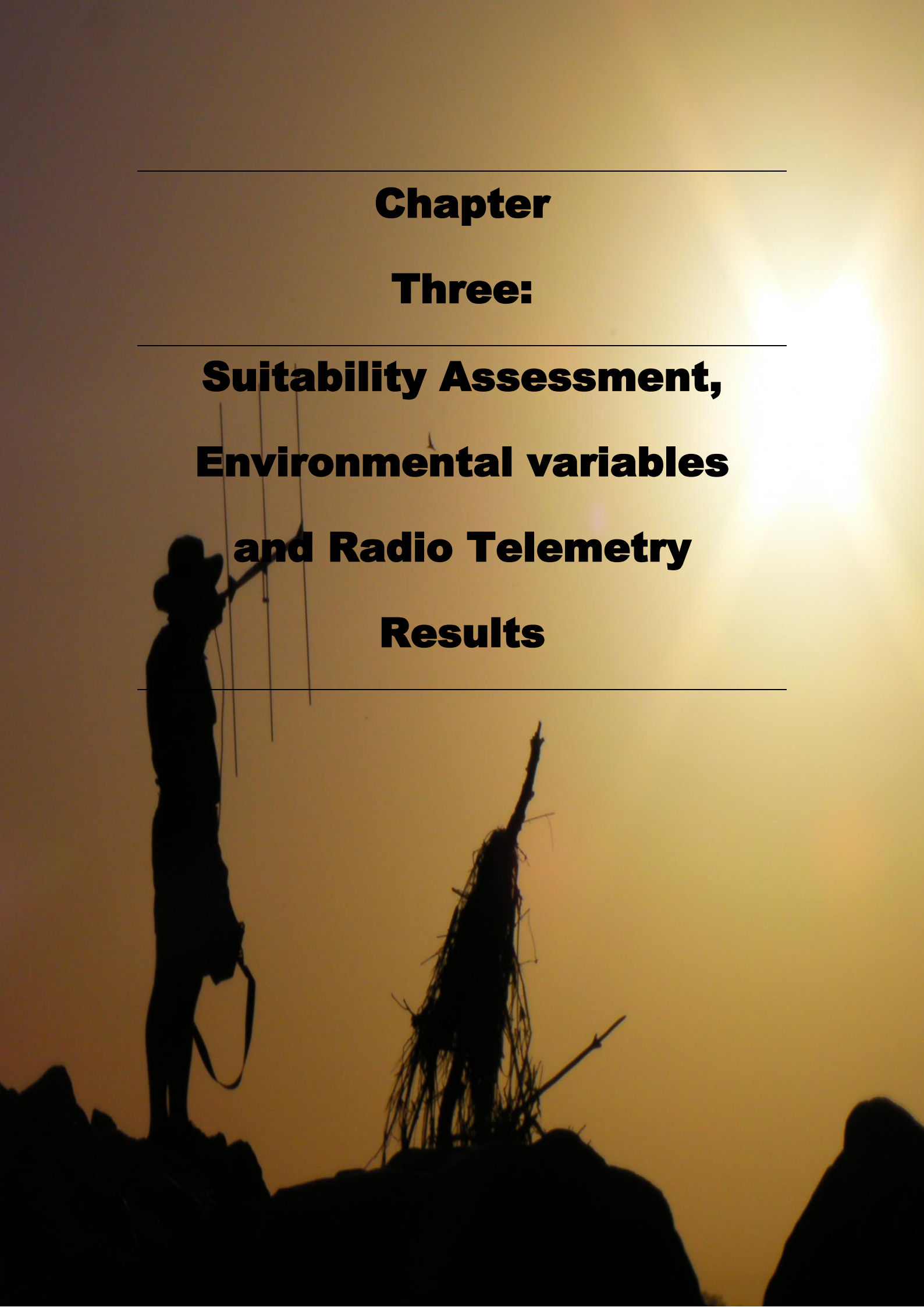
Chapter Three:

Suitability Assessment, Environmental variables and Radio Telemetry Results



3 Suitability assessment, environmental variables and radio telemetry results

3.1 Suitability assessment of Boskop Dam

The fish availability survey to Boskop Dam resulted in 507 fishes being collected using various methods. Seventeen fish species were expected to occur in Boskop Dam; the survey identified at least ten different fish species. All fish collected were measured and photographed (Figure 25) throughout the survey. These 507 fishes included: 5 *Barbus paludinosus* size range (FL 40 mm to 60 mm), 4 *Cyprinus carpio* size range (FL 200 mm to 780 mm), 16 *Labeo capensis* size range (FL 470 mm to 500 mm), 13 *Labeo umbratus* size range (FL 200 mm to 550 mm), 26 *Labeobarbus aeneus* size range (FL 200 mm to 550 mm), 38 *Gambusia affinis* size range *(*TL 13 mm to 20 mm), 8 *Micropterus salmoides* size range (TL 350 mm to 400 mm), 14 *Pseudocrenilabrus philander* size range (TL 20 mm to 60 mm), 380 *Tilapia sparmanii* size range (TL 10 mm to 60 mm) and 3 *Clarias gariepinus* size range (TL 300 mm to 1 500 mm). The survey concluded that Boskop Dam has a suitable *L. aeneus* population that can be used for this radio telemetry study.

Figure 25: Different fish species collected throughout the survey, including: (A) *Micropterus salmoides*; (B) *Labeo umbratus*; (C) *Labeo capensis*; (D) *Clarias gariepinus*; (E) *Cyprinus carpio*; (F) *Pseudocrenilabrus philander*; (G) *Tilapia sparmanii*; (H-I) *Labeobarbus aeneus*; (J) *Barbus paludinosus*; and (K-L) *Gambusia affinis*

3.2 Environmental variables monitored

Temperatures for the Boskop Dam study area were obtained from South African Department of Water Affairs, Boskop Dam, Weather Station (C2R001Q01 UWQ). Dry bulb temperatures (in °C) were recorded at 08:00, 14:00 or 20:00. Data were continually recorded throughout the study and average monthly temperatures were obtained (Figure 26). Monthly temperatures ranged from 21°C in January to 8.1°C in winter.

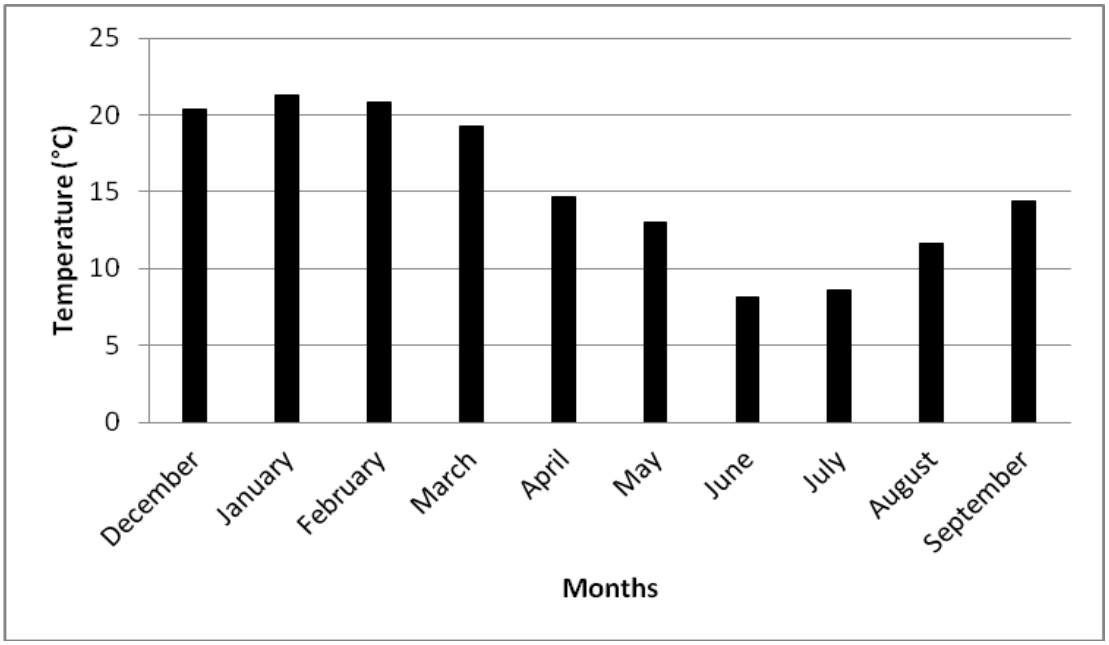


Figure 26: Average dry bulb monthly temperatures of Boskop Dam obtained from the Weather Station at Boskop Dam (C2R001Q01)

For the Vaal River study area the dry bulb temperatures (in °C) were reported at 08:00, 14:00 or 20:00 by the weather station [0436204 1] in Klerksdorp, North West Province, South Africa. The weather station had an elevation of 1 322 m above mean sea level and data were obtained from the South African Weather Service on 2012/10/17 at 15:04. For the purpose of this study average monthly temperatures were used to identify movement activity of species during various seasons (Figure 27).

Atmospheric pressure (in hPa) was reported at 08:00, 14:00 or 20:00. Data were recorded by weather station [0436204 1] in Klerksdorp, North West Province, South

Africa. The data were supplied by the South African Weather Service and were received on the 2012/10/17. The monthly averages for atmospheric pressure were calculated (Figure 28).

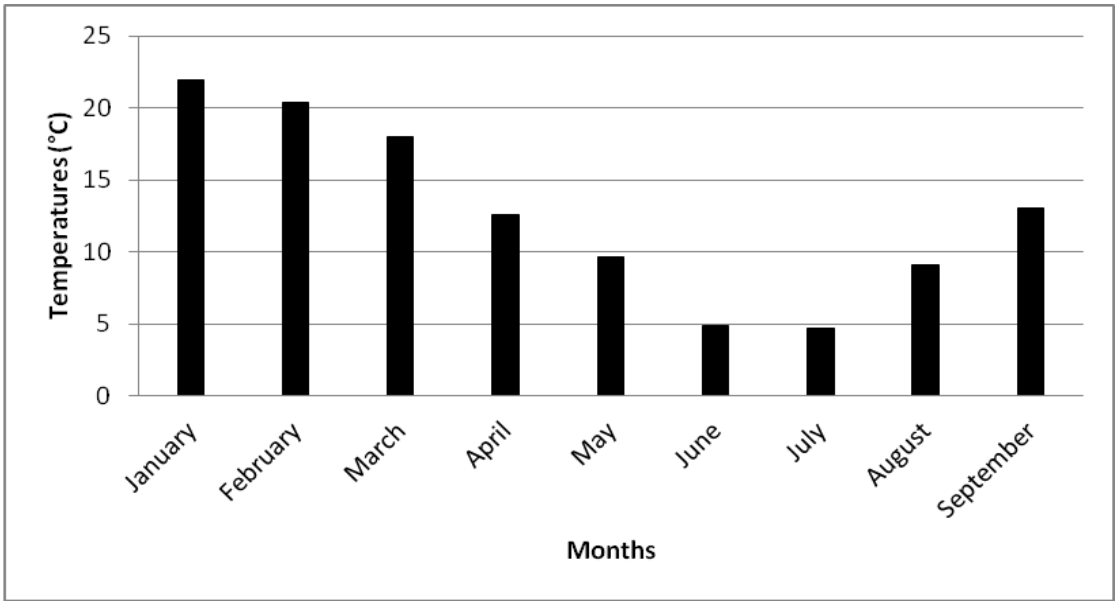


Figure 27: The average monthly temperatures of the Vaal River study area as obtained from the South African Weather Service

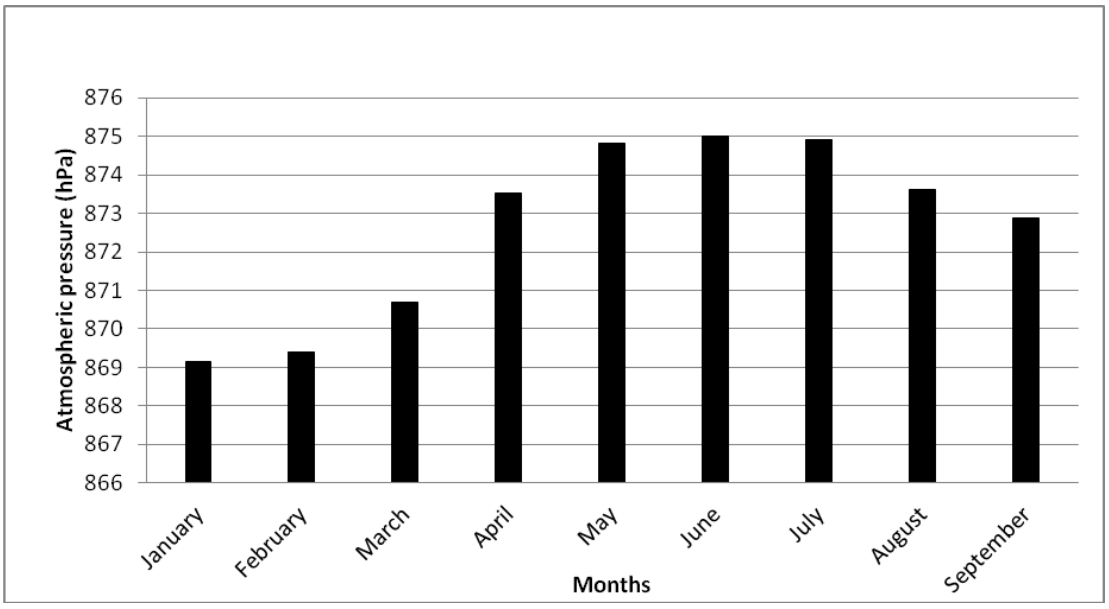


Figure 28: The average monthly atmospheric pressure (in hPa) was obtained from the South African Weather Service

When air temperatures decreases during autumn and winter, the study areas experienced an increase in atmospheric pressure. Autumn (March, April, and May) marks the start of increased atmospheric pressures and a decrease in temperatures. Winter (June, July, August) had the highest atmospheric averages and represented the lowest temperatures (July) throughout the study. Spring (September, October, and November) usually marks the end of winter. The graphs show that atmospheric pressure started decreasing in August and average monthly temperatures started to increase.

Discharge (in m^3/s) in the Vaal River was measured at Pilgrims Estate at site C2H007. This site was located closest to the Vaal River study area and was considered most accurate for the study area. Monthly averages were used to establish whether any relationships existed between the behaviour of yellowfish species and increase and decrease in flows.

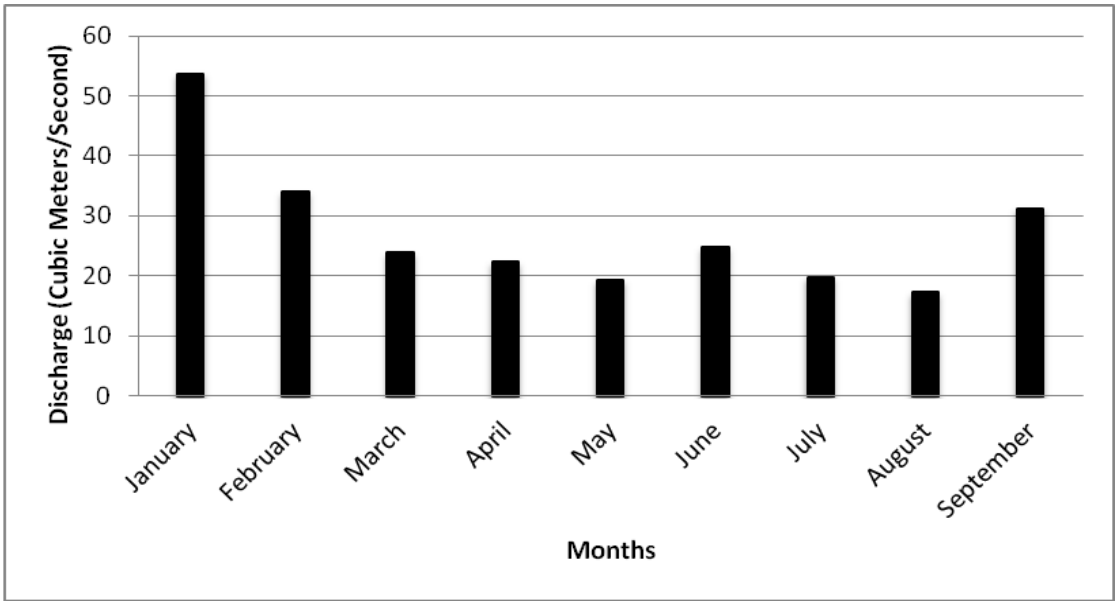


Figure 29: The average discharge (in m^3/s) of the Vaal River study area as obtained from the Department of Water Affairs

Monthly rainfall (in mm) figures were obtained from the South African Department of Water Affairs. Rainfall during 2011/2012 was lower than the normal monthly rainfall for both the study areas (Figure 30)(Figure 31). The highest monthly rainfall for Boskop Dam was recorded in December and for the Vaal River the highest monthly rainfall was recorded in February. Higher rainfall was recorded in spring and summer than during autumn and winter. One specific rainfall event in the middle of winter was

identified to possibly have an effect on the behavioural activity of yellowfish species. This event took place in June 2012 where the average temperature for that month was recorded to be 4.8°C; this month also had the highest average atmospheric pressures throughout the study. The study areas received 18 mm and 10 mm of rainfall, respectively, from the 21-23 June 2012. The barometric pressure decreased by 8.7 hPa and the temperature increased by 6°C during this time period, which is a considerable drop in atmospheric pressure and increase in temperature.

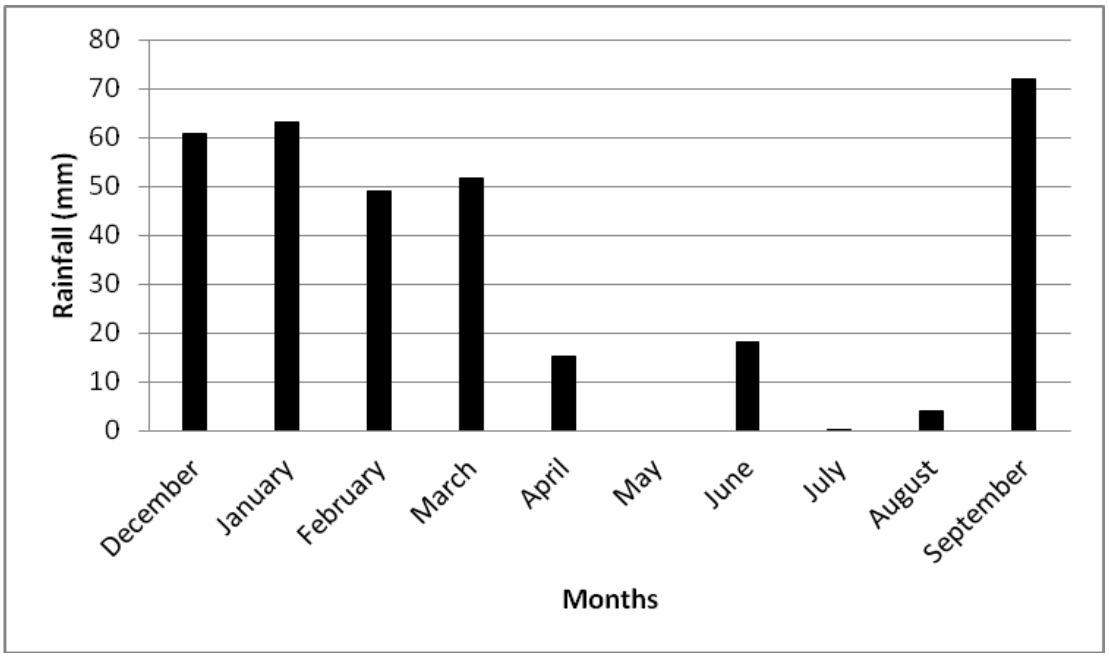


Figure 30: Monthly rainfall (in mm) for Boskop Dam study area. Highest rainfall was recorded during December, with an important rainfall event in the middle of winter (June) 18 mm, which is associated with an increase in temperatures and a drop in atmospheric pressure.

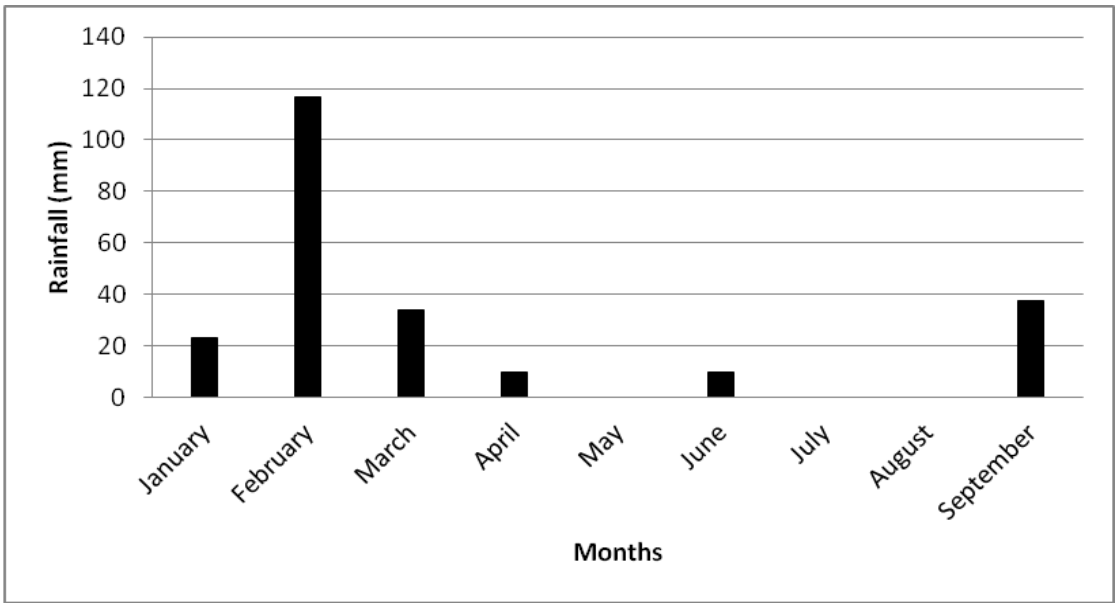


Figure 31: Monthly rainfall (in mm) for Vaal River study area. Highest rainfall was recorded during February with an important rainfall event in the middle of winter (June) of 10 mm, which is associated with an increase in temperature of 6°C and a drop of 8.7 hPa in the atmospheric pressure.

3.3 Radio telemetry results for *Labeobarbus aeneus* in Boskop Dam

The behavioural ecology findings of *L. aeneus* in Boskop Dam are based on information obtained by monitoring four suitable yellowfish individuals that were captured at various locations in Boskop Dam, using a range of different techniques (Figure 18), after which they were sedated, measured, tagged, photographed (Figure 32) and released. Information on yellowfish was recorded on a data sheet (Table 9). Three of the four tags contained activity, temperature and depth peripheral components with the fourth tag containing activity and temperature peripheral components. Radio tags were able to transmit to remote monitoring stations at a maximum depth of about 2 500 mm over 500 m. From the study a total of 9 153 data strings containing movement counts and temperatures for all tags and depth for three tags were recorded by the six remote monitoring stations set up around the study area. Data strings were collected by all six remote monitoring stations, confirming that the entire study area had optimum coverage. These data were used to evaluate the behavioural response, using movement as a behavioural variable, of the yellowfish to changes in environmental variables.

Table 9: General information on yellowfish individuals captured, tagged, released and monitored in Boskop Dam

					(g)	(mm)	(mm)	(mm)	(mm)	
Species	Capture date	Capture method	Tag	Sensor on tag	Mass	Total length	Fork length	Standard length	Girth	Season
L. aeneus 1	16/11/2011	Gill net	39	Act,Temp,Depth	3500	660	610	550	330	Summer
L. aeneus 2	26/01/2012	Gill net	40	Act,Temp,Depth	2100	576	525	482	324	Summer
L. aeneus 3	26/01/2012	Gill net	43	Act,Temp,Depth	1855	560	505	480	310	Summer
L. aeneus 4	27/01/2012	Gill net	36	Act,Temp	1500	510	460	441	281	Summer

Figure 32: The four *Labeobarbus aeneus* that were captured, tagged, photographed, released and monitored in Boskop Dam

***Labeobarbus aeneus* (1)**

Labeobarbus aeneus (1) with radio tag number 39 was monitored from 16/11/2011 until 30/09/2012 during which time 1 810 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *L. aeneus* (1) had movement counts per minute that ranged between 155.5 MC/min and 160.3 MC/min during nocturnal (dark) periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased and ranged between 1 548.3 and 2 349.4 MC/min. *Labeobarbus aeneus* (1) was most active during time periods from 04:00-08:00 whereas least movement counts were between 00:00-04:00 (Figure 33A). Movement count was lower during full moon phases 2 062.2 MC/min than during new moon phases 2 224.3 MC/min (Figure 33B). The seasonal movement count was highest during spring 2 930 MC/min and thereafter summer 1 655.2 MC/min (Figure 33C). The tag on this individual transmitted its last information on the 26/12/2011 to remote monitoring station five. After this recording the tag did not transmit again throughout the duration of the study. It is therefore possible that the individual may have lost the tag, or that the individual had died. Therefore movement behaviour data are limited to spring and summer.

The depth range of *Labeobarbus aeneus* (1) was between 876 mm and 1 673 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 439 mm to 582 mm (Figure 33A). During full moon phases the depth of *L. aeneus* (1) was 543 mm and during new moon phases the depth was 345 mm (Figure 33B). Seasonal variations in depth ranged from 390 mm in spring to 533 mm in summer (Figure 33C).

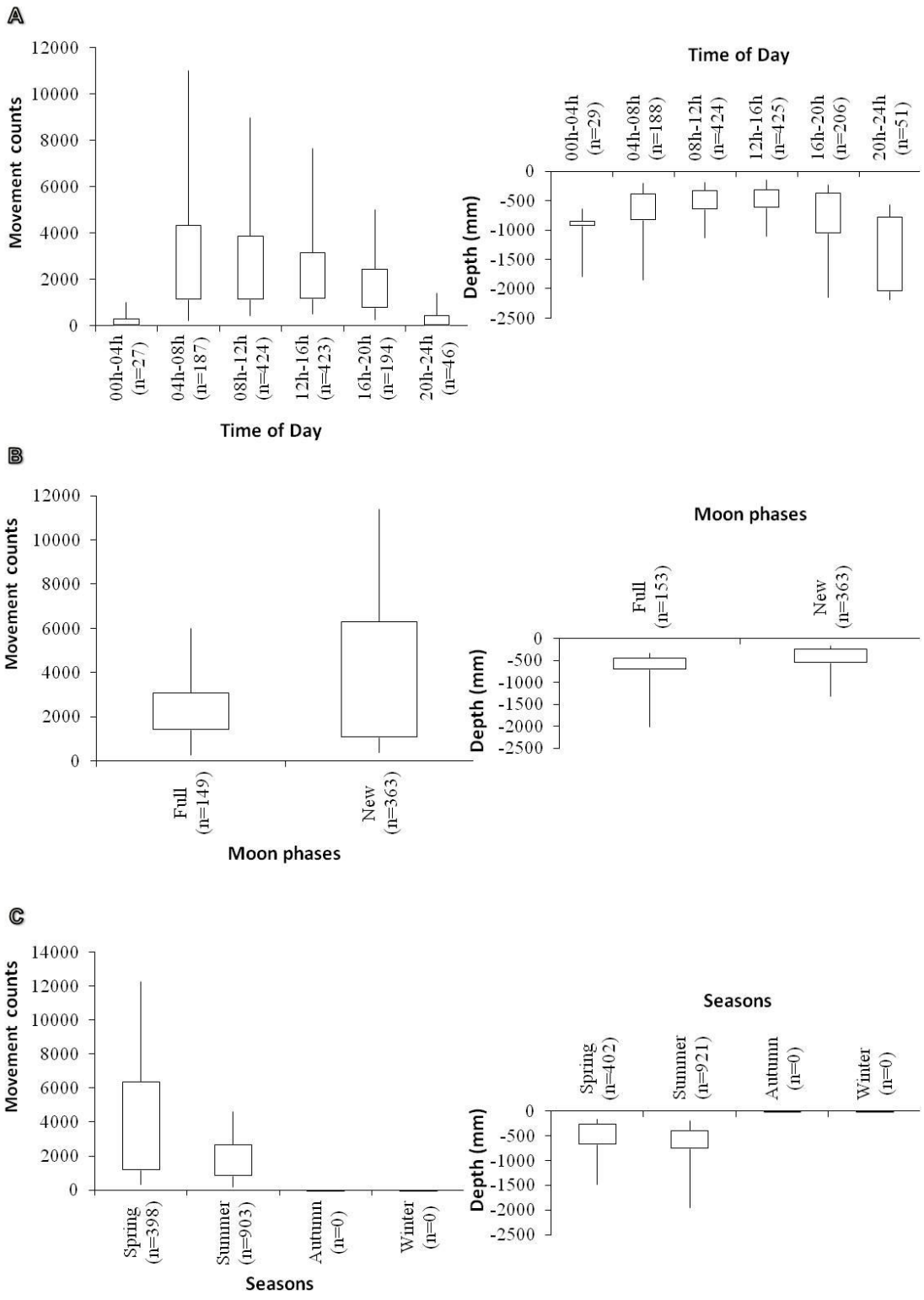


Figure 33: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher activity movement was observed during daytime, new moon phases, spring and summer, whereas this individual with tag number 39 also preferred shallower habitats.

***Labeobarbus aeneus* (2)**

Labeobarbus aeneus (2) with radio tag number 40 was monitored from 26/01/2012 30/09/2012 during which time 6 920 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. *Labeobarbus aeneus* (2) had a movement count range of 19.1 MC/min to 19.2 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased and ranged between 27.0 MC/min and 43.2 MC/min. Peak movement counts were recorded during time periods from 12:00-16:00, whereas lowest movement counts were recorded between 20:00 and 24:00 (Figure 34A). Movement counts were lower during new moon phases with 21.4 MC/min than during full moon phases 33 MC/min (Figure 34B). The seasonal movement count was highest during summer 1 298.5 MC/min, while during autumn the movement count was 27.4 MC/min and during winter the movement count was 23.3 MC/min (Figure 34C). The last information from the radio tag on this individual was recorded on 12/06/2012 to station five. After this no further information from the tag was received; either the radio tag got damaged or the individual died.

The depth range of *Labeobarbus aeneus* (2) was between 267 mm and 460 mm during nocturnal periods (00:00- 04:00 and 20:00-24:00) whereas depth in daylight ranged from 514 mm to 1 570 mm (Figure 34A). During new moon phases the depth of *L. aeneus* (2) was 548 mm and during full moon phases the depth increased to 891.1 mm (Figure 34B). In summer the depth of *Labeobarbus aeneus* (2) was 1 359 mm; however, this is calculated from (n=4) and it is possible that this individual used these depths for recovery as information was recorded directly after tagging. Depth for this individual was 899 mm in autumn and 1 360 mm during winter. During autumn considerably more data were recorded (n=4 795) than during winter (n=258); it is therefore possible that this individual spent time in deeper water during winter at depths greater than the maximum depth where tags could transmit from (Figure 34C).

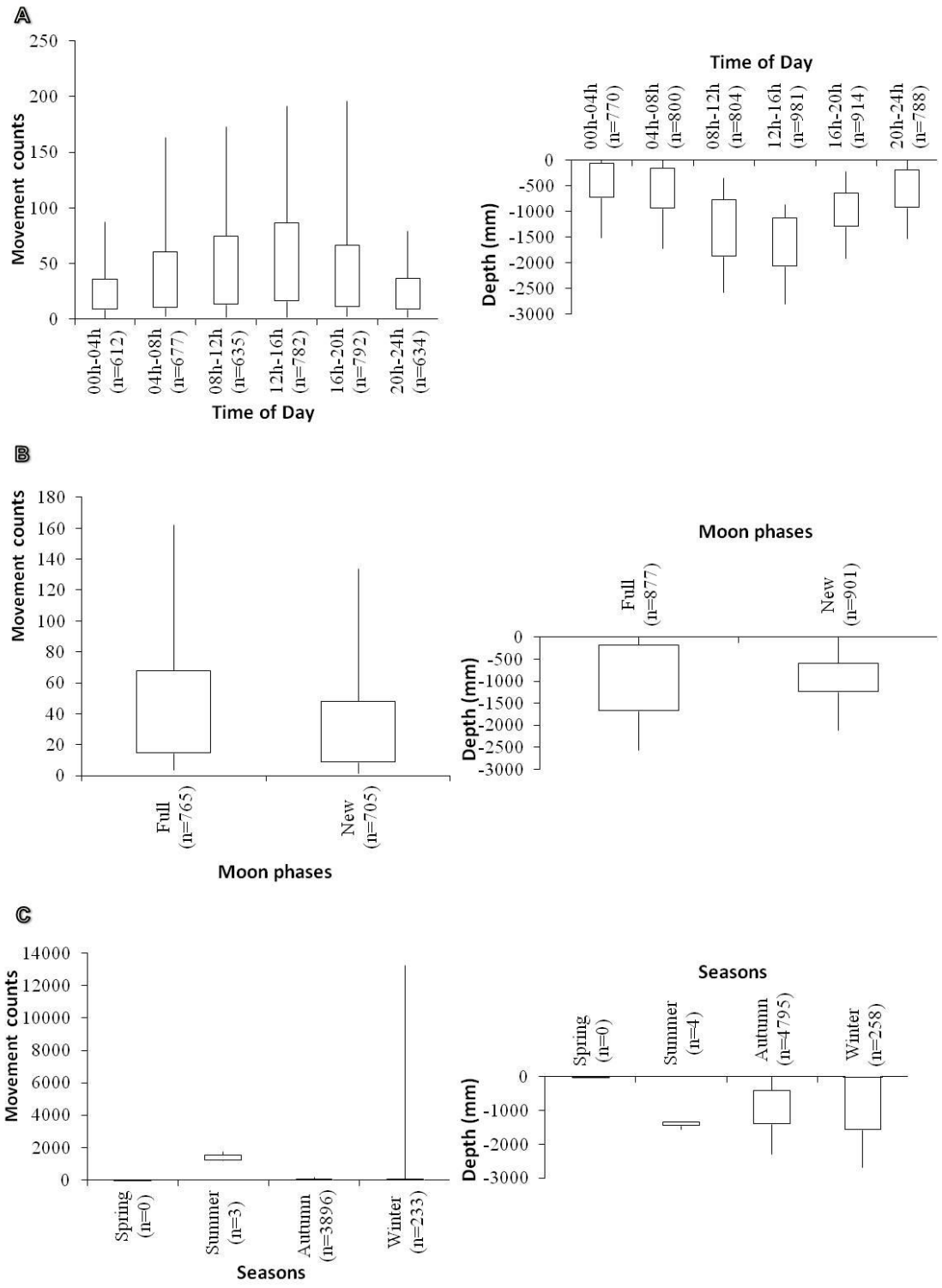


Figure 34: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher activity movement was observed during daytime and full moon phases where deeper habitat was used. Limited data was collected for seasons; however this individual with tag number 40 seemed to prefer deeper habitats towards winter.

***Labeobarbus aeneus* (3)**

Labeobarbus aeneus (3) with radio tag number 43 was monitored from 26/01/2012 during which time 9 152 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (3) had movement count ranges of between 10.5 MC/min and 12.8 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased and ranged between 12.9 MC/min and 30.7 MC/min. *Labeobarbus aeneus* (3) had peak movement counts during time periods from 12:00-16:00 with an of 30.7 MC/min, whereas the lowest movement activity was recorded between 00:00-04:00 with an count of 10.5 MC/min (Figure 35A). Movements were lower during new moon phases 15.2 MC/min than during full moon phases 18.5 MC/min (Figure 35B). The seasonal movement was highest during summer 876.7 MC/min (n=24). Thereafter the movement activity decreased notably to 17.9 MC/min in autumn (n=1 133) (Figure 35C). The last information transmitted by the radio tag was on the 23/04/2012 through remote monitoring station five. Thereafter no information was transmitted by the tag and thus seasonal movement data are limited to summer and autumn.

The depth range of *Labeobarbus aeneus* (3) was between 407 mm and 548 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 559 mm to 848 mm (Figure 35A). During full moon phases the depth of *L. aeneus* (3) was 548 mm and during new moon phases the depth was 529 mm (Figure 35B). Seasonal variations in depth ranged from 62 mm in summer to 662 mm in autumn (Figure 35C). It is possible that the tag got damaged in autumn when the individual moved to deeper water or the individual may have died.

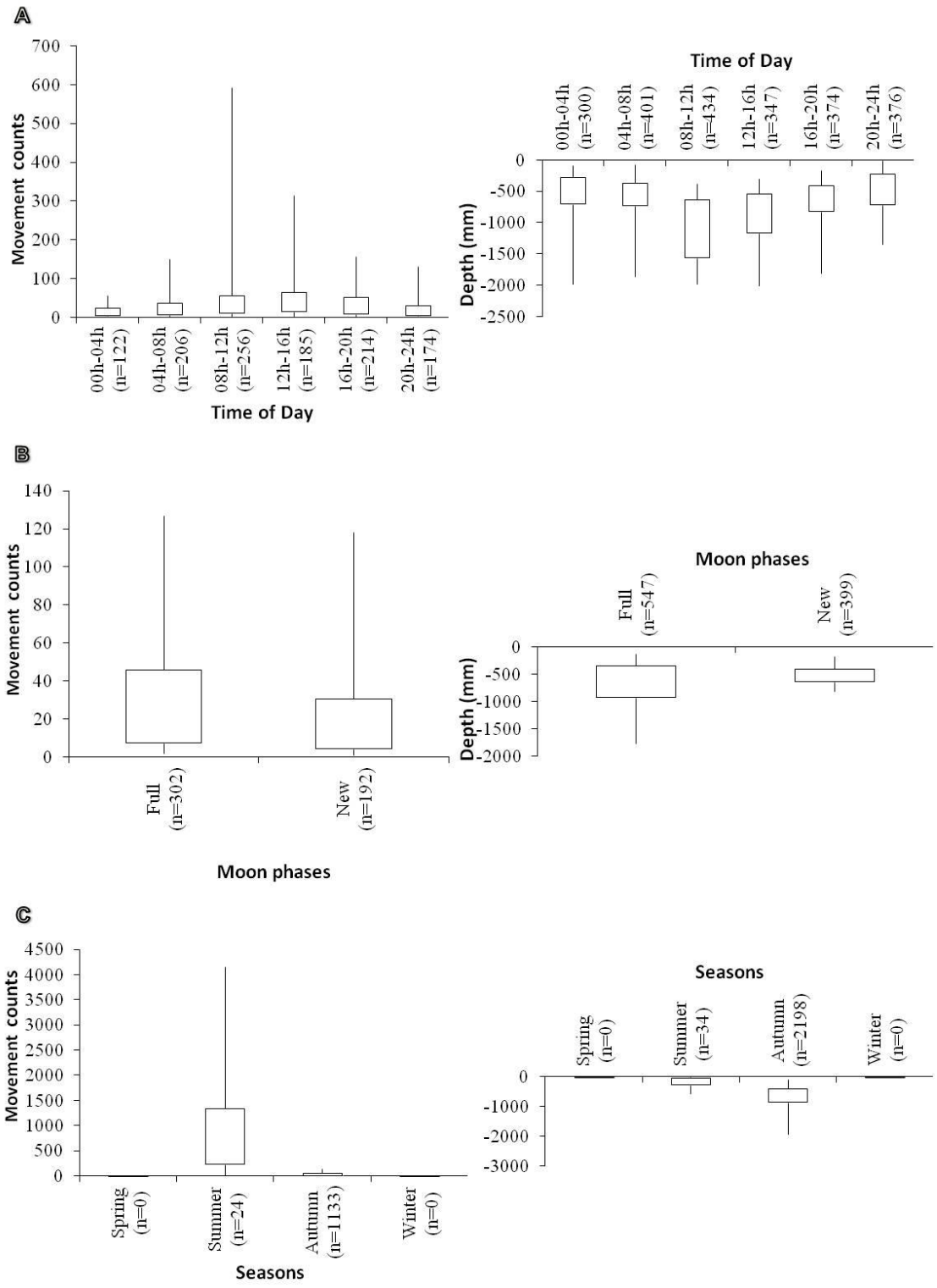


Figure 35: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher movement activity was observed during daytime and full moon phases where deeper habitat was used. Limited data was collected for seasons; however this individual with tag number 43 seemed to prefer deeper habitats towards winter.

***Labeobarbus aeneus* (4)**

Labeobarbus aeneus (4) with radio tag number 36 was monitored from 27/01/2012 during which time 486 data strings were remotely obtained. These strings contained activity and temperature peripheral information. Data showed that *Labeobarbus aeneus* (4) had movement counts ranging between 15.4 MC/min and 20.3 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement increased and ranged from 29.2 MC/min to 80.1 MC/min. *Labeobarbus aeneus* (4) had peak movement counts during time periods from 12:00-16:00 with an count of 80.1 MC/min whereas lowest movement counts were recorded between 20:00-24:00 with an of 15.4 MC/min (Figure 36A). The movement count during new moon phases was 32.1 MC/min but data are limited to new moon phases (Figure 36B). The seasonal movement was highest during summer 231.2 MC/min and thereafter autumn 32.1 MC/min (Figure 36C). The last data were recorded on the 24/03/2012 by remote monitoring station five and thus seasonal movement data were limited to summer and autumn. It is possible that the tag may have been damaged if this individual followed the same trend as the other tagged individuals and moved to deeper water, or the individual may have died.

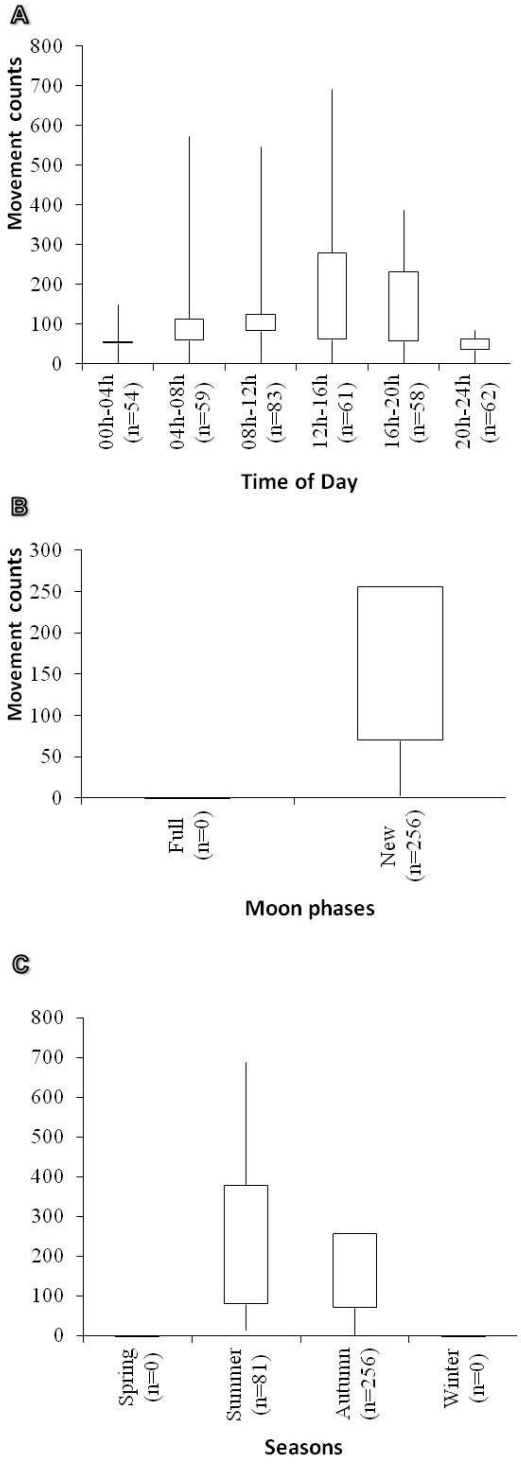


Figure 36: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher movement activity was observed during daytime as opposed to nocturnal periods. This individual with tag number 36 showed higher movement activity during summer opposed to winter.

General behaviour pattern of *Labeobarbus aeneus* in Boskop Dam

The following section presents data from all four tagged individuals incorporated into a single group, to identify the general movement behaviour pattern of *L. aeneus* in Boskop Dam. The following table presents the highest and lowest movement counts during periods throughout a day, moon phases, seasons and shows where data were not available (N/A) (Table 10).

Table 10: Highest and lowest movement counts plotted (x) against time periods, moon phases and seasons; it also shows which data were not available (N/A) from *Labeobarbus aeneus* remotely monitored in Boskop Dam

Highest movement												
	Time period of day						Moon phase		Season			
Tag nmr	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00	Full	New	Spring	Summer	Autumn	Winter
39		x					x		x		N/A	N/A
40				x			x		N/A	x		
43				x			x		N/A	x		N/A
36				x			N/A	x	N/A	x		N/A
Low est movement												
	Time period of day						Moon phase		Season			
Tag nmr	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00	Full	New	Spring	Summer	Autumn	Winter
39	x							x		x	N/A	N/A
40						x		x	N/A			x
43	x							x	N/A		x	N/A
36						x	x	N/A	N/A		x	N/A

This data together with box-and-whisker graphs were used to illustrate the movement counts (activity), depth and number of data strings collected (n=) during time of day, moon phases and seasons of all four tagged individuals (Figure 37). ANOVA together with a coefficients model (Littell *et al*., 1996) and Akaike's Information Criteria (AIC) (Burnham and Anderson, 1998) were used to statistically analyse data and significant values ($P< 0.05$) were calculated using SAS.

Labeobarbus aeneus in Boskop Dam follows distinct behavioural patterns, with some individual variations in behaviour. *Labeobarbus aeneus* exhibited significantly ($P<0.05$) higher movement counts that are associated with deeper water during daylight hours (04:00-16:00). During nocturnal periods *L. aeneus* significantly

(P<0.05) decreased movement activity and preferred shallower water as opposed to daytime (Figure 37A). During new moon phases the box-and-whisker graph shows higher movement counts, but displays incorrect as *Labeobarbus aeneus* (4) showed no data during full moon phases, but showed data during new moon phases and therefore it seems that they have higher movement counts during new moon phases than during full moon phases, when in fact three of the four *L. aeneus* individuals showed higher movement counts during full moon phases. Individuals preferred deeper water during full moon phases than during new moon phases (Figure 37B).

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. Seasonal movement data were, however, limited (Figure 37C).

The influence of rainfall events that were identified in winter (June) and may have had an effect on the behaviour of *L. aeneus* was not confirmed as no data from any individual in Boskop Dam were recorded in that specified period. Atmospheric pressure did not have a significant effect on *L. aeneus* in Boskop Dam; however, as atmospheric pressure is closely related to changes in temperature, it might be necessary for future studies to combine atmospheric pressure and temperature and not separate them as two different environmental variables.

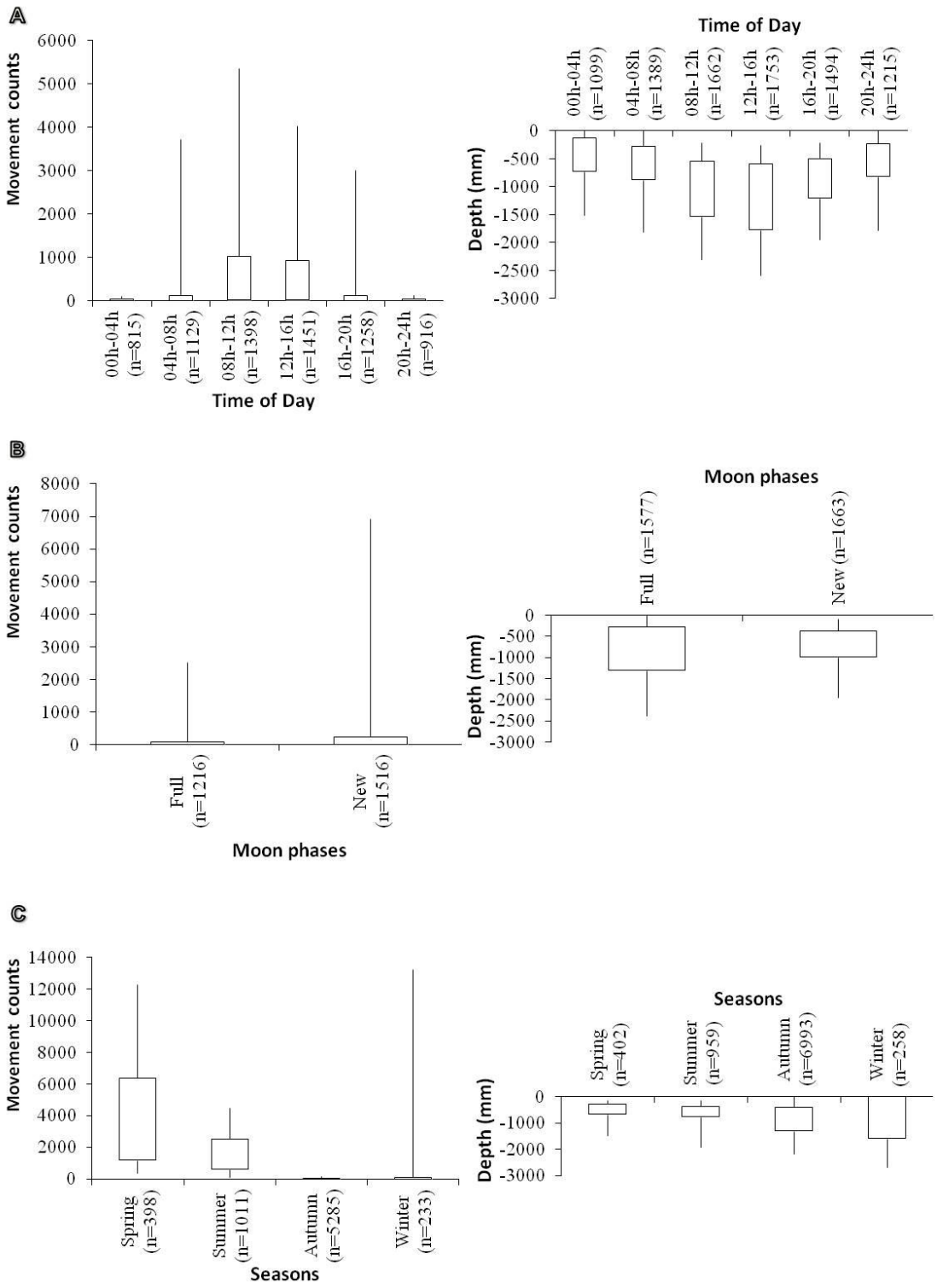


Figure 37: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity increased during daytime periods, whereas depth also increased. Shallower habitats were occupied during full moon phases as well as spring and summer. Individuals gradually increased using deeper habitats during autumn and winter when movement activity decreased as temperatures decreased and atmospheric pressure increased.

Preferred areas of tagged *Labeobarbus aeneus* in Boskop Dam

Data obtained from the remote monitoring stations set up around Boskop Dam were used to identify which areas *L. aeneus* preferred during which seasons (Table 11). *Labeobarbus aeneus* (1) with radio tag number 39 used the entire study area during spring, but spent most of its time during summer in the vicinity of remote monitoring station five (n=786). *Labeobarbus aeneus* (2) with radio tag 40 made use of most of the study area, but avoided the area near remote monitoring station two which consisted of deep water with very little substrate. In summer this individual preferred the area near remote monitoring station one from where *L. aeneus* used the area around remote monitoring station three (n=2 560) which consisted of rocky substrates, gravel and aquatic vegetation. This station recorded more than 35% of the total data. Remote monitoring station five (n=1 543) was preferred during autumn and winter. *Labeobarbus aeneus* (3) with radio tag 43 and *L. aeneus* (4) with radio tag 36 both preferred two areas of the study area. In summer these individuals were located near remote monitoring station one, an area which consisted of rocky substrates, gravel and aquatic vegetation. During autumn both individuals preferred the area around remote monitoring station five.

All four tagged individuals seemed to use the area around remote monitoring station five; more than 50% of the total data were recorded by this monitoring station, although none were caught and tagged in this area (Figure 38). It seems that individuals avoided areas where they were caught and tagged. *Labeobarbus aeneus* preferred the area around remote monitoring station five during various periods throughout the study, but seemed to spend prolonged periods of time there during autumn and winter. The area near remote monitoring staion five was selected as the most preferred area for *L. aeneus* monitored in Boskop Dam, therefore a three-dimensional digital terrain model was built for this specific area (Figure 39). This area is covered with aquatic vegetation, has a depth of up to 8 000 mm, and is characterised by rocky outcrops and reeds surrounding the entire area. The area was also situated in a protected area within Boskop Dam Nature Reserve and was closed to water-related activities. Furthermore, this area was sampled in the winter during the suitability assessment and the results showed that the area held high numbers of *L. aeneus.*

Table 11: The preferred areas marked with an (x) of *Labeobarbus aeneus* in Boskop Dam throughout the study, including tag numbers, seasons and station numbers

Tag nmr	Season	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
39	Spring	x	x	x	x		
	Summer					x	x
	Autumn						
	Winter						
40	Spring						
	Summer	x					
	Autumn			x	x	x	
	Winter						x
43	Spring						
	Summer	x					
	Autumn					x	
	Winter						
36	Spring						
	Summer	x					
	Autumn					x	
	Winter						

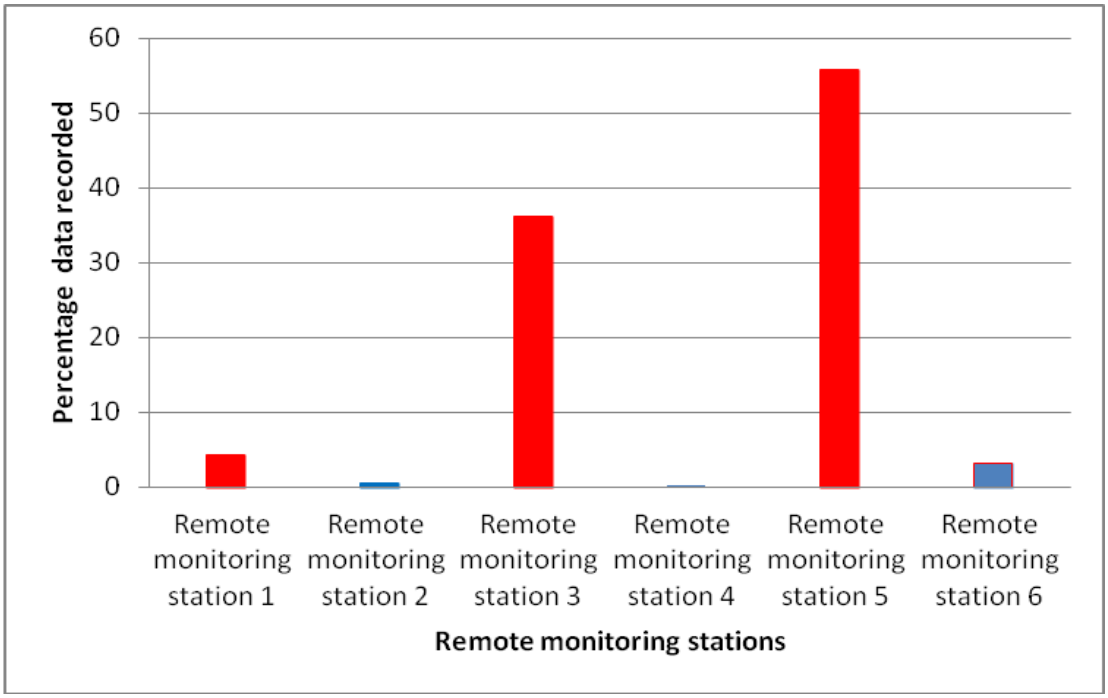


Figure 38: Percentage (%) data recorded by each remote monitoring station around Boskop Dam. Remote monitoring station five recorded more than 50% of the total data followed by station three with more than 35% of the total data.

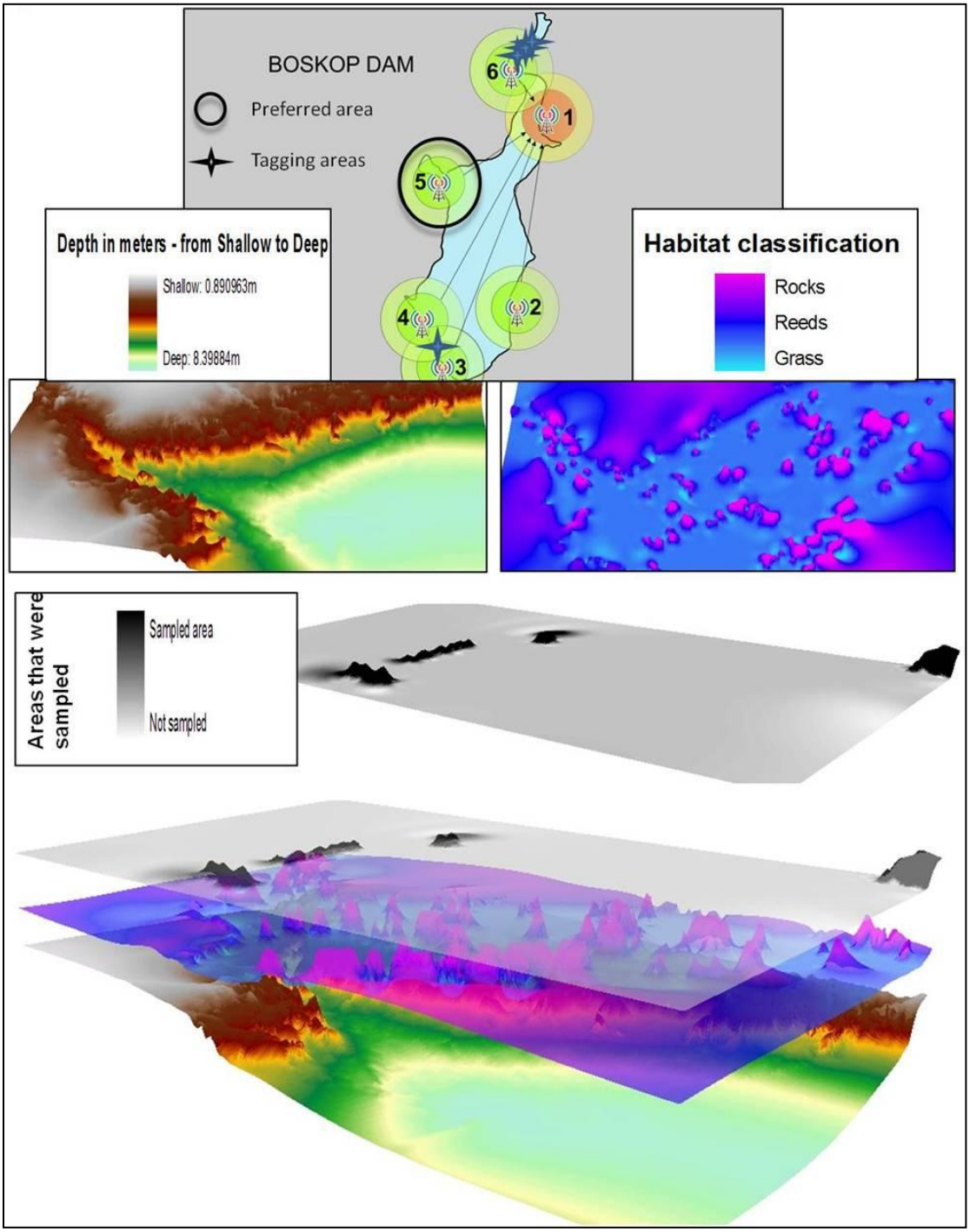


Figure 39: Three-dimensional digital terrain model of the area near remote monitoring station five. This map includes: positions of remote monitoring stations around Boskop Dam, tagging areas, depth and habitat of preferred area and area where *Labeobarbus aeneus* were successfully sampled during fish suitability assessment in Boskop Dam.

3.4 Radio telemetry results for *Labeobarbus aeneus* in the Vaal River

The behavioural ecology findings of *L. aeneus* in the Vaal River are based on information obtained by monitoring 14 suitable *Labeobarbus aeneus* individuals that were captured at various locations using a range of different techniques (Figure 18), after which they were sedated, measured, tagged, photographed and released (Figure 40,Figure 41, Figure 42, Figure 43). Information on tagged *L. aeneus* was recorded on a data sheet (Table 12). Nine of the 14 radio tags contained activity, temperature and depth peripheral components, one tag contained activity, temperature, depth and memory components, and four tags contained activity and temperature components (Table 13). Radio tags were able to transmit to remote monitoring stations at a maximum depth of about 2 500 mm over a range of about 500 m. From the study a total of 94 757 data strings were recorded by the eight remote monitoring stations set up around the study area. The furthest two remote monitoring stations were set up at a distance of about 9 km from each other.

Table 12: General information on *Labeobarbus aeneus,* including species capture dates, capture method, tag number, measurements, and season of capture

Vaal River				(g)	(mm)	(mm)	(mm)	(mm)	
Species	Capture date	Capture method	Tag	Mass	Total length	Fork length	Standard length	Girth	Season
L. aeneus 1	15/02/2012	Fly-fishing	50	2350	580	520	500	310	Summer
L. aeneus 2	20/02/2012	Electro fishing	44	1800	520	470	450	240	Summer
L. aeneus 3	20/02/2012	Electro fishing	46	2300	570	540	470	300	Summer
L. aeneus 4	20/02/2012	Electro fishing	47	2100	490	445	405	270	Summer
L. aeneus 5	20/02/2012	Electro fishing	49	2500	568	525	490	330	Summer
L. aeneus 6	20/02/2012	Electro fishing	51	1400	520	450	420	220	Summer
L. aeneus 7	20/02/2012	Electro fishing	53	4000	680	625	580	390	Summer
L. aeneus 8	20/02/2012	Electro fishing	37	2100	560	490	420	305	Summer
L. aeneus 9	20/02/2012	Electro fishing	38	2500	580	535	500	380	Summer
L. aeneus 10	21/02/2012	Electro fishing	45	1900	540	480	455	290	Summer
L. aeneus 11	21/02/2012	Electro fishing	52	2500	570	525	500	330	Summer
L. aeneus 12	01/08/2012	Lure fishing	20	2400	568	511	487	370	Winter
L. aeneus 13	01/08/2012	Lure fishing	33	2800	570	520	480	380	Winter
L.aeneus 14	07/09/2012	Bait fishing	109	4550	670	610	560	380	Autumn

Table 13: Information on radio tags used, including species, capture dates, tag number, tag functions, manual, remote fixes and comments on the performance of the radio tags used

Species	Capture date	Radio tag number	Tag functions	Manual fixes	Remote fixes	Comments
L. aeneus 1	15/02/2012	50	Act, Temp, Depth	0	0	Tag failed
L. aeneus 2	20/02/2012	44	Act, Temp, Depth	0	0	Tag failed
L. aeneus 3	20/02/2012	46	Act, Temp, Depth	0	29661	Satisfactory
L. aeneus 4	20/02/2012	47	Act, Temp, Depth	0	3246	Satisfactory
L. aeneus 5	20/02/2012	49	Act, Temp, Depth	0	666	Limited data
L. aeneus 6	20/02/2012	51	Act, Temp, Depth	328	25586	Limited data
L. aeneus 7	20/02/2012	53	Act, Temp, Depth	151	26399	Limited data
L. aeneus 8	20/02/2012	37	Act, Temp	0	0	Tag failed
L. aeneus 9	20/02/2012	38	Act, Temp	0	0	Tag failed
L. aeneus 10	21/02/2012	45	Act, Temp, Depth	0	56	Satisfactory
L. aeneus 11	21/02/2012	52	Act, Temp, Depth	0	2478	Satisfactory
L. aeneus 12	01/08/2012	20	Act, Temp	0	3974	Satisfactory
L. aeneus 13	01/08/2012	33	Act, Temp	0	3356	Limited data
L. aeneus 14	07/09/2012	109	Act, Temp, Depth, Memory	0	0	Tag failed

Radio tags were tested at WW facilities before they were brought into the field. Before any tag was externally attached to an individual it was again tested to ensure that they worked properly. All 14 radio tags worked before they were attached to individuals; however, radio tag numbers 50, 44, 37, 38 and 109 failed as soon they were attached to individuals and did not transmit any data to remote monitoring stations. Tag numbers 49, 51 and 52 resulted in limited data when depth sensors on tags failed. Tag number 33 was a production error as temperature peripheral components were not included in the tag and five tags, i.e. numbers 46, 47, 20, 45 and 52, performed satisfactorily.

Figure 40: *Labeobarbus aeneus* number 1-4 captured, tagged and monitored in the Vaal River. Note the scar on *L. aeneus* 3.

Figure 41: *Labeobarbus aeneus* number 5-8 captured, tagged and monitored in the Vaal River

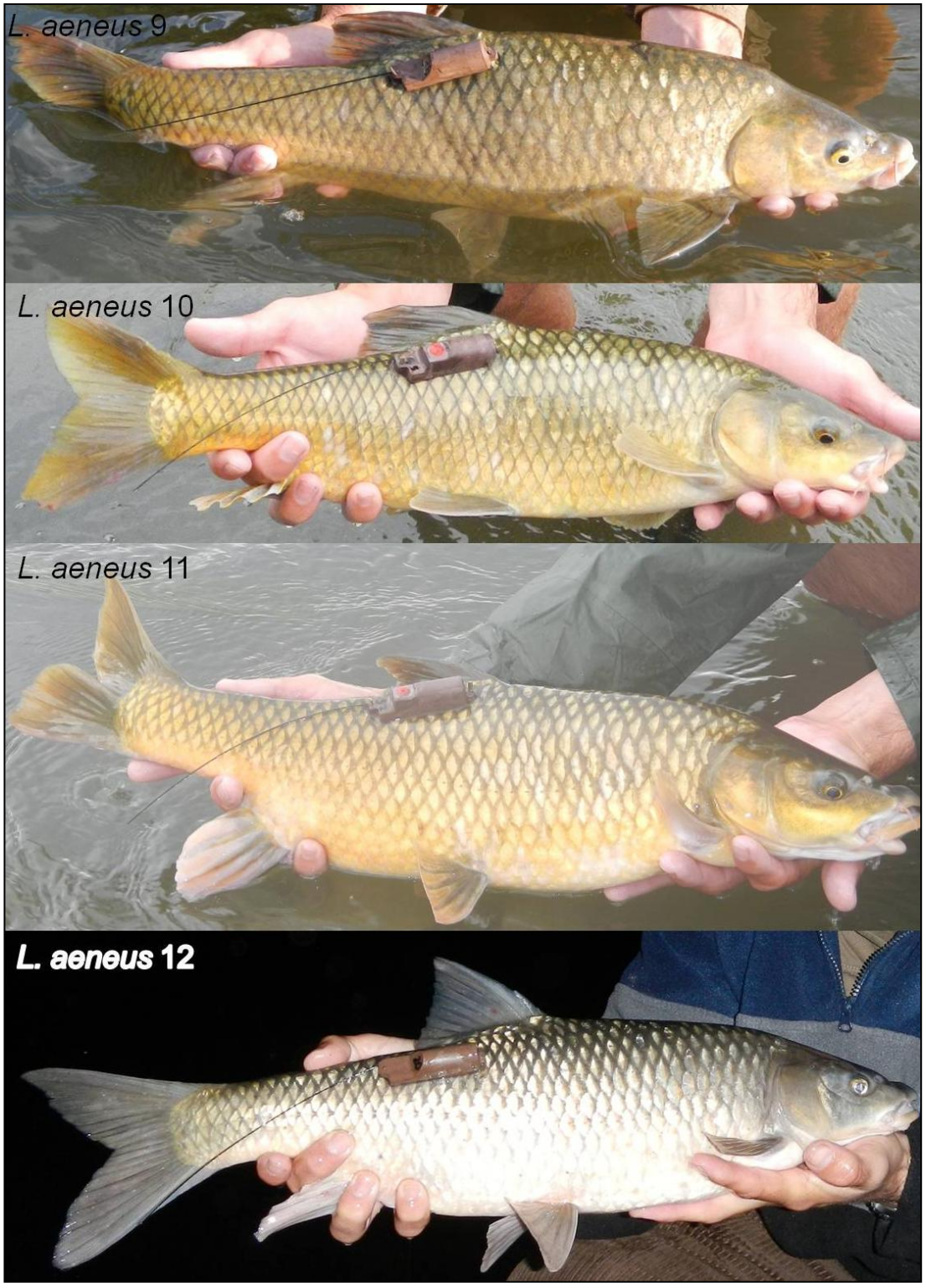


Figure 42: *Labeobarbus aeneus* number 9-12 captured, tagged and monitored in the Vaal River

Figure 43: *Labeobarbus aeneus* number 13-14 captured, tagged and monitored in the Vaal River

***Labeobarbus aeneus* (3)**

Labeobarbus aeneus (3) with radio tag number 46 was monitored from 20/02/2012 during which time 29 661 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (3) had movement counts in the range of 64 MC/min to 67.4 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased and ranged from 106.5 MC/min to 193.5 MC/min. *Labeobarbus aeneus* (3) had peak movement counts during time periods from 08:00-12:00 with an count of 193.5 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an count of 64 MC/min (Figure 44A). Movement counts were lower during new moon phases 117.4 MC/min (n=1 485) than during full moon phases 121.3 MC/min (n=955) (Figure 44B). The seasonal movement was highest during summer 117.5 MC/min (n=192), thereafter autumn 117.5 MC/min (n=6 735), winter 0.5 MC/min (n=518) and very limited data were collected in spring 0.1 MC/min (n=3) (Figure 44C).

Labeobarbus aeneus (3) maintained a depth range of 577 mm to 643mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight hours ranged from 558 mm to 641 mm (Figure 44 A). These depths overlapped during night and day time and may be as a result of the limited water column in the Vaal River.

During full moon phases depth of *L. aeneus* (3) was 667 mm (n=644) and during new moon phases depth was 611 mm (n=826) (Figure 44B). Seasonal variations in depth d from 558 mm (n=1 973) in summer to 618 mm (n=5 232) in winter. Limited seasonal depth data were recorded and seasonal depth is based on summer and winter data (Figure 44C).

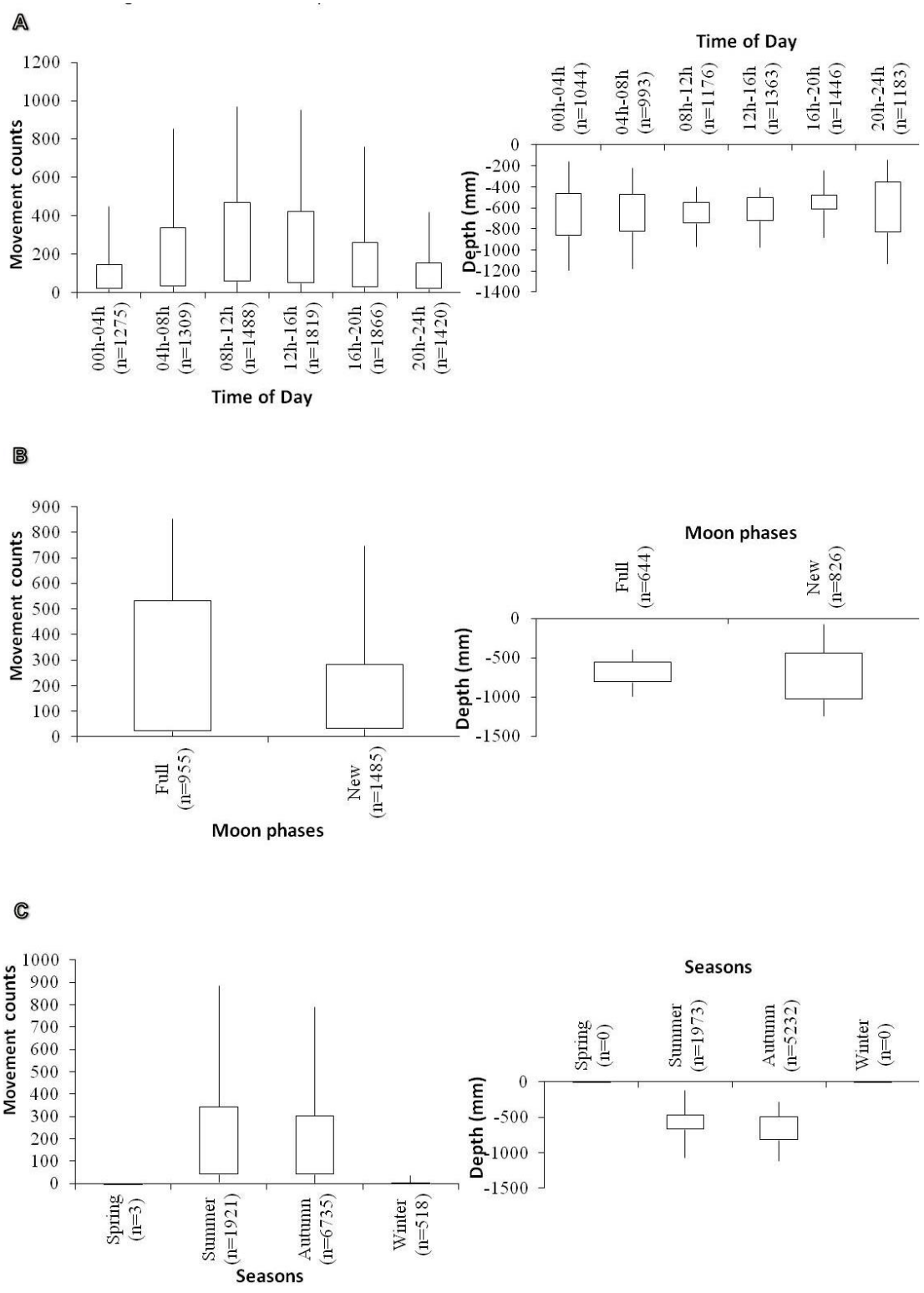


Figure 44: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity was higher during daytime periods, full moon phases and summer. This individual with tag number 46 preferred shallower habitats during full moon phases and summer.

***Labeobarbus aeneus* (4)**

Labeobarbus aeneus (4) with radio tag number 47 was monitored from 20/02/2012 during which time 3 246 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (4) had movement counts ranging between 123.5 MC/min and 137.1 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased and ranged from 142.8 MC/min to 226.6 MC/min. *Labeobarbus aeneus* (4) had peak movement counts during time periods from 08:00-12:00 with an count of 226.6 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an count of 123.5 MC/min (Figure 45A). Movement counts were higher during new moon phases 186.4 MC/min (n=182) than during full moon phases 83 MC/min (n=182) (Figure 45B). The seasonal movement was highest during autumn (181.1 MC/min) (n=687), and then summer 142 MC/min (n=151). This trend may be as a result of the limited data obtained during summer (Figure 45C). The radio tag on this individual transmitted data until 12/03/2012 and therefore seasonal data are limited. The radio tag might have been damaged against the rocks in the Vaal River or the fish may have died.

Labeobarbus aeneus (4) maintained a depth range of 563 mm to 608 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 589 mm to 648 mm. Depth ranges overlapped, which means that *L. aeneus* used the entire water column available (Figure 45A). During full moon phases depth of *L. aeneus* (4) was 664 mm (n=668) and during new moon phases depth was 498 mm (n=556) (Figure 45B). Seasonal variations in depth d from 619 mm (n=175) in summer to 577 mm (n=1 491) in autumn. It seems that *L aeneus* (4) still used the entire water column available, although water temperatures decreased during autumn (Figure 45C).

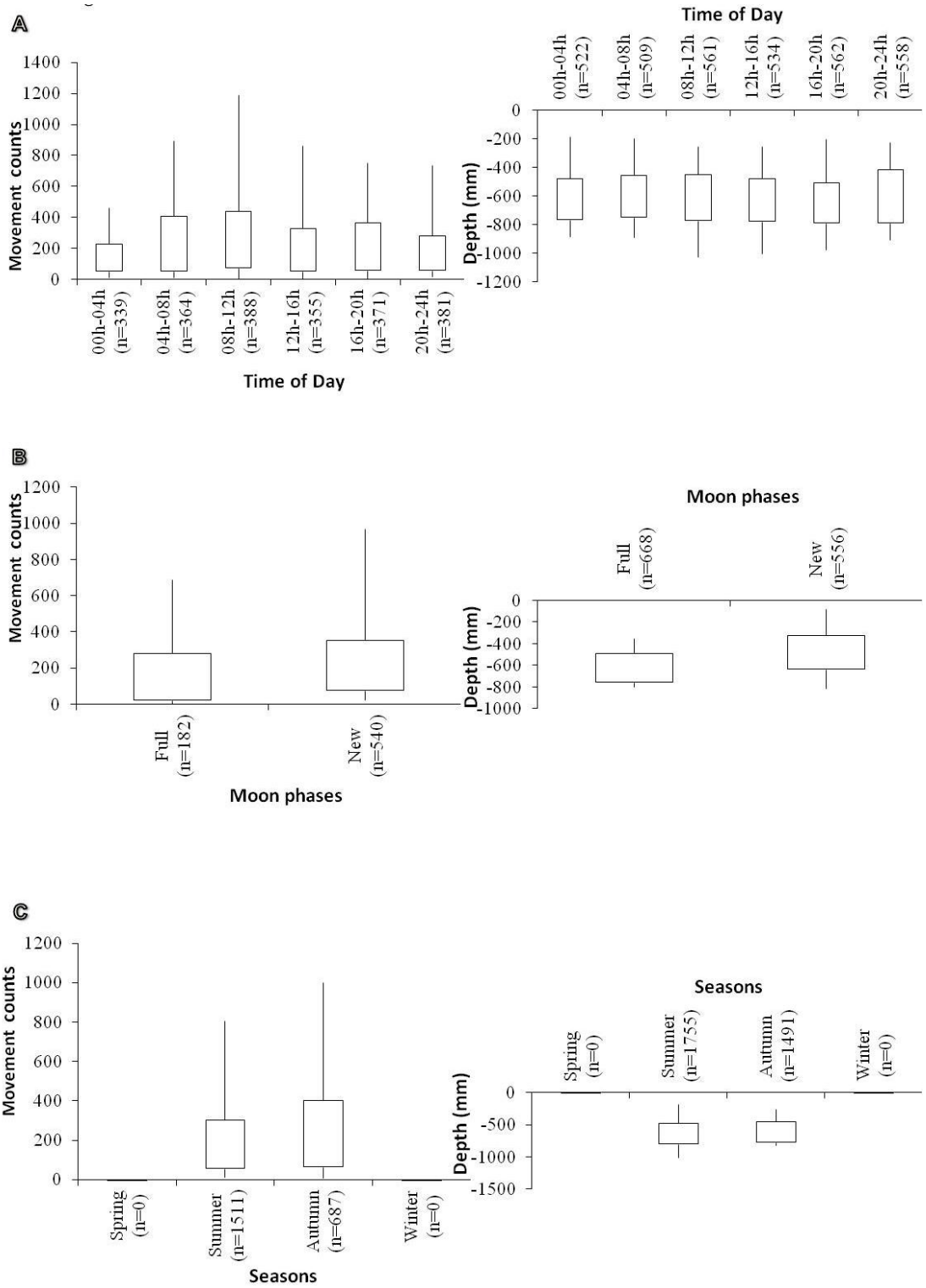


Figure 45: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher movement activity was observed during daytime periods, new moon phases and autumn. Individual with tag number 47, habitats during diurnal periods seemed to be uniform; however shallower habitats were preferred during new moon phases.

***Labeobarbus aeneus* (5)**

Labeobarbus aeneus (5) with radio tag number 49 was monitored from 20/02/2012 during which time 666 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (5) had movement counts ranging between 48.8 MC/min and 49.1 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased to between 72.4 MC/min and 128.9 MC/min. *Labeobarbus aeneus* (5) had peak movement counts during time periods from 08:00-12:00 with an count of 128.9 MC/min whereas lowest movement counts were observed between 20:00-24:00 with an count of 48.8 MC/min (Figure 46A). Moon phase data were limited and a movement count during new moon phases of 72.3 MC/min (n=472) (Figure 46B). The seasonal movement during summer was 70.5 MC/min (n=568). Data from this tag were limited and movement counts were restricted to summer (Figure 46C).

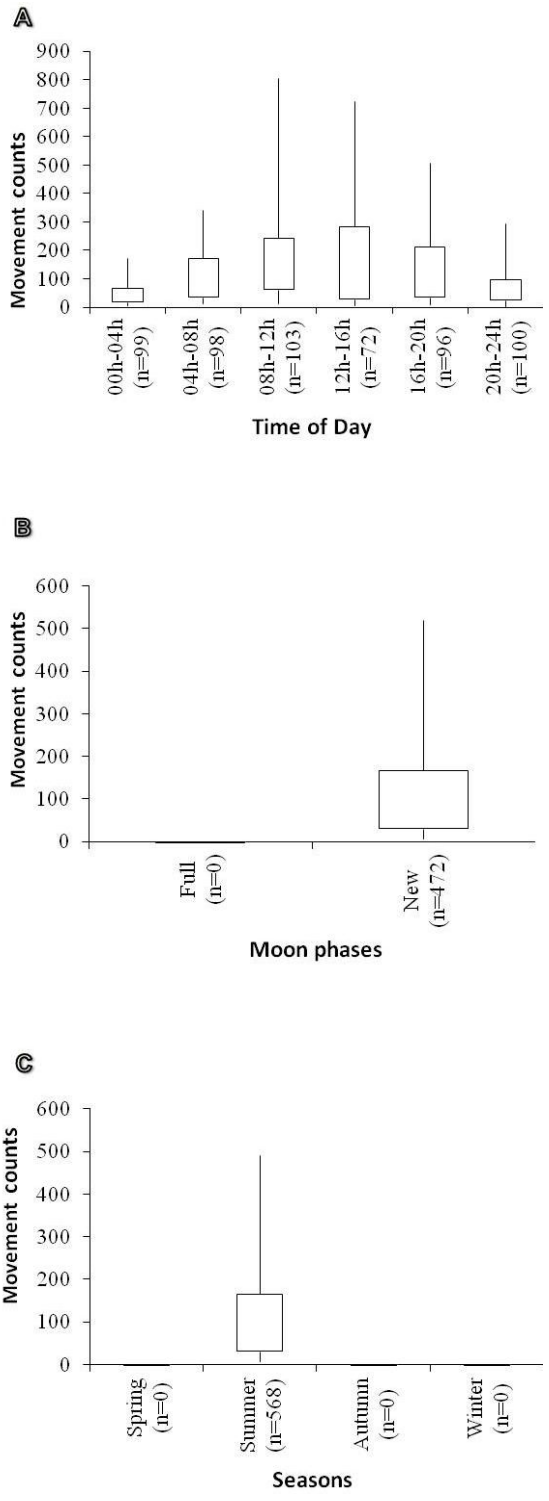


Figure 46: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Highest movement activity of individual with tag number 49 was observed during daytime periods as opposed to nocturnal periods.

***Labeobarbus aeneus* (6)**

Labeobarbus aeneus (6) with radio tag number 51 was monitored from 20/02/2012 during which time 25 586 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (6) had movement counts ranging between 15.3 MC/min and15.6 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement increased and ranged from 27.3 MC/min to 45.3 MC/min. *Labeobarbus aeneus* (6) had peak movement counts during time periods from 12:00-16:00 with an count of 45.3 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an of 15.3 MC/min (Figure 47). Movement counts were higher during new moon phases 31.6 MC/min (n=2 298) than during full moon phases 23.7 MC/min (n=2 262) (Figure 47A). The seasonal movement count was highest during summer 334.5 MC/min (n=1437), then autumn 29.3 MC/min (n=8 104), spring 16.3 MC/min (n=1 247) and then winter 12 MC/min (n=2 363) (Figure 47B). Depth for this individual ranged from 150 mm to 180 mm throughout the entire monitoring period (Figure 47C). Depth data were limited although the tag transmitted data throughout the entire study period up until the 30/09/2012, which resulted in continuous data being recorded.

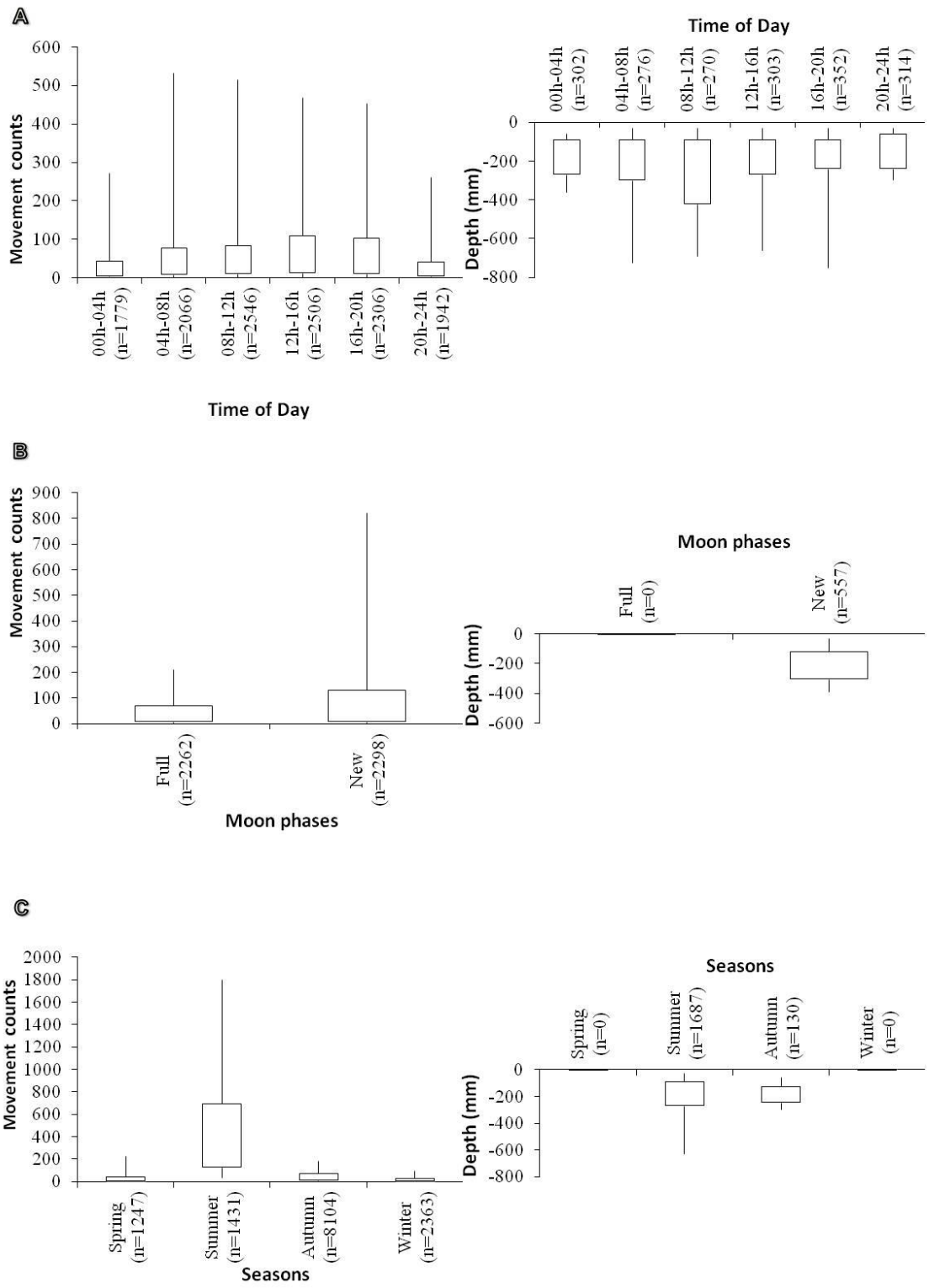


Figure 47: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity and depth of tag number 51 increased in daytime and new moon phases. Highest movement activity was observed during summer and lowest movement activity during autumn and winter.

***Labeobarbus aeneus* (7)**

Labeobarbus aeneus (7) with radio tag number 53 was monitored from 20/02/2012 during which time 26 399 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (7) had movement counts ranging between 19.2 MC/min and 19.3 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased to 25.5 MC/min to 41.3 MC/min. *Labeobarbus aeneus* (7) had peak movement counts during time periods from 12:00-16:00 with an count of 41.3 MC/min whereas lowest movement counts were between 00:00-04:00 with an count of 19.2 MC/min (Figure 48A). Movement counts were higher during new moon phases 33.6 MC/min (n=2 508) than during full moon phases 26.3 MC/min (n=2 536) (Figure 48B). The seasonal movement was highest during summer 34.7 MC/min (n=853), autumn 34.7 MC/min (n=1 220), spring 10.5MC/min (n=225) and then winter 9.5 MC/min (n=3 335) (Figure 48C). The radio tag on this individual transmitted data until 30/09/2012 and provided satisfactory data.

Labeobarbus aeneus (7) maintained a depth range of 796 mm to 840 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 630 mm to 810 mm (Figure 48A). Depth seems to overlap during night and daytime, suggesting that *L. aeneus* (7) uses the entire water column throughout a 24 h day cycle (Figure 48 B). During full moon phases the depth of *L. aeneus* (7) was 750 mm (n=4 281) and during new moon phases depth was 780 mm (n=3 700) (Figure 48). Seasonal variations in depth ranged from 780 mm (n=1 013) in summer, 411 mm (n=733) in spring, 630 mm (n=1 442) in autumn and 796 mm (n=4 560) in winter (Figure 48C).

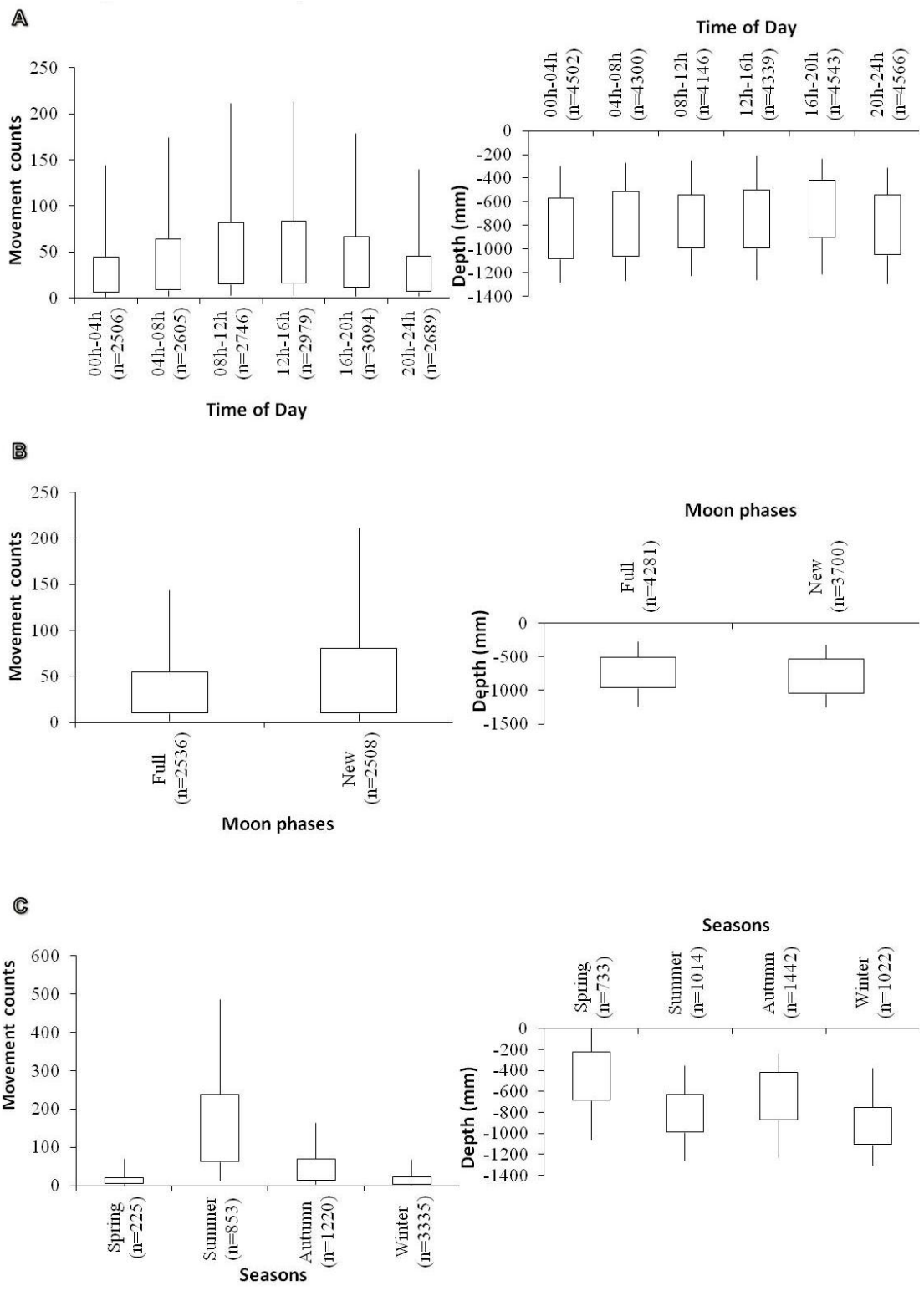


Figure 48: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity increased during daytime, new moon phases and summer. Deeper habitats where preferred by tag number 53 during new moon phases and winter.

***Labeobarbus aeneus* (10)**

Labeobarbus aeneus (10) with radio tag number 45 was monitored from 21/02/2012 during which time 56 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (10) had movement counts ranging between 48.2 MC/min and 57.9 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement increased and ranged from 188.8 MC/min to 464.6 MC/min. *Labeobarbus aeneus* (10) had peak movement counts during daytime periods from 08:00-12:00 with an of 464.6 MC/min whereas lowest movement counts were between 20:00-24:00 with an of 48.2 MC/min (Figure 49A). Movement during new moon phases was 81.1 MC/min (n=52) (Figure 49B). The seasonal movement counts were limited to summer with a movement count of 81.1 MC/min (n=52) (Figure 49C). The tag on the individual transmitted data until the 22/02/2012, after which the tag got damaged or the fish died.

Labeobarbus aeneus (10) maintained a depth range of 177 mm to 437mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 177 mm to 437 mm (Figure 49A). Data were limited during moon phases and only new moon phases were recorded with an depth of 332 mm (n=52) (Figure 49B). Summer depth for this individual were 332 mm (n=56) in summer (Figure 49C).

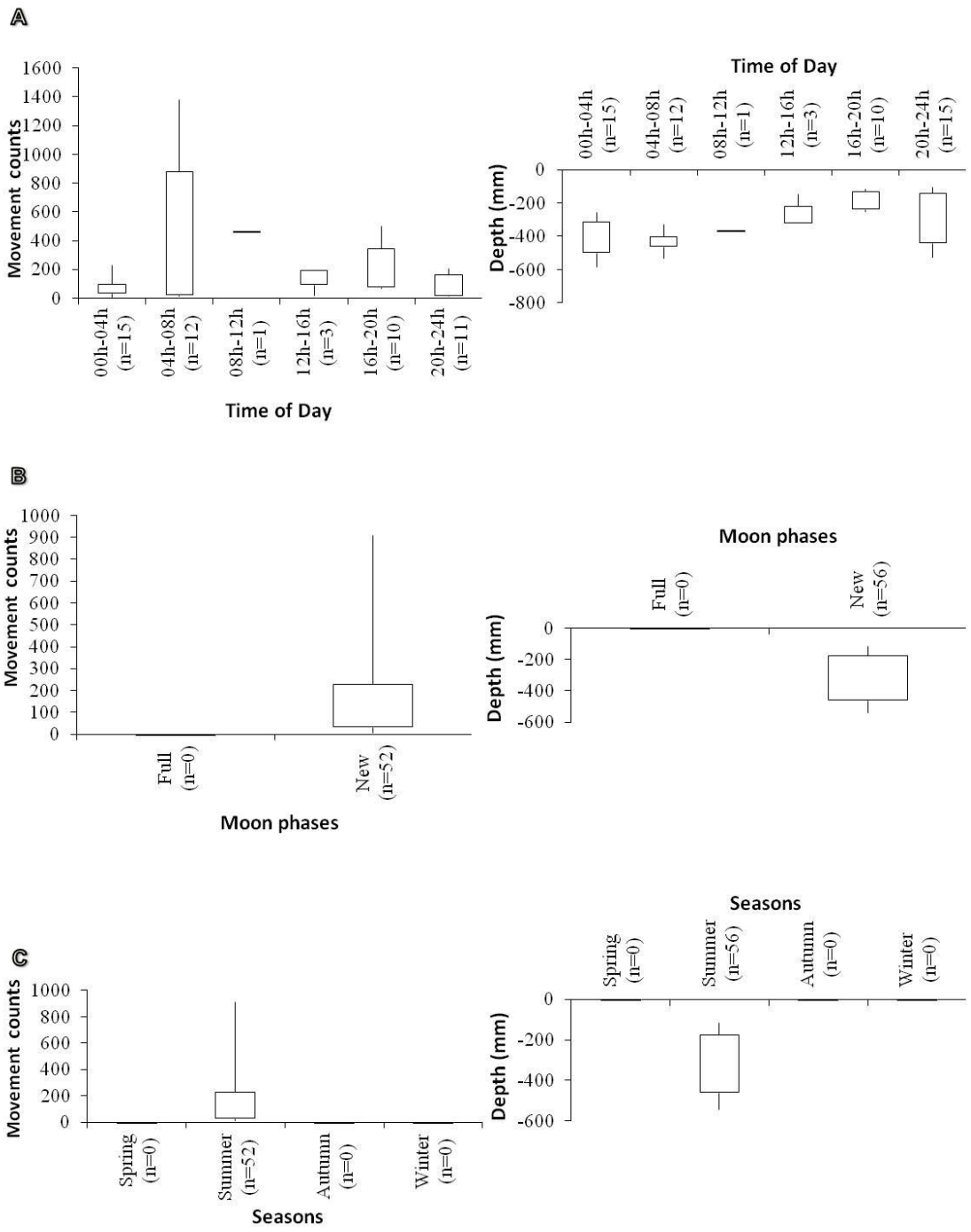


Figure 49: Box-and-whisker plot of the movement counts for tag number 45 and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles.

***Labeobarbus aeneus* (11)**

Labeobarbus aeneus (11) with radio tag number 52 was monitored from 21/02/2012 during which time 2 478 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus aeneus* (11) had movement counts ranging between 15 MC/min and 24.7 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement count ranges increased to between 55 MC/min and 105.8 MC/min. *Labeobarbus aeneus* (11) had peak movement counts during daytime periods from 12:00-16:00 with an count of 105.8 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an count of 15 MC/min (Figure 50A). Movement counts were higher during new moon phases 64 MC/min (n=598) than during full moon phases 55.2 MC/min (n=141) (Figure 50B). The seasonal movement was highest during autumn 88.7 MC/min (n=1421), summer 78.5 MC/min (n=170), spring 29.7 MC/min (n=14) and then winter 9.3 MC/min (n=536) (Figure 50C). The tag on this individual transmitted data until 24/09/2012 and provided continuous data.

Labeobarbus aeneus (11) maintained a depth range of between 291 mm and 300 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight ranged from 270 mm to 390 mm (Figure 50A). During full moon phases depth of *L. aeneus* (11) was 240 mm (n=40) and during new moon phases depth was 360 mm (n=560) (Figure 50B). Seasonal variations in depth ranged from 435 mm (n=220) in summer to 287 mm (n=1 272) in autumn. Limited data were obtained and depths during different seasons are based on data recorded during summer and autumn (Figure 50C).

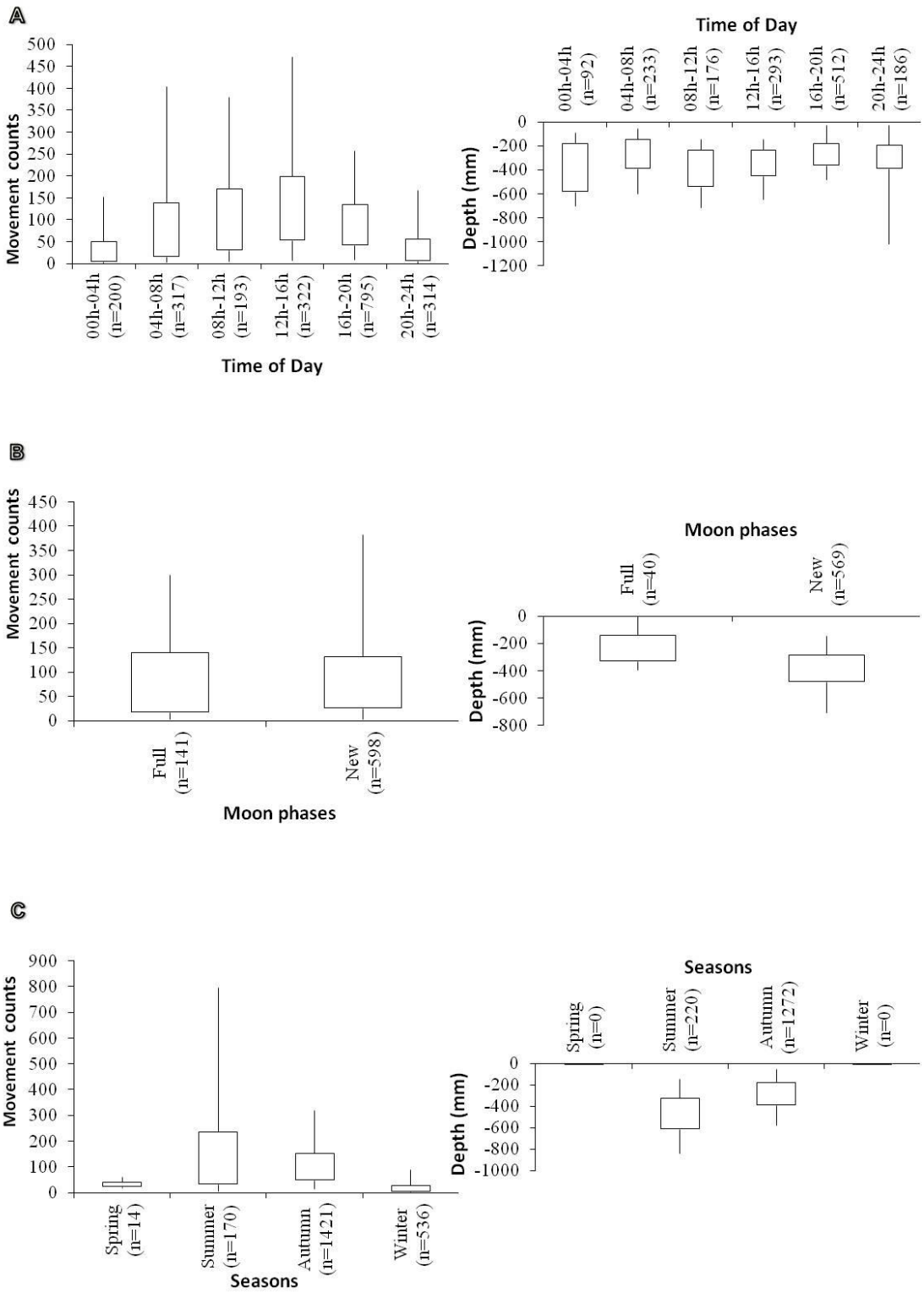


Figure 50: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity of tag number 52 increased during daytime, full moon phases and summer. There is a slight increase in habitat depth during daytime and during new moon phases.

***Labeobarbus aeneus* (12)**

Labeobarbus aeneus (12) with radio tag number 20 was monitored from 01/08/2012 during which time 3 974 data strings were remotely obtained. These strings contained activity and temperature peripheral information. Data showed that *Labeobarbus aeneus* (12) had movement counts ranging between 14.5 MC/min and 18.4 MC/min during nocturnal periods (00h00-04h00 and 20h00-24h00) of the day whereas daytime movement counts increased to between 23.7 MC/min and 51.2 MC/min. *Labeobarbus aeneus* (12) had peak movement counts during time periods from 12:00-16:00 with an count of 151.2 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an count of 14.5 MC/min (Figure 51A). Movement counts were higher during new moon phases 30.3 MC/min (n=203) than during full moon phases 24.1 MC/min (n=422) (Figure 51B). Seasonal data were limited and movement count during winter was 25.8 MC/min (n=1 375) (Figure 51C).

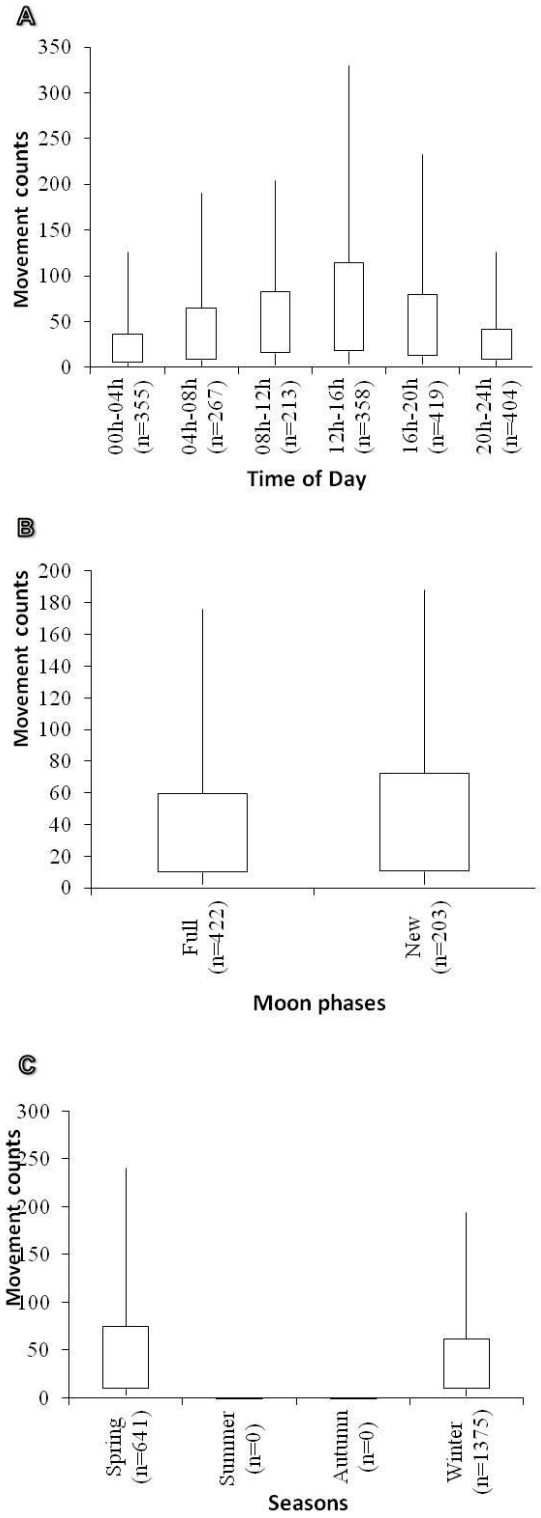


Figure 51: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Movement activity of tag number 20 increased during daytime, new moon phases and spring.

***Labeobarbus aeneus* (13)**

Labeobarbus aeneus (13) with radio tag number 33 was monitored from 01/08/2012 during which time 3 356 data strings were remotely obtained. These strings contained activity and temperature peripheral information. Data showed that *Labeobarbus aeneus* (13) had movement counts ranging between 15.4 MC/min and 16.9 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas the daytime movement count range increased to between 41.4 MC/min and 72.6 MC/min. *Labeobarbus aeneus* (13) had peak movement counts during time periods from 12:00-16:00 with an of 72.6 MC/min whereas lowest movements were observed between 00:00-04:00 with an of 15.4 MC/min (Figure 52A). Movement counts were higher during new moon phases 46.4 MC/min (n=321) than during full moon phases 20 MC/min (n=241) (Figure 52B). Limited seasonal data were obtained and the movement count during spring was 46.9 MC/min (n=97) and during winter it was 36.9 MC/min (n=1 978) (Figure 52C).

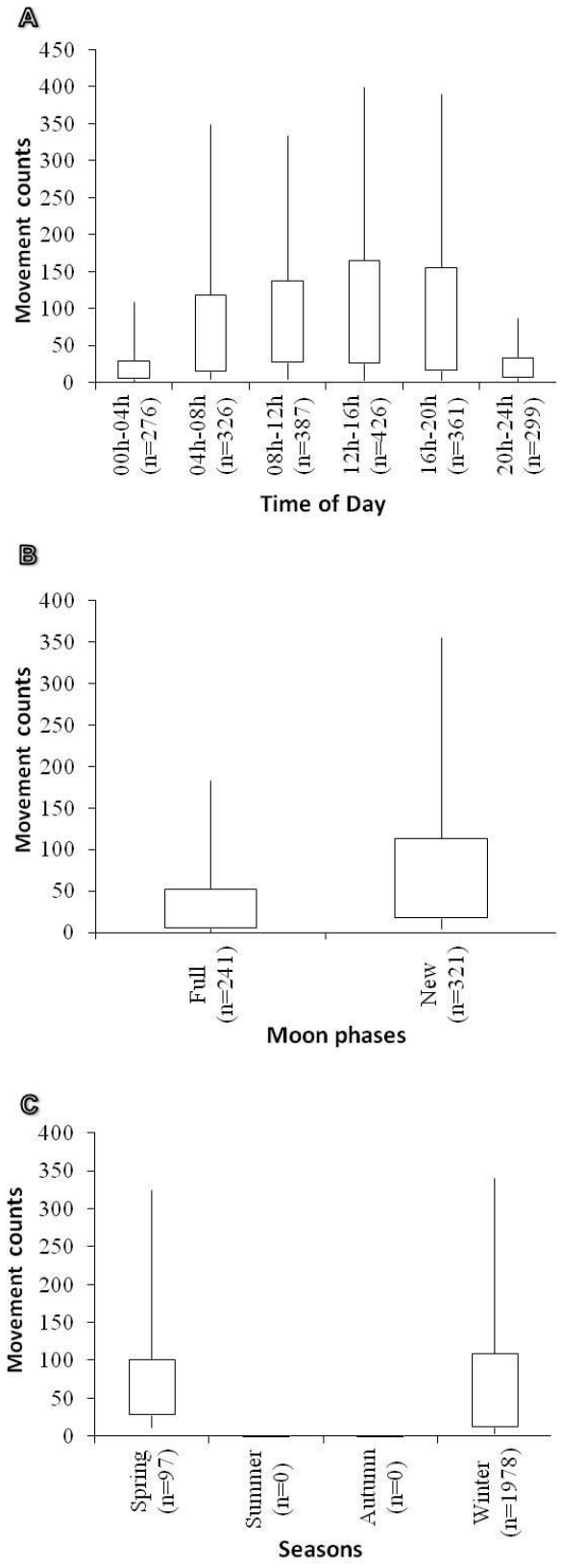


Figure 52: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Higher movement activity of tag number 33 was observed during daytime and new moon phases.

General behavioural pattern of *Labeobarbus aeneus* in the Vaal River

The following section presents data from all tagged individuals incorporated into a single group, to identify the general movement behaviour pattern of *L. aeneus* in the Vaal River. The same procedure as used with Boskop Dam data was followed for the Vaal River study area (Table 14).

Labeobarbus aeneus in the Vaal River follows distinct behavioural patterns, with some individual variations in behaviour. *Labeobarbus aeneus* in the Vaal River showed a significant decrease ($P<0.05$) in movement activity with increasing flows, and significantly increased ($P<0.05$) movement activity during stable flows. *Labeobarbus aeneus* exhibited significantly ($P<0.05$) higher movement counts during daylight hours (08:00-20:00). During the nocturnal time of day *L. aeneus showed a* decrease in movement activity (Figure 53A). *Labeobarbus aeneus* showed significantly ($P<0.05$) higher movement counts during new moon phases. Individuals preferred deeper water during full moon phases than during new moon phases (Figure 53B).

Movement counts were higher and individuals preferred shallower habitats with increased temperatures in summer and spring whereas movement activity significantly ($P<0.05$) decreased with decreased temperatures and increased depth in autumn and winter (Figure 53C).

The rainfall event that occurred in winter (21-23 June) may have had an effect on the behaviour of *L. aeneus* but this was not confirmed as data obtained during that period were insufficient to draw an accurate conclusion. Atmospheric pressure alone did not have a significant effect on *L. aeneus* in the Vaal River.

Table 14: Highest and lowest movement counts plotted (x) against time periods, moon phases and seasons. It also shows which data were not available (N/A) for *Labeobarbus aeneus* remotely monitored in the Vaal River.

Highest movement

	Time period of day						Moon phase		Season			
Tag nmr	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00	Full	New	Spring	Summer	Autumn	Winter
46			x				x			x		
47			x					x	N/A		x	N/A
49			x				N/A	x	N/A	x	N/A	N/A
51				x				x		x		
53				x				x		x		
45			x				N/A	x	N/A	x	N/A	N/A
52				x				x			x	
20				x				x	x	N/A	N/A	
33				**x**				**x**	x	N/A	N/A	

Low est movement

	Time period of day						Moon phase		Season			
Tag nmr	00:00-04:00	04:00-08:00	08:00-12:00	12:00-16:00	16:00-20:00	20:00-24:00	Full	New	Spring	Summer	Autumn	Winter
46						x		x				x
47	x						x		N/A	x		N/A
49						x	N/A	x	N/A	x	N/A	N/A
51	x						x					x
53	x						x					x
45						x	N/A	x	N/A	x	N/A	N/A
52	x						x					x
20	x						x			N/A	N/A	x
33	**x**						**x**			N/A	N/A	x

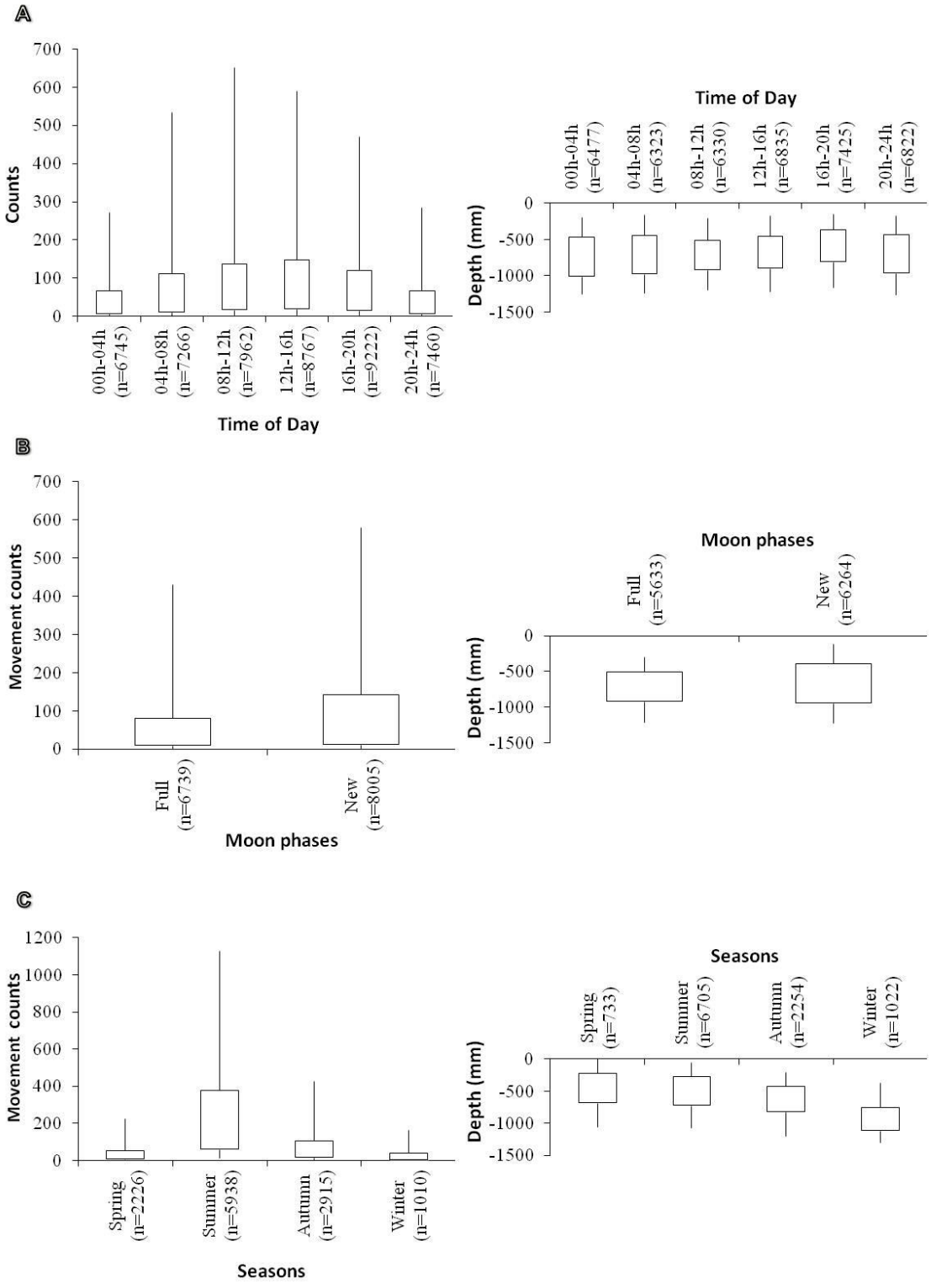


Figure 53: Box-and-whisker plot of the movement counts and depth against time of day (A) moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. Overall highest movement activity where observed during daytime, new moon phases and summer. Lowest movement activity was during winter where individuals also preferred deepest habitats.

Preferred areas of *Labeobarbus aeneus* in the Vaal River

Data obtained from the remote monitoring stations set up along the Vaal River were used to identify which areas *L. aeneus* preferred in the study area (Table 15). *Labeobarbus aeneus* seemed to use the entire study area during the year, especially the areas around remote monitoring station two, four, five, six, seven and eight. These areas contained a large diversity of habitat types including deep pools, undercut banks with submerged roots and trees, fast rapids, riffles with reeds and vegetation, sand, gravel beds with boulders and aquatic vegetation. It seemed that *L. aeneus* used a large area in the Vaal River as information was collected by every station in the study area.

The area usage of *L. aeneus* could, however, not be accurately identified as tags were sometimes recorded by more than one station, therefore implicating the statistical evaluations of position. The minimum distances were not significantly evaluated because of the aforementioned problem; therefore distances were calculated using the furthest two remote monitoring stations that recorded data from a specific individual. The largest area usages for individuals ranged from remote monitoring station two all the way downstream to remote monitoring station eight, that is approximately 9 km in length. Tagged individuals that were recorded throughout the specific focus area had an movement range of approximately 2 km in length. However, these data are influenced by depth and position of individuals and is the reason why continuous data were not obtained for individuals moving from one area to another.

Table 15: The preferred areas marked with an (x) of *Labeobarbus aeneus* in the Vaal River throughout the study: including tag numbers and station numbers.

Tag nmr	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6	STATION 7	STATION 8
46				x	x	x	x	x
47					x	x	x	x
49					x		x	x
51		x		x	x	x	x	x
53		x		x	x	x	x	x
45		x			x		x	x
52	x	x	x					
20		x	x	x	x			
33					x	x	x	x

Manual monitoring results for Labeobarbus aeneus in the Vaal River

Due to the nature of the manual monitoring equipment development process, manual monitoring surveys was started during winter. Two (tagged at same location) of the 14 tagged fish were tracked during June, July, August and September 2012 in the Vaal River. During time of manual tracking these two yellowfish mostly occupied the same areas. The limited time available for manual monitoring surveys resulted in adapting the original monitoring plan of locating an individual every 10 min for 40 min. Instead surveys aimed at maximizing data. Once a tagged individual was located, a GPS fix together with all relevant information was recorded every 10 min for as long as possible. *Labeobarbus aeneus* (6) with radio tag number 51 was monitored for a total of nine separate days during which time 328 GPS fixes were manually obtained. *Labeobarbus aeneus* (7) with radio tag number 53 was monitored for six separate days during which time 151 GPS fixes were manually obtained (Figure 54). During manual monitoring surveys these two individuals had an average habitat preference of less than 1 km^2, with only one downward movement of more than 1 km^2, after which both yellowfish returned to the same area.

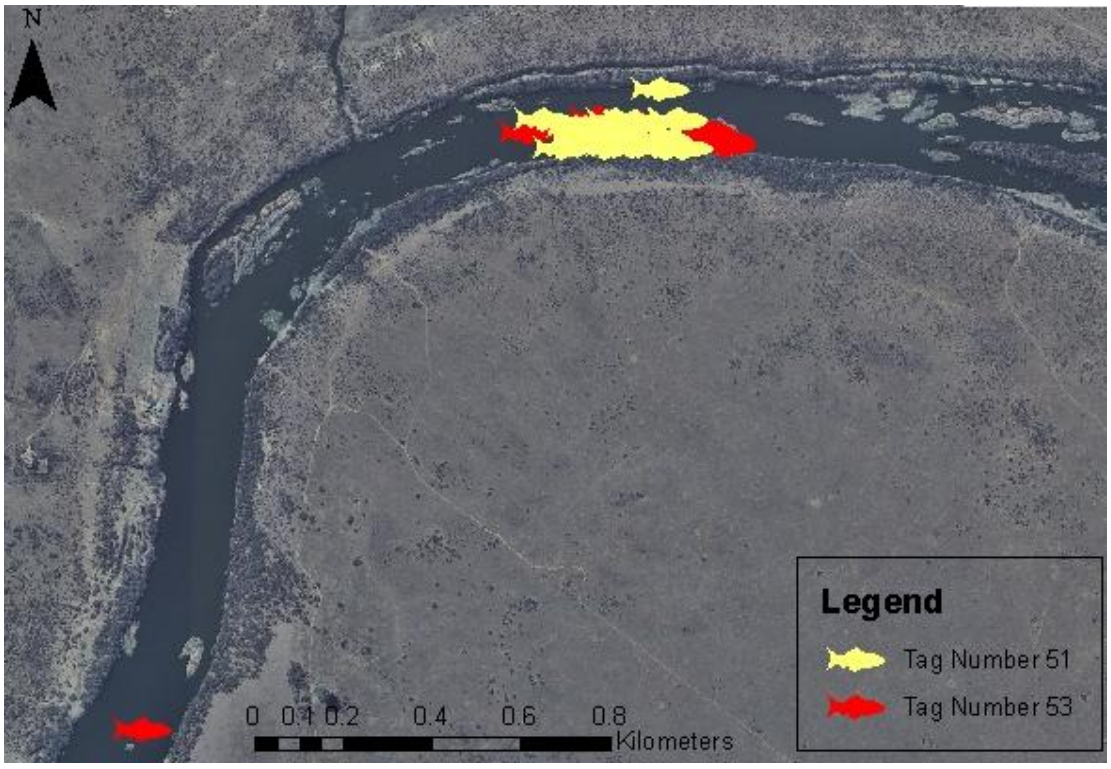


Figure 54: A total of 479 GPS fixes was obtained from manually monitoring (Tag 51=328, Tag 53=151). These two individuals had an average habitat preference of less than 1 km^2 in range of remote monitoring station 4, 5, 6 and 7, and showed only one movement event outside this area.

Habitat utilization

Both yellowfish were located mostly in the middle of the river during tracking surveys. They seemed to prefer this area and consisted of scattered boulders, cobbles and gravel with relatively deep pools > 1 000 mm during daytime. Movement activity was high during these periods and yellowfish moved over short distances < 2 m regularly. The two individuals mostly moved away from this area during low light periods. *Labeobarbus aeneus* (6) had habitat preferences for undercut bank/roots with submerged roots and trees during low light periods often moving over longer distances > 10 m after which yellowfish returned to area in the middle of the river. *Labeobarbus aeneus* (7) different to *L. aeneus* (6) was found to have habitat preferences for fast rapids, riffles with reeds and vegetation during which time yellowfish would continue moving over short distances < 2 m regularly (Figure 55).

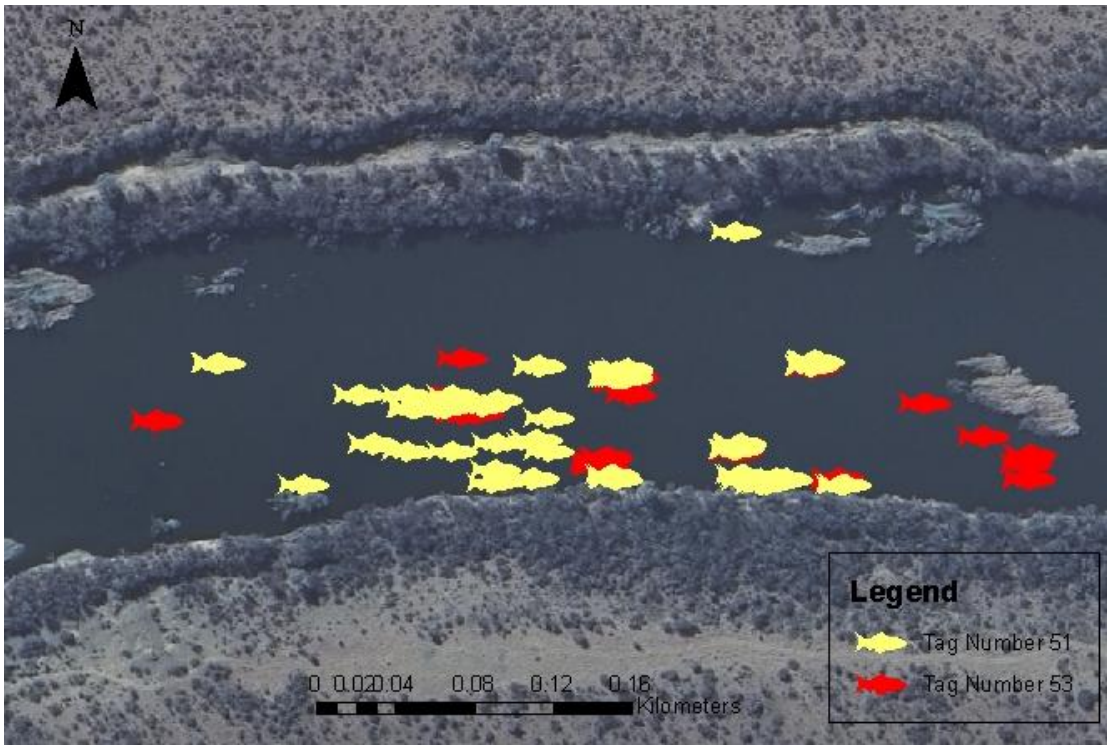


Figure 55: Yellowfish seemed to prefer an area in the middle of the river that consisted of scattered boulders, cobbles and gravel with relatively deep pools > 1 000 mm during daytime after which *Labeobarbus aeneus* (6) had habitat preferences for undercut bank/roots with submerged roots, trees and *Labeobarbus aeneus* (7) preferred fast rapids, riffles with reeds and vegetation during low light periods.

3.5 Radio telemetry results for *Labeobarbus kimberleyensis* in the Vaal River

The findings on the behavioural ecology of *L. kimberleyensis* in the Vaal River are based on information monitored from three suitable largemouth yellowfish that were captured at various locations using a range of different techniques (Figure 18), after which they were sedated, measured, tagged, photographed and released (Figure 56). Information of tagged *L. kimberleyensis* was recorded on a data sheet (Table 16) for future reference. All the radio tags contained activity, temperature and depth peripheral components. Of these four radio tags, two tags had malfunctions which resulted in lost data (Table 17). Radio tags were able to transmit to remote monitoring stations at a maximum depth of about 2 500 mm over a range of about 500 m. A total of 5 701 data strings were recorded by the eight remote monitoring stations set up around the study area.

Table 16: General information on *Labeobarbus kimberleyensis* including: species capture dates, capture method, tag number, measurements, and season of capture

				(g)	(mm)	(mm)	(mm)	(mm)	
Species	**Capture date**	**Capture method**	**Tag**	**Mass**	**Total length**	**Fork length**	**Standard length**	**Girth**	**Season**
L. kimberleyensis 1	20/02/2012	Electro fishing	48	1150	485	430	400	240	Summer
L. kimberleyensis 2	18/07/2012	Gill nets	54	2300	530	510	500	300	Winter
L. kimberleyensis 3	02/08/2012	Gill nets	47	3800	560	520	510	320	Winter

Table 17: Information on radio tags used, including species, capture dates, tag number, tag functions, manual, remote fixes and comments on the performance of the radio tags used

Species	**Capture date**	**Radio tag number**	**Tag functions**	**Manual fixes**	**Remote fixes**	**Comments**
L. kimberleyensis 1	20/02/2012	48	Act, Temp, Depth	0	5512	Satisfactory
L. kimberleyensis 2	18/07/2012	54	Act, Temp, Depth	0	46	Limited data
L. kimberleyensis 3	02/08/2012	47	Act, Temp, Depth	0	143	Limited data

Figure 56: *Labeobarbus kimberleyensis* number 1-3 caught, tagged, photographed and monitored in the Vaal River study area. Note *L. kimberleyensis* 2-3 have sores covering large parts of their bodies.

***Labeobarbus kimberleyensis* (1)**

Labeobarbus kimberleyensis (1) with radio tag number 48 was monitored from 20/02/2012 during which time 5 512 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus kimberleyensis* (1) had movement counts ranging between 85.5 MC/min and 86.6 MC/min during nocturnal periods (00:00-04:00 and

20:00-24:00) of the day whereas daytime movement counts increased to between 111.9 MC/min and 220.4 MC/min. *Labeobarbus kimberleyensis* (1) had peak movement counts during time periods from 12:00-16:00 with an count of 220.4 MC/min whereas lowest movement counts were observed between 00:00-04:00 with an count of 85.5 MC/min (Figure 57A). Movement counts were higher during full moon phases 112.4 MC/min (n=644) than during new moon phases 99.8 MC/min (n=889) (Figure 57B). Limited data were obtained during seasons and the movement count was highest during summer 396.6 MC/min (n=1 119), and then autumn 90.6 MC/min (n=4 035) (Figure 57C). The radio tag on *L. kimberleyensis* (1) transmitted information up until 05/08/2012. The individual seemed to spend a lot of time around station five where it was captured and tagged; from there *L. kimberleyensis* (1) used habitats around station six and seven, which contained rocky substrates, riffles and rapids, aquatic vegetation, undercut banks with deeper pools.

Labeobarbus kimberleyensis (1) maintained a depth range of 516 mm to 586 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight periods ranged from 546 mm to 1 043 mm. Depth ranges overlapped, but *L. kimberleyensis* (1) seemed to prefer the deepest water during time periods of highest light intensity (Figure 57A). During full moon phases the depth of *L. kimberleyensis* (1) was 676 mm (n=697) and during new moon phases depth was 536 mm (n=944) (Figure 57B). Limited seasonal variations in depth were obtained and ranged from 548 mm (n=1 142) in summer to 635 mm (n=4 370) in autumn (Figure 57C).

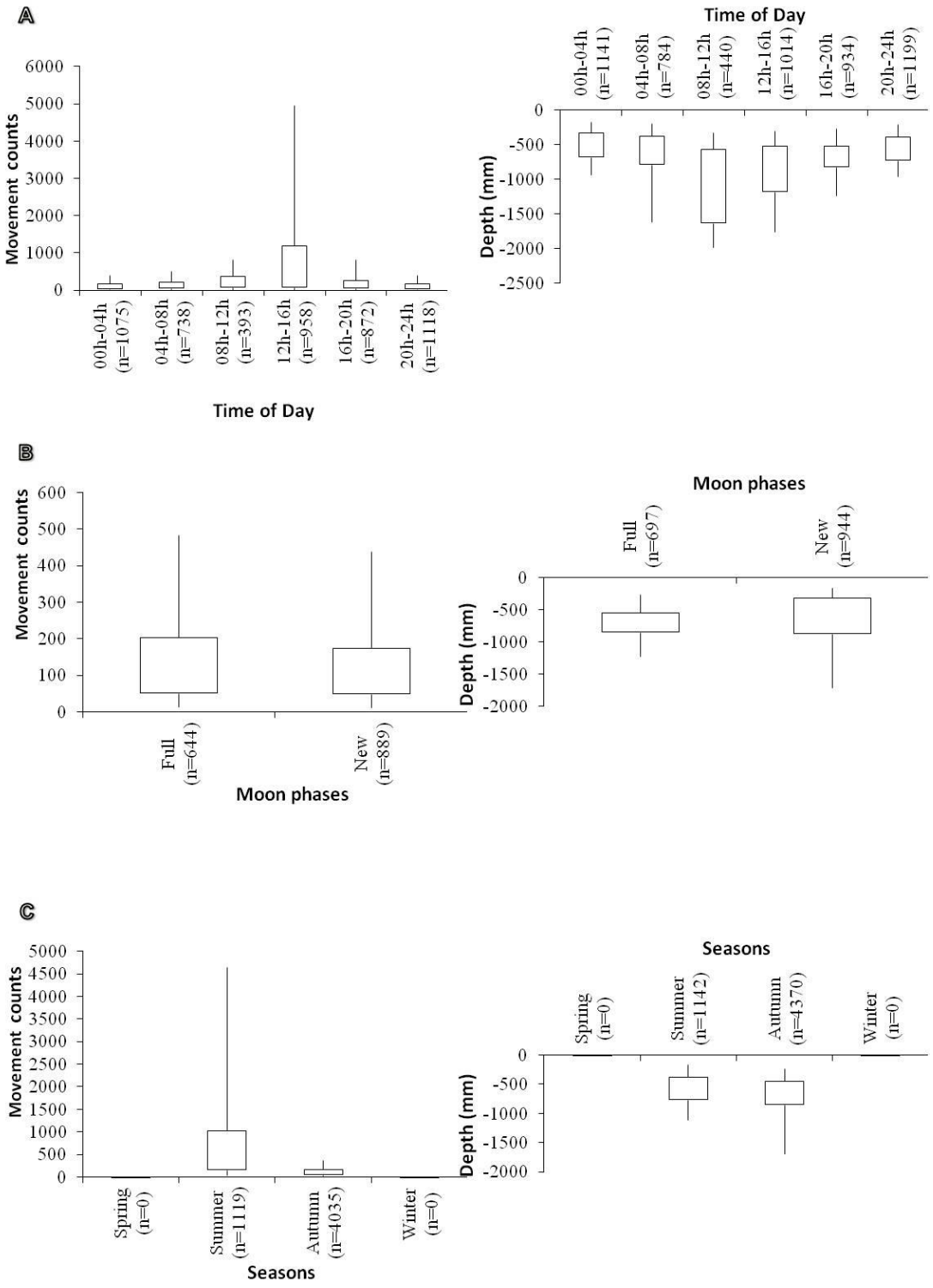


Figure 57: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles. High movement activity of tag 48 was observed during daylight periods, full moon phases and summer. Deeper habitats where preferred with higher movement activity during daylight periods, full moon phases and autumn.

***Labeobarbus kimberleyensis* (2)**

Labeobarbus kimberleyensis (2) with radio tag number 54 was monitored from 18/07/2012 in which time 46 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data showed that *Labeobarbus kimberleyensis* (2) maintained an depth range of 338.3 mm to 379 mm during nocturnal periods (00:00-04:00 and 20:00-24:00) whereas depth in daylight periods ranged from 317 mm to 1 269 mm (Figure 58). Limited data were collected during moon phases and depth was 539 mm (n=38) during new moon phases. Seasonal data were limited to winter and recorded depth down to 748 mm (n=46) (Figure 58).

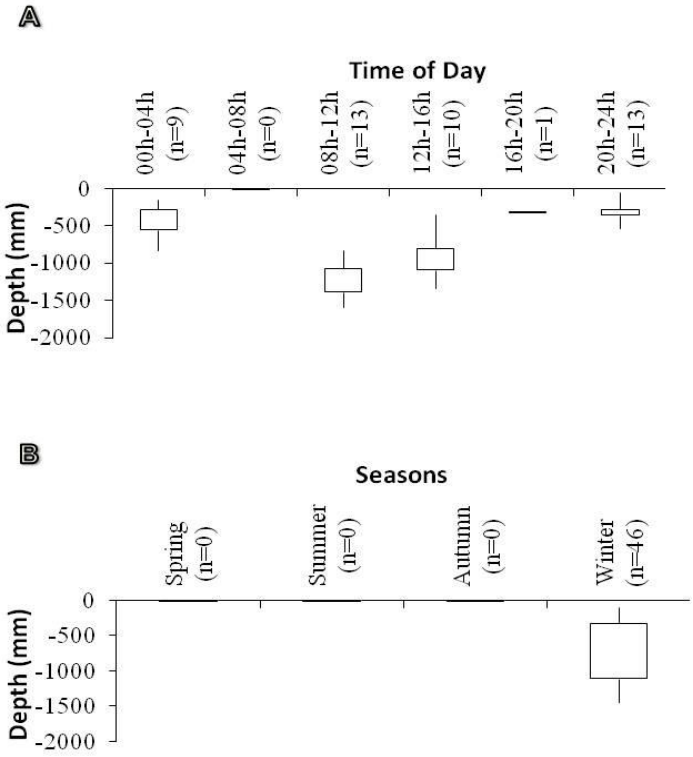


Figure 58: Box-and-whisker plot of tag 54 shows the movement counts and depth against time of day (A) and seasons (B). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles.

***Labeobarbus kimberleyensis* (3)**

Labeobarbus kimberleyensis (3) with radio tag number 47 was monitored from 02/08/2012 months during which time 143 data strings were remotely obtained. These strings contained activity, temperature and depth peripheral information. Data

showed that *Labeobarbus kimberleyensis* (3) had movement counts of 12.1 MC/min during nocturnal periods (00:00-04:00 and 20:00-24:00) of the day whereas daytime movement counts increased to 171.1 MC/min. *Labeobarbus kimberleyensis* (3) had peak movement counts during time periods from 04:00-08:00 with an of 171.1 MC/min whereas lowest movement counts were observed between 20:00-24:00 with an count of 12.1 MC/min. Limited data were obtained and the movement count during full moon phases was 13.9 MC/min (n=34) (Figure 59). Limited seasonal movement during winter was 12.1 MC/min (n=43) (Figure 59).

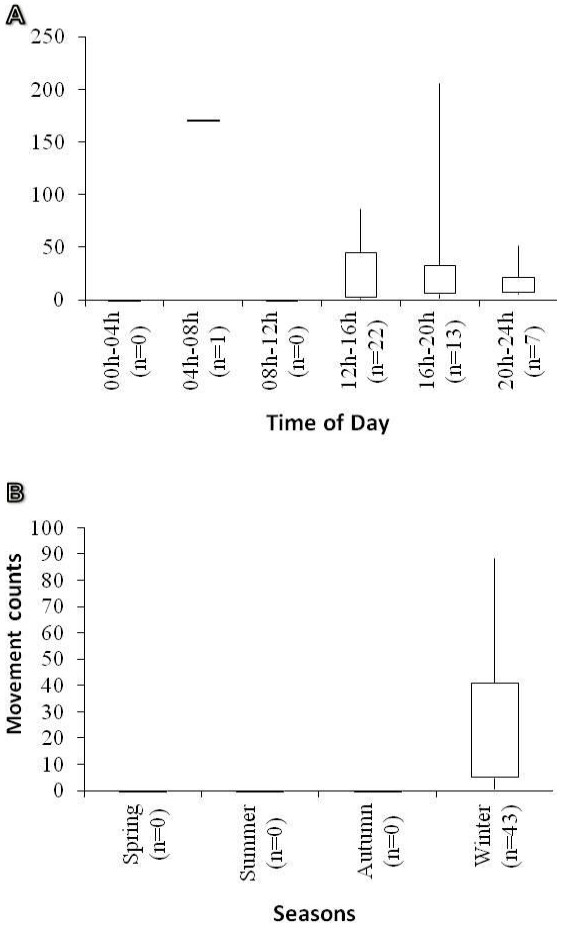


Figure 59: Box-and-whisker plot of tag 47 shows the movement counts and depth against time of day (A) and seasons (B). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles.

General behavioural pattern of *Labeobarbus kimberleyensis* in the Vaal River

The following section presents data from all three tagged individuals incorporated into a single group, in order to identify the general movement behavioural pattern of *L. kimberleyensis* in the Vaal River. The same procedure as used with Boskop Dam data was followed for the Vaal River study area.

The amount of data collected is insufficient; however, a general behavioural pattern can be identified, as it can be accepted that there will be individual variations in behaviour. *Labeobarbus kimberleyensis* in the Vaal River showed higher movement counts during daylight hours (08:00-20:00) than during nocturnal hours of the day (Figure 60A). *Labeobarbus kimberleyensis* showed higher movement counts during full moon phases than during new moon phases, whereas individuals preferred deeper water during full moon phases than during new moon phases (Figure 60B). Movement counts were higher during summer and individuals preferred shallower habitats with increased temperatures whereas movement decreased with decreasing temperatures and individuals used deeper habitats during autumn and winter (Figure 60C).

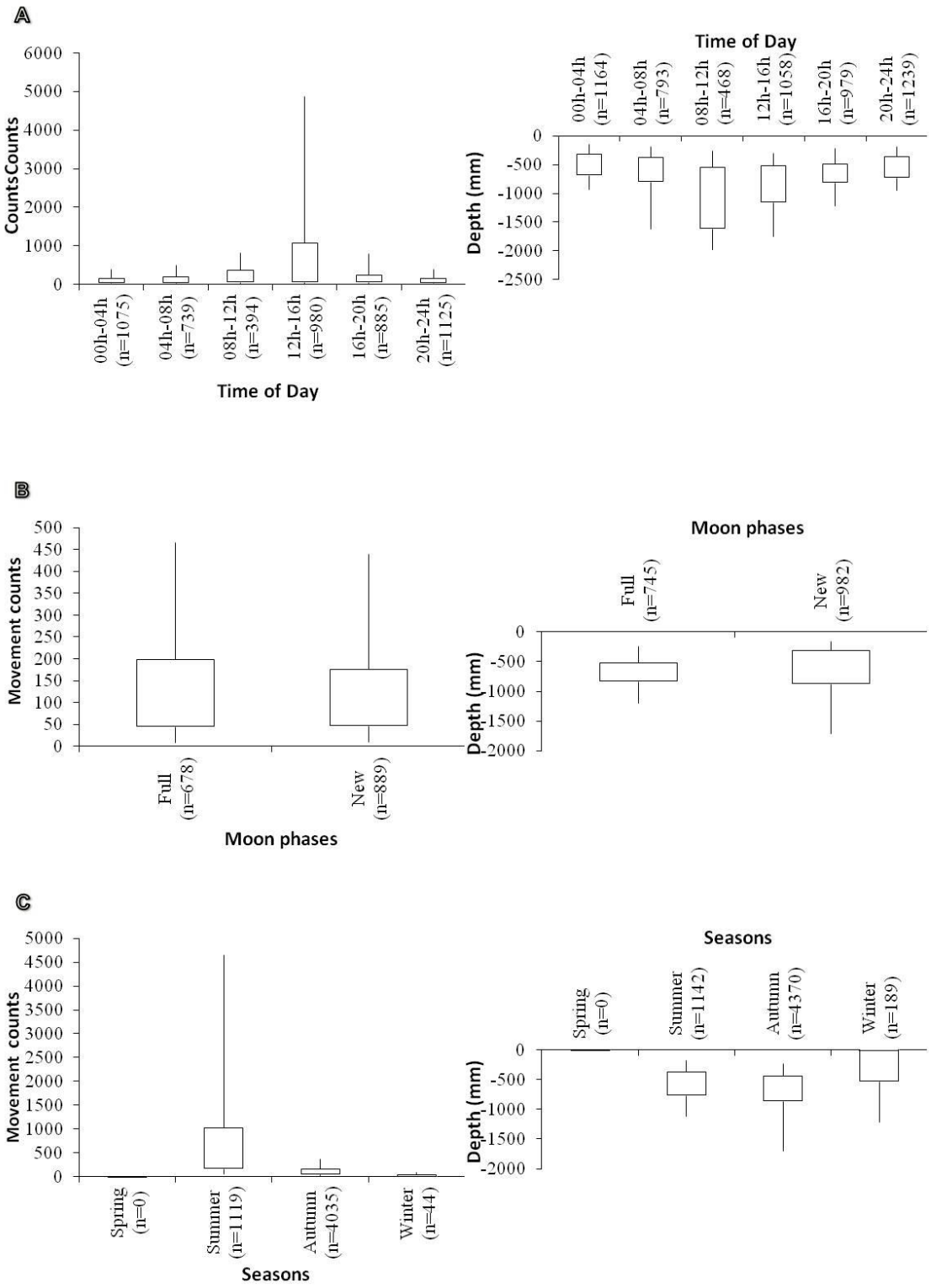


Figure 60: Box-and-whisker plot of the movement counts and depth against time of day (A), moon phases (B) and seasons (C). The box estimates are based on the 25th and 75th percentiles while the whisker extremes are based on 5th and 95th percentiles.