and Diehl, 1994). This tactic can and will, however, change during certain times of the year when individuals will leave their advantage points and actively hunt smaller fishes. This tactic has been witnessed by numerous anglers where shoaling *L. kimberleyensis* have been seen rounding up fodder fishes and attacking them from all sides. It is possible that younger (smaller) individual *L. kimberleyensis* prefer to move around in shoals therefore increasing their chances of survival and finding food (Webb and Skadsen, 1980; Hart and Hamrin, 1988; Eklöv and Diehl, 1994). *Esox lucius* are known to cover large distances and may end up using different habitats than where they started from (Eklöv and Diehl, 1994). When they reach a suitable new habitat they again employ the sit-and-wait tactic which is identified by short bursts of movement around the same area (Eklöv and Diehl, 1994). It is possible that *L. kimberleyensis* uses the same tactic as it is known for long-distance movements of up to 12 km, after which they will occupy that specific area for a specific period (O'Brien *et al.,* 2013). During this period *L. kimberleyensis* uses a small area, until it makes another long-distance movement.