
Ecology and Behaviour of the Southern River Otter
***Lontra provocax* THOMAS 1908 in Chile**

Dissertation

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To
MARTINA

„ Everything should be made as simple as possible,
but not simpler“.

(Albert Einstein, 1879 - 1955)

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Preface

There are 5 chapters within this thesis, with the different aspects of methodology being discussed in Chapter 2. The thesis contains unpublished data, however Chapters 4 and 6 have been written as a manuscript for upcoming publication. Therefore some descriptions regarding the study area and methodology are repeated in these chapters.

1 General introduction

1.1 Introduction

Within the group of mammalian carnivores, the most diverse and numerous are the family of mustelides. The subfamily Lutrinae today contains seven genera, with a total of 13 species, which are adapted to semi-aquatic life, which distinguishes them from the rest of mustelides (KOEPLI & WAYNE, 1998). Members of Lutrinae utilise habitats such as rivers, lakes, wetlands and coastal areas, where they prey on fish, crustaceans, mussels, amphibians and occasionally on birds and small mammals. Otters can be found in Asia, Africa, America (North and South) and Europe (MASON & MCDONALD, 1986). The new world otter, former classified to the *Lutra* genus, are grouped in the genus *Lontra* (VAN ZYLL DE JONG, 1987). Four species of otters, the Neotropical otter *Lontra longicaudis*, the giant otter *Pteronura brasiliensis*, the marine otter *Lontra felina* and the southern river otter *Lontra provocax* can be found in South America.

One of the two extant otter species in Chile is the southern river otter. The southern river otter was first scientifically described by THOMAS (1908). *Lontra provocax* is described as a very shy species and extremely rare to observe (MILLER & ROTTMANN, 1976). The native name for the southern river otter is *huillin* which originates from the Mapuche language, but the name *lobito de río patagónico* and *gato de agua* are also commonly used (PARERA, 1996). The southern river otter was hunted by the indigenous people for its fur and for its baculum as an aphrodisiacal.

The head-body length of the southern river otter is 610 - 700 mm; the tail length is about 400 – 460 mm which makes an average total length of 1010 - 1160 mm. The female is smaller in weight and length than the male southern river otter. The dorsal colouring of *L. provocax* is brown which contrasts with the ventral colouring of light brown. The otter has a torpedo shaped form and uses its webbed pads and tail for locomotion in water. As semi-aquatic mammals like otters do not have body fat or only very little for insulation, they rely on waterproof fur (DUNSTONE & GORMAN, 1998). A thick fur with outer layer of guard hairs and a layer of under fur protects the otter against cooling by swimming in cold water (KRÜGER, 1995). KRÜGER (pers. comm.) reported that captive European otter *Lutra lutra* in

Hankensbüttel/Germany were filmed with a thermograph camera and only the pads of the animal appeared coloured, which stands for the only possibility to emit heat. Hence it seems that becoming too cold is not the problem, but rather preventing overheating.

The territorial behaviour was recently described by SEPULVEDA (2003) as intrasexually territorial. Therefore adult animals are solitary and are only seen together during mating season for copulation. Only females with their offspring form family groups. CHANIN (1985) reports that young ones stay in family groups in the first year until they disperse. This species is described as usually nocturnal (CHANIN, 1985), however individual reports of diurnal behaviour by local farmer exist.

One hundred to one hundred and fifty years ago the southern river otter had a longitudinal distribution from the centre to the southern part of Chile. Specifically, from the rivers Cauquenes and Cachapoal (34° S) to the Magellan Region (53° S) and from the Andes to the Pacific (HARRIS, 1968; MEDINA-VOGEL, 1996; MELQUIST, 1984; MILLER & ROTTMANN, 1976; OSGOOD, 1943). In the past the southern river otter had an extensive distribution ranging from rhitron to potamon rivers and Andean oligotrophic lakes to shallow lakes and Coastal wetlands (CHEHÉBAR & PORRO, 1998; MEDINA & CHEHÉBAR, 2000; MEDINA-VOGEL, 1996). From south of the XI. Región of Chile (Region of Aysén) *L. provocax* was also found in marine ambience especially in the Patagonian and Fuegian channels and straits (SIELFELD & CASTILLA, 1999). Since the European colonisation in 1860, the southern part of Chile's rivers and lakes have been used as transport routes. Riparian vegetation was removed, forests cleared and wetland turned into farm land. This interference resulted in a gradual destruction of the habitat of the southern river otters (LARA & ARAVENA, 1997; SOTO & CAMPOS, 1997; TOLEDO & ZAPATER, 1991). Furthermore, it seems that habitat characteristics - such as water depth, surface area, velocity of river current, riparian vegetation, riparian and subsurface woody debris - have an impact on prey occurrence, which in turn has a significant effect on the spatial distribution of the otter population (CROOK & ROBERTSON, 1999; KAIL, 2005; KRUIK, 1995). Today the distribution of the southern river otter in freshwater habitats in Chile is

limited to only few isolated areas between Cautín (39° S) and Futaleufú (43° 30' S) and it is most likely the otter species with the smallest distribution in the world (CHEHÉBAR *et al.*, 1986; MEDINA-VOGEL, 1996).

The southern river otter is listed internationally as CITES Appendix I, and therefore in the EU by law 338/97 it is cited in Annex A. In the IUCN Red List of the vertebrates the otter is assessed as 'endangered' (UNEP-WCMC, 2002). In the Chilean Red List of vertebrates it is classified as 'in danger of extinction' (GLADE 1987) and in the National Wildlife List of Argentina the otter is listed as 'endangered' (CHEHÉBAR *et al.*, 1986). The extermination of the otter started in small river basins but expanded. Habitat destruction, stream and river diversion and wetland drainage have contributed considerably to the decline of the southern river otter's distribution in the last decades and in the present (MEDINA, 1991). Other factors like hunting, dogs, farming and water pollution are suspected of having further endangered the southern river otters (REDFORD & EISENBERG, 1992). The lack of recolonisation is possibly the reason for the high mortality rate or the low reproductive success.

Prior studies of the diet diversity of southern river otters in lakes and rivers were investigated by SIELFELD (1984) MEDINA (1998; 1997), CHEHEBAR (1985; 1986) and newer ones in the Boroa wetland by GONZALEZ (2006). Briefly, the data indicate that the southern river otter mainly preys on crustacean species and seems to be, to an unknown degree, a specialist. Studies on the influence of riparian vegetation, woody debris and stream morphology and the use by southern river otters show that the animals prefer sites which are in natural conditions and without human influence (MEDINA-VOGEL *et al.*, 2003).

Many studies on other otter species like *L. lutra* or *Lontra canadensis* exist, while the species which are living cryptically like the southern river otter have not been intensively investigated and much about their ecology and behaviour is still unknown.

1.2 Aim of study

The essential aim of the present study is to gain knowledge about: a) the behaviour and b) the factors which may effect the distribution and abundance of the southern river otter.

Furthermore the answers to these topics will be important contributions for further conservation programs of this endangered species and in order to maintain biodiversity in Chile.

The objectives of the studies are:

- Ø to describe individual home-ranges, core areas, travel rates, activity patterns and movements of three southern river otters in the Upper Queule River,
- Ø to assess their preference for habitat use,
- Ø to identify the effect of cubs on activity and space patterns of the parents,
- Ø to examine the prey utilisation, prey availability and diversity and additional abiotic factors which may limit prey distribution,
- Ø to identify if the methodology of age determination via tooth and skull is applicable.

Since different subject areas in this particular study will be determined, they are briefly listed here but the specific scopes and aims are detailed elucidate in following respective chapters.

Chapter 2 deals with the aspects of trapping, surgery and housing methods for the southern river otter. Furthermore initial investigations of basic energy needs are examined.

In **Chapter 3** the objectives of home range, activity patterns and the preference for habitat use are presented in detail. For geographic spacing patterns the accessibility to the animal's home range, total range, and different levels of core area are considered. To determine activity patterns the occurrence and duration of movement, stationary activity and inactivity are investigated, as well as travelled duration and distance. Also presented here are detailed measures of preferred habitat use like hunting areas, den sites and spraint sites.

The change of spacing patterns of female with cubs was compared in **Chapter 4**. Home range, travelled distance and activity patterns were also examined. Furthermore a model is presented which illustrate the reproduction cycle of this species.

Prey availability, diversity and abiotic factors which may limit the distribution of prey and consequently the distribution of the southern river otter is determined in **Chapter 5**. Areas of otter occurrence were investigated for potential prey like amphibians, fish and crustaceans. For a seasonal variation of prey ingestion spraint analysis were carried out for 12 month on the Upper Queule River. To gain additional information of abiotic conditions water analysis on several stations was conducted for one year. Furthermore it was determined if an interspecific competition exist between *L. provocax* and the American mink *Mustela vison*.

Chapter 6 is about the feasibility of using tooth and skull analysis for age determination of the southern river otter.

1.3 Study area

Chile is a narrow land with an average width of 180 km and a length of about 4300 km between 17° 3' S and 56° 30' S. Except for the tropical climate all types of climate can be found on Chile's mainland which is strongly dependent upon the Humboldt stream. The north of Chile is dominated by the Andes whereas central and south Chile are formed by two parallel mountain ranges colon the costal mountain range (Cordillera de la Costa) and the Andes, in north-south expansion. The central valley (Valle Central), with its arable land, is situated between the two mountain ranges.

Politically the country is divided into 13 regions. The area in which the investigation was conducted lies in the IX Region, the Araucania region (Fig. 1.3.1), which has a temperate climate. The investigated river is called Queule and is approximately 87 km¹ long, originates in the coastal mountain range at an altitude of about 550 m (39° 12' 45" S; 73° 00' 24" E) and terminates at the village Queule, where it pours into the Pacific Ocean (39° 26' 32" S; 73° 12' 59" E). The Queule River is partially covered by a temperate evergreen ombrophilous swamp forest which is composed primarily by *Myrceugenia exsucca*, *Eleocharis macrostachya*, *Scirpus californicus*, *Juncas procerus*, *Temu divaricatum* and *Drimys winteri* (HAUENSTEIN *et al.*, 2002; RAMÍREZ *et al.*, 1983). The river currents are mainly regulated by rainfall which reaches an average of 2110 mm per year with seasonal low level during summer time and high level during winter time.

¹ As no data of Queule River length were available, length of river was measured six times with measuring tool in ArcView™ 3.1 and average was calculated (\bar{x} = 87126.167 m; SE = 106.681 m)

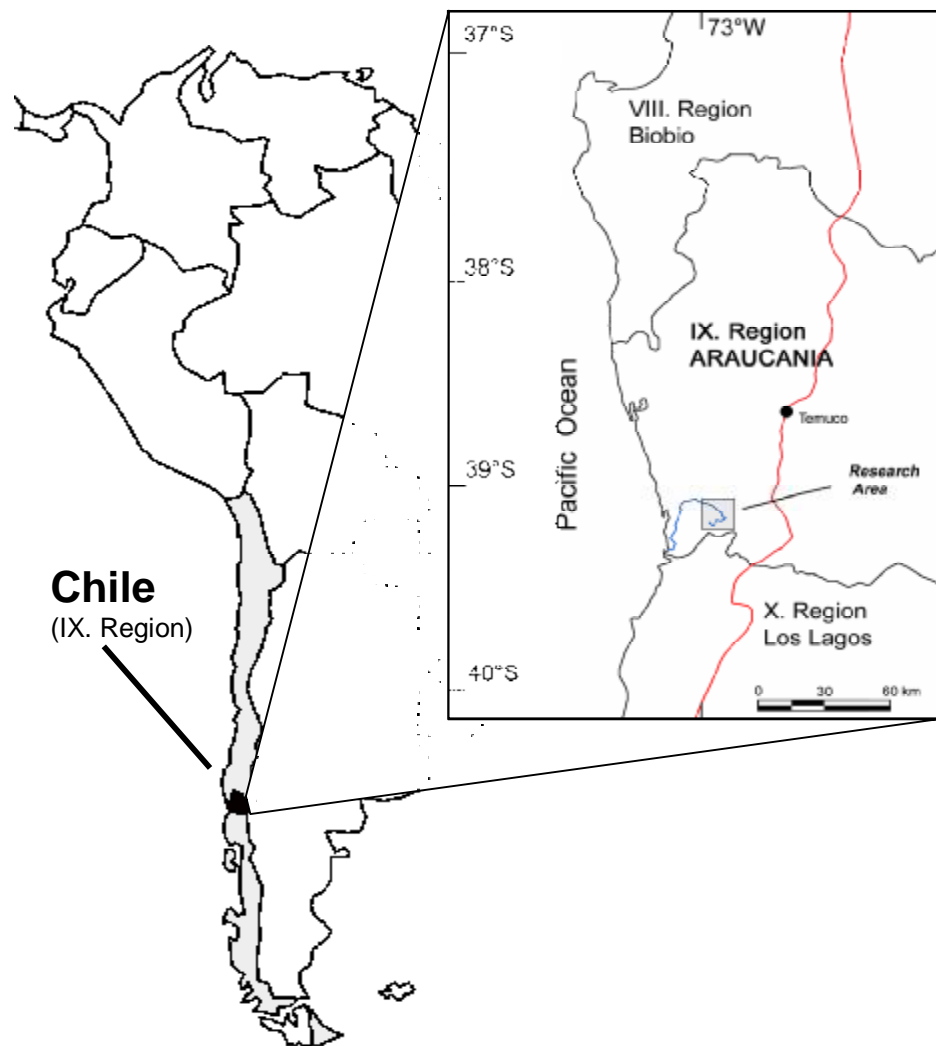


Fig. 1.3.1: Location of investigation area in the IX. Region (Region Araucania) in Chile with main road (red line)

The research area is located in the southern part of the province Toltén. The Upper Queule River (UQR) area is dominated by silviculture. As a consequence of forestry, for example clear-cutting, road constructions, permanent road improvements, wood logging machines and heavy logging trucks, the human impact on the environment there is high. The forestry work is usually limited to the dry months but the effects of clear-cutting include severe flooding in autumn and winter within the past years, particularly in the region where the study took place. The research area is surrounded by farm land and silviculture. Barely a small band of the original ombrophilous swamp forest is present (Fig. 1.3.2).

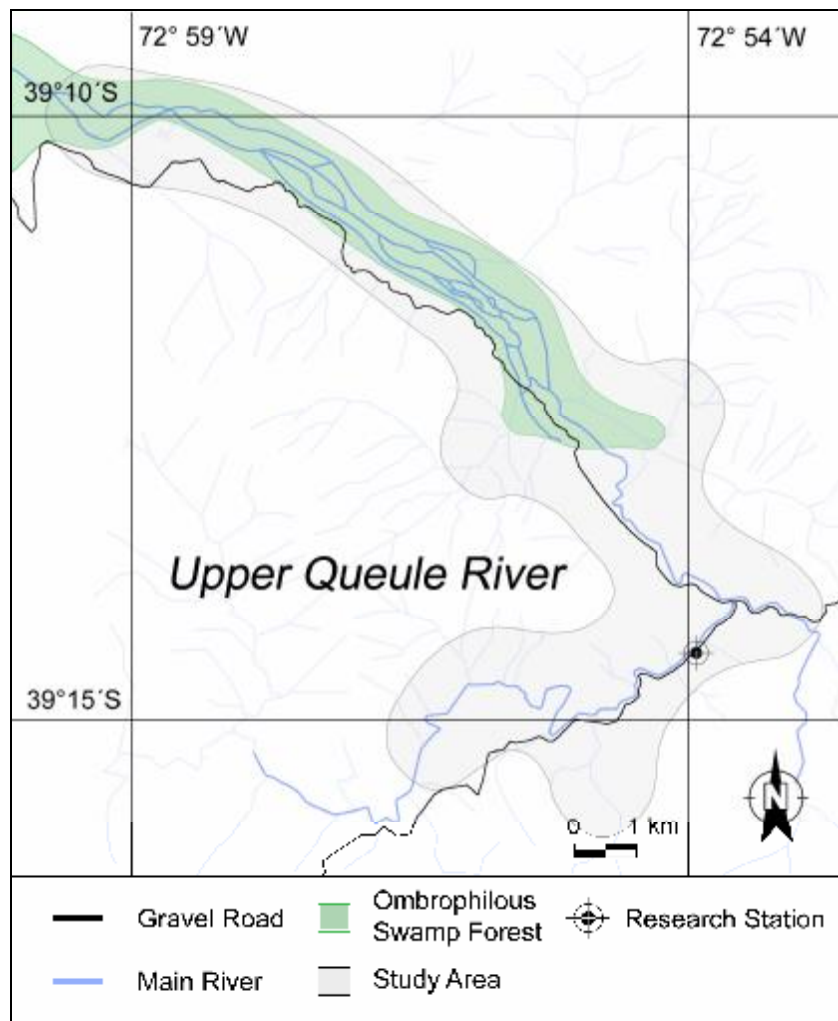


Fig. 1.3.2: Study area in the Upper Queule River

The research in the field took place between the 06th of January 2003 and the 15th of August 2004. Two months before the end of 2002 there was the possibility to get acclimated to spatial circumstances on-site. Way reference points were installed along the UQR every 250 m, as calculated by GPS (GPS 12; GARMIN INC.), during this time.

2 Methods: trapping, surgery, housing and nutrition of *Lontra provocax*

2.1 Trapping

2.1.1 Introduction

It is very difficult to study carnivores, which usually have a cryptic and nocturnal behaviour, are rarely observed, and seldom are leaving faeces or tracks (RUETTE *et al.*, 2003). Direct observations can only be made at the expense of significant amounts of personnel, money and time. One alternative is trapping and fitting animals with a radio transmitter, which allows researchers to conduct direct and indirect observation of the behaviour and moving patterns of the subject. For some animals it is possible to trap them using long-distance immobilization such as tranquilizer darts. For other animals that are harder to find, trapping with harmless traps is more effective but requires people to check the traps regularly. The otter, since it lives secretly, is reported as mostly nocturnal and is very shy to any disturbance, is one such animal for which harmless traps are most effective in trapping (BLUNDELL *et al.*, 1999).

In January of 2003, in the IX. Region (the Lake District) of Chile, several different river systems were searched for signs of otters. In this process, we looked for evidence of otter presence such as dens, footprints, faeces and smears. The investigations were limited to the IX. Region because prior surveying and mapping had uncovered more evidence of otters there than in other regions (pers. comm., MEDINA-VOGEL). We located 21 positive sites, including the upper part of the Queule River, which was a particularly promising area because fresh faeces was found there in several sites that were well suited to setting up our traps.

2.1.2 Method

Trapping locations

To trap southern river otters we used “leg-hold traps” (1.5 Victor Soft Catch Trap), which were connected to a 1.5 m iron chain link. The chain was clamped to a 12 kg block of concrete.

The areas for setting the soft-catch traps were selected according to the following criteria:

- river depth,
- active exit; normally in connection with marking places or dens,
- possibility to fix the traps (concrete block) to the riverbed.

The traps were fixed to a level surface in the river such that they were covered by 3-5cm of water and so that the chain was not visible in the sediment. The concrete block was also positioned under water and additionally fixed to sticks of 1 m length, such that it could not be moved.

In other spots, such as bridges, the chain was fixed to the wooden bridge with at least three 10cm long steel nails. Within a radius equal to the length of the chain plus an extra of 1.5 meters, all roots and similar obstacles above and below the water were removed with a saw to minimize the risk that the trapped animal could become entangled and drown. After the trap was set, the manipulated riparian bank was rinsed with water to minimize human odours. No bait was used. After the trapping period, all traps were completely removed.

Trapping

The first traps were installed in the summer of 2003 (January). The following trapping period lasted 22 days, and was followed by 34 days in the winter (May - June). In 2004, the trapping period lasted 79 days (Tab. 2.1.1).

Tab. 2.1.1: Periods of trapping in 2003 and 2004

Date	Days of trapping
23. Jan 2003 – 13. Feb. 2003	22 days
12. May 2003 – 14. June 2003	34 days
08. Jan 2004 – 29. March 2004	79 days

Traps were checked every 12 hours so that the animal did not become overly cool because of prolonged submergence in the water. The checking of the traps was performed at 08:00 in the morning and at 20:00 in the evening during the summer, and at 06:00 in the morning and 18:00 in the evening in the winter. The reason for the time difference between summer and winter is that we wanted to conduct the trap inspections and potential immobilizations while there was still some light.

A trap found closed but without an animal was reactivated and the area once again rinsed with water.

In the case that animals other than otters were caught ("bycatch"), if not already drowned, we removed them from the trap, medicate them, and after a period of convalescence, released them back into the wild.

2.1.3 Results

The results of the trappings are illustrated in the following table (Tab. 2.1.2). The part of the river where the trappings were performed was divided into two sections (upper - and lower). The upper section was mainly influenced by arable farm land and pine plantation, in strong contrast to the lower section, which was covered with a temperate evergreen ombrophilous swamp forest - called "Hualve".

Because of the low trapping success in the summer of 2003 (only one adult female was caught), an additional trapping period for the winter season was decided upon for the first time.

In spite of heavy precipitation and the resulting strong fluctuations of water level, we succeeded in trapping another southern river otter (an adult male). After an additional 27 days with very little indication of otter activity, heavy precipitation, and very low air and water temperature, the trapping season was terminated. In the summer of 2004 (January), the trapping area was extended further down the lower section of the river.

In 2003, over a length of 7.3km, and in 2004, over a length of 11.1 km, on average 24 active traps were set. Out of 1662.5 trapping nights, the success rate for trapping otters was 0.002. In the upper section of the Queule River, during 2003 and 2004 a total of five southern river otters were trapped, whereas only one animal was caught in the lower section. The density of southern river otters represents 0.4 animals per kilometre. Among the captured animals were two adult

females, one juvenile male and three adult males. A total of three animals died, including one juvenile and two adult males.

Table 2.1.2: Trapping success (F = adult female; M = adult male; m = juvenile male, * = average)

Specific location	2003	2004	Total*
Upper section	1F/1M	1m/2M	1F/1m/3M
Lower section	0	1F	1F
Total number of otters	1F/1M	1F/1m/2M	2F/1m/2M
Identified dead otters	1M	1m/1M	1m/2M
Distance covered (km)	7.3	11.1	9.2
Average active traps	22 - 26 (24*)	18 - 29 (24*)	24
Number of night	55	79	67
Number of traps/night	1340	1985	1662.5
Otters per traps/night	0.002	0.002	0.002
Otters/kilometres	0.3	0.4	0.4
One otter per kilometres	3.70	2.80	3.25

The gathered data were noted directly. In addition to sex, body weight and body length, we also estimated the age of the animal. As an estimation parameter we used weight, length and the condition of the teeth (Tab. 2.1.3).

Tab. 2.1.3: Morphometric data of caught otters. Names are given to already known animals or with successful transmitter implantation. Specification: F = adult female; M = adult male; m = juvenile male; followed by year of capture; behind / = frequency of transmitter or x = died before operation

Year	Period 2003		Period 2004			
Name	Esperanza	Rey	(died)	Millaray	(died)	Pelantaro
Specifications	F 03/36	M 03/x1	m 04/x1	F 04/54	M 04/x2	M 04/40
Date of capture	30. Jan	18. May	03. Feb	10. Feb	02. March	31. March
Sex	Female	Male	Male	Female	Male	Male
Body weight (kg)	8.0	9.1	5.1	10.0	14.5	11.0
Approximate age	Adult	Adult	Juvenile	Adult	Adult	Subadult
Total body length (cm)	107	119	97	115	120	122
Tail length	40	41	37	40	40	43

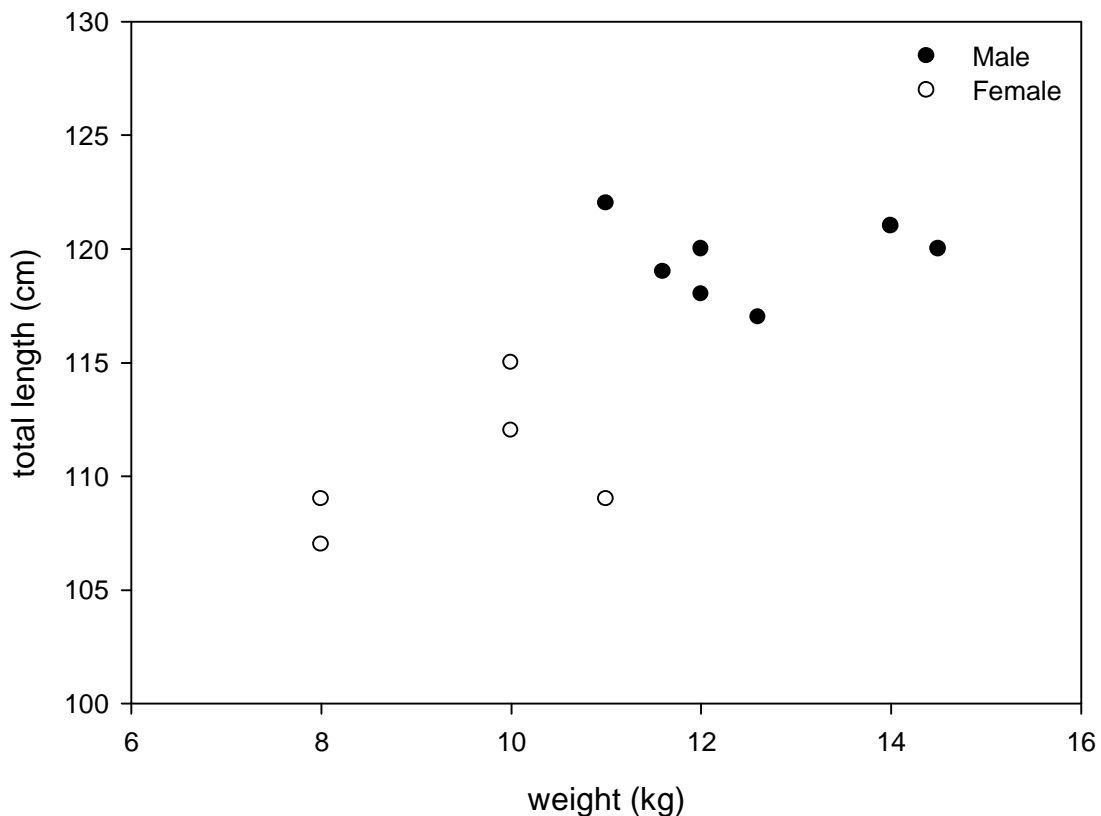


Fig. 2.1.1: Total length versus weight by all captured individuals from 2000 - 2004

The Fig. 2.1.1 shows that the males and females southern river otter form different groups. Values were tested for normal distribution and a t-test run if condition was met. The result indicates that the differences in the mean values among the groups male/kg vs. female/kg are greater than expected by chance. A statistical significance was found ($t=4.96$; $df=10$; $p<0.001$). Also a statistical significance was found among the groups male/length vs. female/length ($t=6.618$; $df=10$; $p<0.001$). This indicates that a sexual dimorphism by size and weight exist.

The sexual dimorphism index in length is 1.08 (ratio: ♂ length/♀ length) and in weight is calculated as 1.33 (ratio: ♂ weight/♀ weight).

Within the trapping periods, birds and small mammals were noted as bycatch (Tab. 2.1.4; 2.1.5). *Pardirallus sanguinolentus*, a wading bird, represented the majority of the bycatch. Birds that survived being trapped received slight to severe injuries to one leg. These birds were taken to the field station and were there medicated by veterinarian students. After three to five days of convalescence,

these animals were released. The only mammal besides otters that was caught in the soft-catch trap was the brown rat, *Rattus norvegicus*, which was always found dead in the traps.

Tab. 2.1.4: Bycatch in trapping area in both years (2003, 2004) († = died in trap because of drowning)

January 2003	February 2003	April 2003	January 2004	February 2004	March 2004
<i>Pardirallus sanguinolentus</i> †	<i>Pardirallus sanguinolentus</i>	<i>Rattus norvegicus</i> †	<i>Rattus norvegicus</i> †	<i>Specularnas specularis</i>	<i>Rattus norvegicus</i> †
	<i>Nycticorax nycticorax</i>		<i>Rattus norvegicus</i> †	<i>Rattus norvegicus</i> †	<i>Caracara plancus</i>
	<i>Rattus norvegicus</i> †		<i>Pardirallus sanguinolentus</i> †	<i>Rattus norvegicus</i> †	<i>Rattus norvegicus</i> †
			<i>Pardirallus sanguinolentus</i>	<i>Pardirallus sanguinolentus</i>	<i>Pardirallus sanguinolentus</i> †
					<i>Pardirallus sanguinolentus</i>

Tab. 2.1.5: Scientific, English and Local names of bycatch in trapping area

Class	Scientific Name	English Name	Local Name
Aves	<i>Pardirallus sanguinolentus</i>	Plumbeous Rail	Piden
Aves	<i>Caracara plancus</i>	Southern Caracara	Traro / Carancho
Aves	<i>Anas specularis</i>	Spectacled Duck	Pato anteojillo
Aves	<i>Nycticorax nycticorax</i>	Black-crowned Night-Heron	Huiaravo
Mammalia	<i>Rattus norvegicus</i>	Brown rat, Norway rat	Guarén

2.1.4 Discussion

Trapped wild animals experience potentially high levels of stress until they are released back into the wild. This trapping stress is described for several classes of animals, such as reptiles (MATHIES *et al.*, 2001), fishes (CLEMENTS *et al.*, 2002), birds (ROMERO & ROMERO, 2002) and mammals (ELVIDGE *et al.*, 1976; GERICKE & HOFMEYR, 1976; HATTINGH, 1992; LARSON & GAUTHIER, 1989;

PLACE & KENAGY, 2000; SWART, 1992). Usually the animal attempts to flee until it is out of danger, and therefore expends its strength by trying to get out of the trap and does not give up easily. Other factors like unknown noises, smells, unfamiliar surroundings, and the presence of humans, can cause additional stress for the animals. One of the main causes of capture myopathy and mortality during trapping is excessive stress (EBEDES *et al.*, 2002). Therefore, when handling wild animals, it is important to minimize the level of stress that they experience.

Capturing semi-aquatic mammals like the southern river otter turned out to be a considerable challenge. The following factors were problematic in trapping *L. provocax*.

- **Trap:**
The trap contained a plate of only five centimetres. The otter had to put one of its extremities exactly on the plate in order to activate the catch mechanism.
- **Exit:**
Southern river otters consistently mark their territory at the same spots on land, but the point at which they exit the water onto the shore varies by about one to two meters.
- **Modification of exit:**
To some extent the exit was very strongly modified visually, because all roots were taken out of the water.
- **Water level:**
Due to strong precipitation the traps had to be adjusted to the new water level or had to be deactivated.
- **Disturbance:**
Some of the traps were not visible from the bank line. One person had to go into the water to check the trap.
- **Theft:**
Some of the traps were visible to other humans (like anglers and hunters), and in three cases were stolen.

Further disadvantages may arise by modification of the traps or exits because of remaining odours, which could frighten off the animal and thereby decrease the trapping success.

Some of the traps have been closed and were pulled away from their original spot where we found hairs of otter between the rubber layers. This trapping spots were avoided for some days, but several days later otter signs were detected again, however otters were never captured in this traps. It seemed that the otter remembered and stayed away from this trap. MASON & MCDONALD (1986) mentioned the awareness of presence of traps for *L. lutra* in Britain.

There are different types of traps that are usually used to trap otters for research. In Scotland, hunters have often used special otter houses to hunt these animals. Inspired by this KRUIK (1995) built a wooden-tunnel box which was set in the Shetland area where otters had been seen. Before being armed, the box was left in place for years before being activated so that the otter became accustomed to its presence. However, it would not be possible to catch the southern river otter with a wooden-tunnel box, because of the precipitation and out of it resulting fluctuation of the river level. Within three to four hours the river level can arise rapidly and flood larger areas. On the other hand, thievery is a serious problem and it could be possible that persons will illegally hunt the southern river otter with this kind of traps. In addition, the right setting for the wooden-tunnel box would be difficult due to the animals' behaviour. It seems that the animal is very strong bound to the water and do not walk larger distances (for example: marking sites are very close to the river), since the otter never has been seen further away than three meters from the river (southern river otters only left the water for marking). For this study another type of trap which was originally used by fur trappers was applied. The teeth were flattened and covered with rubber to not harm the animal. These traps have already been used to successfully trap otters (BLUNDELL *et al.*, 1999; FERNÁNDEZ-MORAN *et al.*, 2002; MELQUIST & HORNOCKER, 1983; MITCHELL-JONES *et al.*, 1984), as well as other mammals like beavers (WHEATLEY, 1989), cats (MEEK *et al.*, 1995); (SHORT & TURNER, 2005), foxes and wild dogs (FLEMING *et al.*, 1998).

RUETTE (2003) and SHORT (2001) demonstrated that trapping experience had significant affect of capture rates on small carnivores and mammals. Therefore,

people from previous trapping seasons (2000 – 2002) supported us in setting traps to avoid a negative effect.

The trapping period was usually chosen in summer because of weather conditions and former experiences. However, in summer 2003 less otter activity as in the last years were recorded. A possible explanation for the low activity could be the very low water level during the summer in the upper part of the Queule River. Therefore, for the first time trapping was conducted also in the winter period. However, otter activity was not very high. More otter activity occurred in summer 2004 where four animals were caught.

In comparison to trapping of the southern river otter in previous years (2000 - 2002) were the trapping success three times higher, 0.006 otters per trapnight (unpublished data), than in our study (0.002 otters per trapnight).

One of the causes for less otter activity and trapping success could be the clear cutting of the surrounding pine plantation. Roads were rebuilt for the heavy logging machines and soil, rocks and trees have been pushed into the river. Heavy logging trucks were working for several weeks in 24-hour shifts and the roads are mostly situated very close to the river.

All animals appeared healthy, except for M 03/x1, which was captured in the winter of 2003. This adult male was a recaptured animal which had lost a significant amount of weight since its previous capture (2000 = 12.6 kg; 2001 = 10.0 kg; unpublished data by MEDINA-VOGEL).

Sexual dimorphism is also reported in *L. provocax* (LARIVIÈRE, 1999b) as well as in other *Lontra* species, such as the neotropical river otter *Lontra longicaudis* (LARIVIÈRE, 1999a) and the northern river otter *Lontra canadensis* (LARIVIÈRE & WALTON, 1998). An exception is the marine otter *Lontra felina*, which does not show sexual dimorphism (LARIVIÈRE, 1998).

In the review by LARIVIÈRE (1999b), sexual dimorphism for *L. provocax* is reported by OSGOOD (1943), whereby the female otters are approximately 90 % the size of males. These findings are similar to our data where females were in average 92 % of the size of males.

My results indicate that the sexual dimorphism in length is very small ($\text{♂} = 119.57 \text{ cm}$, $\text{♀} = 110.40 \text{ cm}$; sexual dimorphism index of 1.08). However, all female animals were under the length of 115 cm (107 – 115 cm) and all adult male otters were $\geq 117 \text{ cm}$ (117 – 122 cm) long.

A sexual dimorphism was also found in the weight ($\sigma = 12.53$ kg, $\text{♀} = 9.4$ kg; sexual dimorphism index of 1.33), where the female otters were 75 % the weight of males. The juvenile m 04/x1 and adult M 03/x1 (a recaptured animal who's weight had decreased since 2000) were omitted from the calculations.

I conclude that the statistical significant findings on sexual dimorphism, average weight and average length are more probable than those reported in former literature, because in this study the sample size was larger, and their findings on average weight and length were based on only four samples.

The leg-hold traps like this one used in our study have to be installed in shallow water and therefore it is especially problematic for warding birds, since three out of ten birds drowned and one of the species which were caught, *Anas specularis*, is listed in the IUCN Red list as low risk/near threatened (IUCN, 2004). It is possible that the birds were attracted by the shininess of the activation plates, since they were usually trapped in very new traps where the plate was still very shiny and not oxidised as it was in the older ones. When setting the traps we tried to spread sand from the riverbed over the plate to camouflage it, but the current of the river often washed this sand away. It seems that bycatch such as warding birds may be unavoidable as it also is reported by trapping Eurasian otters in Spain by SAAVEDRA (2002).

2.2 Anesthetization

2.2.1 Introduction

Medical immobilization was conducted for rescuing endangered animals, such as antelope, for the first time at the end of the 1950s in Africa. This technique, which originates from the Indians of the tropical forest, is nowadays widely used for handling wild animals. These days the medication for immobilisation is more sophisticated and the rate of mortality is reduced. Usually a combination of neuroleptica and analgetica is given to the animal, but it has to be considered that even animals within the same family or genus do not react equally to the drugs (GÖLTENBOTH, 1995; LÖSCHER, 2002).

For the southern river otter, first a Ketamin-Xylazin combination was used, but in 2004 the medical treatment for sedation and anesthetization was different. In 2004

it was possible to obtain different drugs which were already successfully tested on other otter species (LEWIS, 1991; SPELMAN *et al.*, 1994; SPELMAN, 1999). A detailed description of the sedation and anesthetization on the *L. provocax* in 2004 is described by SOTO-AZAT *et al.* (in press).

2.2.2 Method

Sedation

Traps were checked by two people, because for the sedation of the otter at least two people are required. The animal was immobilized by one person with a telescope bar. This procedure consisted of a rubber isolated metal loop being put under its arm and around the neck and then tightened. The second person conducted the sedation with a mixture of Ketamin (Imalgene[®]) and Xylazin (Rompun[®]) which was injected in the muscle of its hind leg (*longissimus dorsi*). Ketamin effects a rapid immobilisation, loss of consciousness and extensive analgesia. Xylazin, in addition to having strong tranquilizing and strong central relaxing effects, is the only neuroleptic that causes an animal specific analgesia. The advantages of a Ketamin-Xylazin combination include better muscle relaxation, less strain on the circulatory system than with Ketamin alone, and more immediate, painless, and reliable effectiveness than with just Xylazin (HATLAPA & WIESNER, 1982). In contrast to other sedation medications, there is no antidote for Xylazin.

The dose rate was based on the condition and calculated weight of the trapped animal; 9.61 mg/kg Ketamin, as well as 0.4 mg/kg Xylazin.

Once an animal was sedated and no longer aggressive, the traps were opened and the animal taken to the river bank. The eyes of the sedated animal were covered with a cloth, the respiratory track was checked to prevent obstruction, and the otter was examined for injuries caused by the trap. Aseptic inflammation of the foot pad caused by the trap, was treated with the intramuscular application of 0.1 mg/kg Dexamethason (Dispert dex[®]). Additionally, we applied to their eyes an eye drop combination supplement (Mixgen[®]), the main components of which, Bethamethason and Gentamicin, have an anti-infectious and anti-inflammatory effect. Furthermore it protects the cornea against desiccation.

The sedated animal was then transported in a coarsely meshed hard plastic net in a heated vehicle to the enclosure at the field station.

A broad spectrum anthelmintic (Drontal plus®) containing a combination of Febantol (for cestodes), Praziquantel, and Pyrantel embonat (for nematodes) was given to the otter.

Animals that showed infections caused by trapping were given an additional broad spectrum antibiotic (Baytril®) via their food.

The injuries were treated with a 10 % iodine solution (Betadine®). This iodine solution was sprayed onto the wound through the fence from outside the enclosure while the animal was fed. Furthermore, vitamin supplements (Longvid®) were given daily in tablets.

Anesthetization / Surgery

On earlier studies it was tried to use collars or harness to track river otter but there is the danger that the animals become stuck (MASON & MCDONALD, 1986). Therefore, the most appropriate method is to use implanted radio transmitter, as well as no influence or negative effects on the reproduction were noted in studies on *L. lutra* (REID *et al.*, 1986).

Animals were starved for eight hours prior surgery. For the placement of the intraperitoneal radio transmitter, anaesthesia was carried out as described above for sedation. Therefore, the animal was fixed with a nyliner in his PVC tube and an intramuscular injection was given. For the surgery the animal was fixed to the table by its limbs. After shaving a small part of the abdominal region, a short incision of four to five centimetres was made and the southern river otter was examined for an old radio transmitter. In the case the animal was a recapture the old radio transmitter was removed and replaced with a new one. The new radio transmitter (Sirtrack Ltd., Havelock North 4201, New Zealand) was activated by a magnet, checked with the receiver for function and after sterilization was placed in the abdominal cavity. For the placement of the transmitter it has to be ensure that it does not interfere with body functions (SMITH, 1980). Within 45 minutes the operation was completed. The animal was put convalescence into a smaller cage that was connected with its former PVC tube.

2.2.3 Results and Discussion

All animals showed very aggressive behaviour when trying to sedate them. The trapped and sedated animals were taken immediately to their cages and provided with a bowl of water. The otter F 03/36 left the tube immediately and tried to move around the cage, whereas the male M 03/x1 remained in its tube. Both animals showed hallucinations and hissed. Ketamin is known to produce hallucinations after recovery (HATLAPA & WIESNER, 1982). After 1.5 hour the animals displayed normal behaviour.

All trapped animals were more or less injured by the trapping procedure. The healing of the wound on the trapped paw took up to ten days. All otters used their injured paw while walking in the cage. Therefore the impact of the injury was recognized as not severe.

During the operation of the adult female F 03/36 while the transponder was interperitoreal set, the animal suffered two times of apnoea, but in the end fully recovered. Most likely this was due to recirculation of anaesthetic drug. The animal was then returned to its smaller cage where it regained consciousness and displayed behaviour typical for individuals recovering from the sedation from the trap, namely hallucinations and hissing. After 1.5 hours the otter seemed to have recovered and was again drinking water.

2.3 Housing and nutrition

2.3.1 Introduction

Captured animals that are released within an enclosure are confronted with a new situation in which their space and range of behaviour patterns are limited and they respond with stress on external stimulus. Most animals adapt very quickly to the new environment when the environment is quiet and escape is impossible (EBEDES & VAN ROOYEN, 2002).

Animals that are not kept in species-appropriate enclosures may display abnormal behaviour, such as stereotypic pacing and head movements, aggression and fur plucking, all of which can be interpreted as an indicator of reduced welfare

(GILLOUX *et al.*, 1992). Nowadays zoos in particular are emphasizing behaviour enrichment of their animals, introducing devices like feeding boxes or puzzle feeders in order to minimize abnormal behaviour. In our study, animals were held captive for less than 25 days and therefore no environmental enrichment was necessary or performed. However, to limit the stress factor for the southern river otter, human contact with the animal was minimized by limiting visitors to the research camp, and performing only the necessary work, like feeding and cleaning the enclosure, all in the intention of reducing the stress of the animals (HOSEY, 2006).

2.3.2 Method

Housing

Animals were sheltered in wire mesh enclosures with a volume of 250 x 250 x 170 cm and with a lattice door of 50 x 50 cm. The enclosures included a pool of 200 x 200 x 50 cm, narrow resting places on the side, a six-litre freshwater bowl and a plastic tube with wooden guillotine doors in the front and on the back, for possible withdrawal. The tubes were shaded with an extra cover to prevent overheating.

The main enclosures were fenced on the side and top additionally, so that no external person had entrance to the main enclosures. A jute cloth was placed in the cage, which was used by the animals for padding in their plastic tube. During the trapping season, animals were kept in enclosures long enough to avoid trapping the same animal twice.

Before entering the main cage, rubber boots were disinfected in a basin outside. The enclosure was cleaned daily of faeces and leftover food, and the water pool and jute cloth were changed as well.

After the operation, the animals were kept in a 40 x 48 x 90 cm cage that was connected to the plastic tube in which they were initially kept. The cage and the tube were set on concrete blocks so that the faeces could drop through the cage and be less likely to infect any wounds.

Furthermore, the small cage made treating their wounds easier since their movement was restricted and the otter forced to hold still.

Treated animals were checked regularly and their wounds treated with iodine during feeding. After eight days of operation animals were released at the site at which they were originally caught.

Nutrition

The diet of the southern river otter is comprised primarily of crustaceans (EBENSPERGER & BOTTO-MAHAN, 1997; MEDINA, 1998). As crustaceans were unavailable, fresh sea silverside fish *Odontesthes regia* were used instead while the southern river otters were kept in their enclosures. These fish, which occurs in the pacific, brackwater and fresh water, were bought fresh and gutted at the market in Valdivia. The fish was kept cool in ice while being transported to the field station and once there were frozen with a gas-powered freezer. Before feeding, the fish was thawed for 12 hours in the refrigerator, and then prepared with medication. The otters were given this meal four times a day. To calculate the fish intake, the weight of the offered fish and its remains after feeding were both recorded.

To calculate the energy intake, gutted *Odontesthes regia* was calorimetrically measured at the Institute of Animal Production at the University Austral of Chile, Valdivia (Instituto Producción Animal, Universidad Austral de Chile). The caloric content for *Odontesthes regia* was 125 kcal/100g.

To estimate the energy intake for a given otter, the consumed fish was converted into kcal using this value (125 kcal/100g). Data on energy intake do not exist for *L. provocax*; hence data from *L. lutra* were used for comparison.

Since the food consumption is related to their condition, the condition index K is calculated for all animals at the time of trapping.

The condition index was based on the formula by LE CREN (1951; mentioned in KRUIK 1995) who calculated the relationship between average weight and average body length of fish which he expressed as (W = weight in kg, L = total length)

$$W = aL^b,$$

and therefore:

$$K = W / aL^b.$$

If the condition index is $K = 1$, then the otter is deemed healthy and normal. On the other hand, an overweight individual could have a K value of 1.4 and an underweight one could have a condition index as low as $K = 0.5$ (KRUUK, 1995).

KRUUK (1995) calculated the constants a and b from 25 *L. lutra* road-kill samples. The constants for female otters are $a = 5.02$, $b = 2.33$ and for males $a = 5.87$, $b = 2.39$. The calculated condition index for females is:

$$K = W / 5.02L^{2.33},$$

and for males

$$K = W / 5.87L^{2.39}.$$

The condition index with the calculated constants from KRUUK (1995) was also used for calculations on the southern river otter. However, most animals had a K value > 1 , including even the females and the male m 03/x1 which had lost 3.5 kg between 2000 and 2003. Therefore, the constants a and b were newly calculated for the southern river otters which were captured from 2000 to 2004 ($n = 12$). Data for animals which lost weight during this time were not taken into calculation.

Based on observations of four otters sheltered in a large enclosure including a swimming pool, KRUUK (1995) concluded a daily ingestion of 11.9 to 12.8 percent of body mass. However, KRUUK (1995) suggests using a more conservative estimate of 15 percent of body mass per day, which will be used to allow comparison of the existing data on the Eurasian otter to that which were found on the southern river otter. This percentage will be converted to the caloric content for the sea silverside fish measured at the University Austral of Chile. For further comparison the resting metabolic rate (RMR) will be used as described in KRUUK (1995) as $3.2 W \text{ kg}^{-1}$.

2.3.3 Results

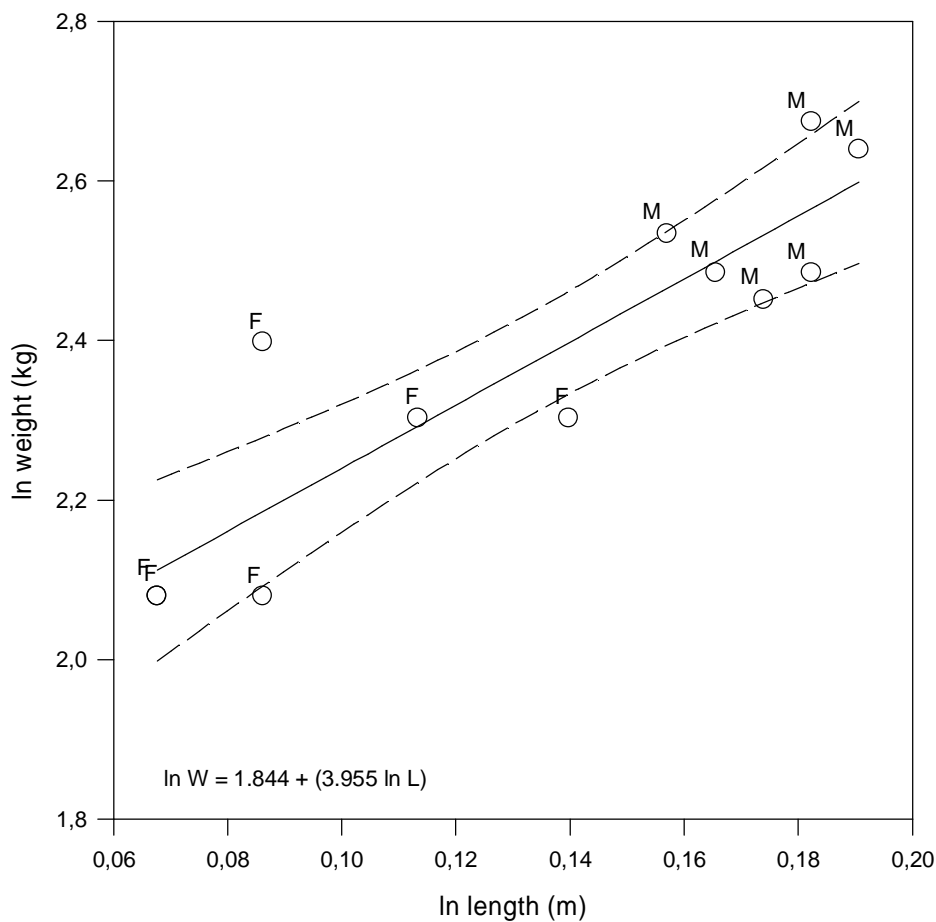


Fig. 2.3.1: Logarithms length-weight relationship of captured southern river otter (n = 12). F = adult females; M = adult males

Length and weight of all captured otters were transformed to natural logarithm and a linear regression was calculated (see Appendix 10.1) which resulted in the equation:

$$K = W / 6.32L^{3.96} .$$

I calculated for females $a = 6.780$, $b = 3.130$, and for males $a = 6.639$, $b = 3.719$. The condition index can now be calculated for females as

$$K = W / 6.78L^{3.13} ,$$

and for males as

$$K = W / 6.64L^{3.72} .$$

Tab. 2.3.1: Days in captivity (sorted by date of capture). M = male, F = female, capital letter = adult, small letter = juvenile, † = died, rel. = released

ID	Animals	Date of capture	Days in enclosure	Date of operation	Days in small cage	Date of release or death	Days in captivity	Condition index K
F 03/36	Esperanza	30. Jan 2003	15	14. Feb 2003	8	rel. 21. Feb 2003	23	0.95
M 03/x1	Rey	18. May 2003	7	--	--	† 24. May 2003	7	0.71
m 04/x1	--	03. Feb 2004	12	--	--	† 14. Feb 2004	12	(0.68)
F 04/54	Millaray	10. Feb 2004	14	24. Feb 2004	8	rel. 02. Mar 2004	22	0.95
M 04/x2	--	02. Mar 2004	--	--	--	† 02. Mar 2004	1	1.10
M 04/40	Pelantaro	29. Mar 2004	2	31. Mar 2004	8	rel. 07. Apr 2004	10	(0.79)

The days in captivity, especially in the big enclosure varied among the animals due to the trapping season and success. After the operation, the animals were kept as short as possible but minimum eight days. When no problems for wound healing occurred they were liberated after the eight day.

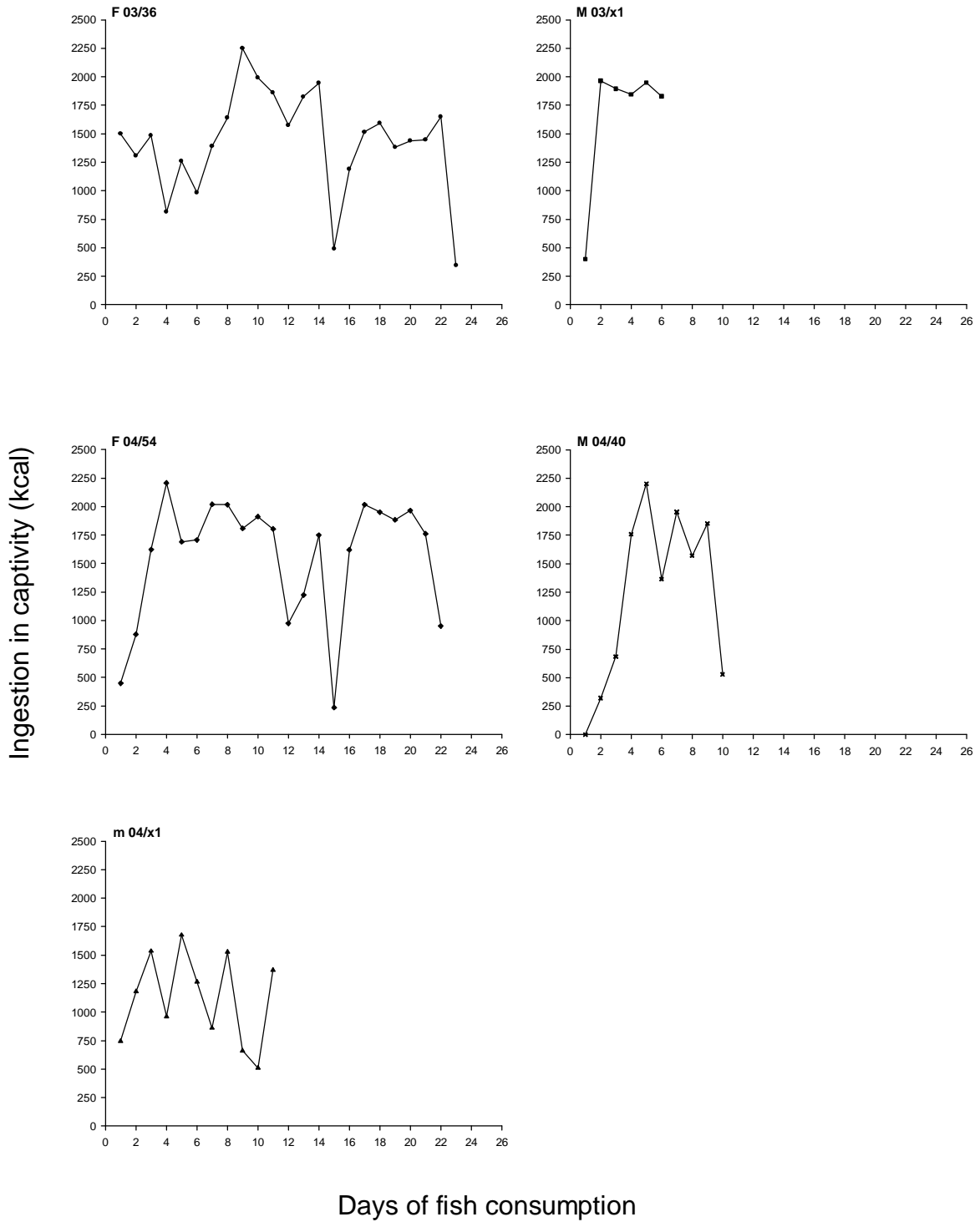


Fig. 2.3.2: Curve of daily kcal intake. F = adult female; M = adult male; m = juvenile male; followed by year of capture; behind / frequency of transmitter or x = died before operation

The chronological sequence of daily ingestion is shown in Fig. 2.3.2. Only the adult female F 03/36 ate more than 1500kcal from the beginning. The other otters took several days to become accustomed to eating the fish. The low kcal intake for

the otters F 03/36 and F 04/54 in the 15th day was due to the operation. The operation on M 04/40 was conducted on its third day in captivity, rather than on the 15th, as was the case with the others.

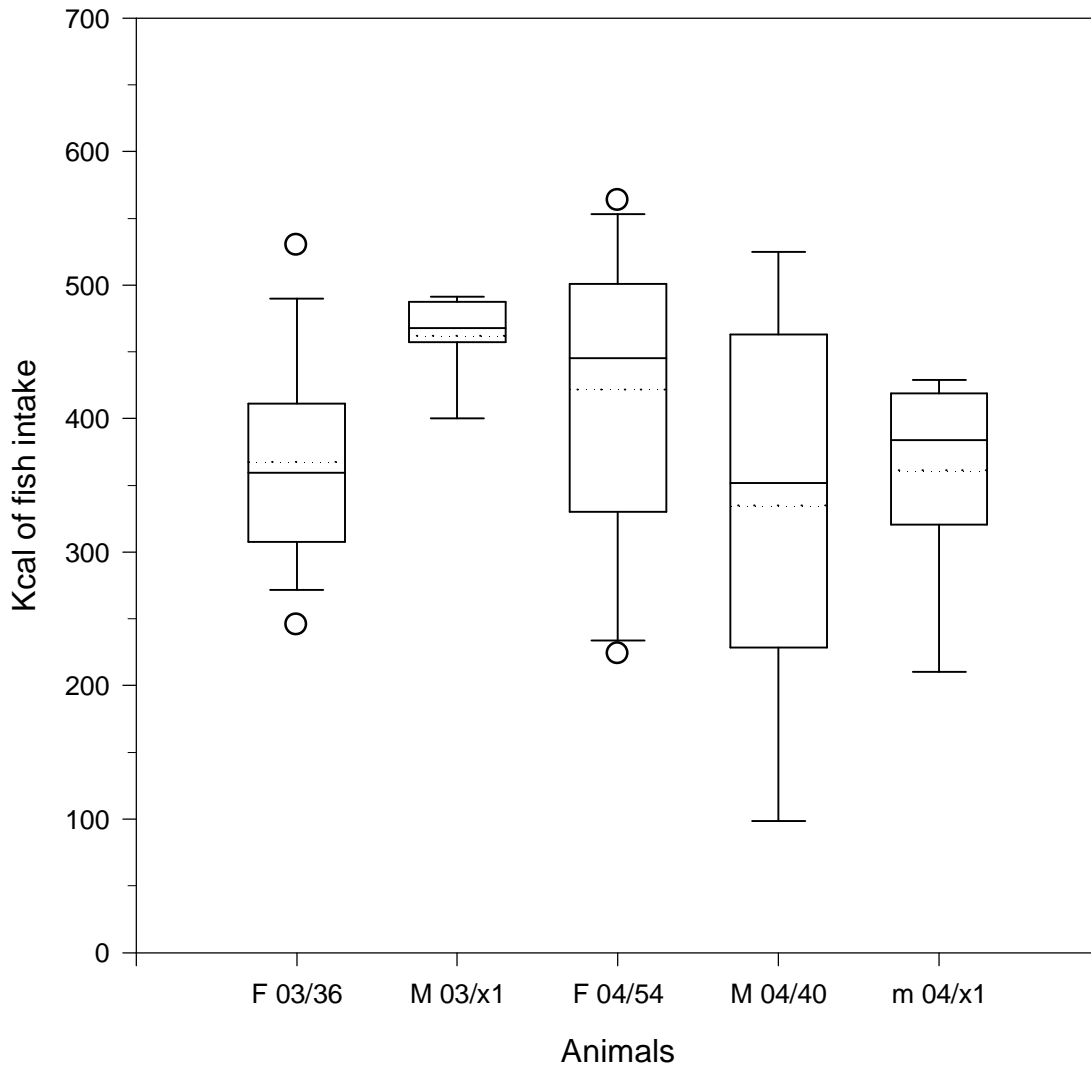


Fig. 2.3.3: Average kcal intake per feeding in captivity. F = adult female; M = adult male; m = juvenile male; followed by year of capture; behind / frequency of transmitter or x = died before operation

The average amount of fish eaten per feeding session for all captured animals is shown in Fig. 2.3.3. No significant differences were found with an analysis of variance of the average fish eaten per feeding session (One-way ANOVA: $F=2.02$; $df=4$; $p=0.102$). The average kcal intake for all otters per feeding was (390.69 ± 98.32) kcal. The median for F 03/36: 359.38 kcal (311.25/410.47); M 03/x1: 467.81 kcal (457.18/487.50); F 04/54: 445.31 kcal (355.16/497.66);

M 04/40: 351.58 kcal (228.29/457.30); m 04/x1: 383.75 kcal (320.42/419.06). The animal M 04/40 did not eat fish on the first day in captivity. Hence this 0-value, is an outlier and was omitted for all analyses of fish feeding calculations.

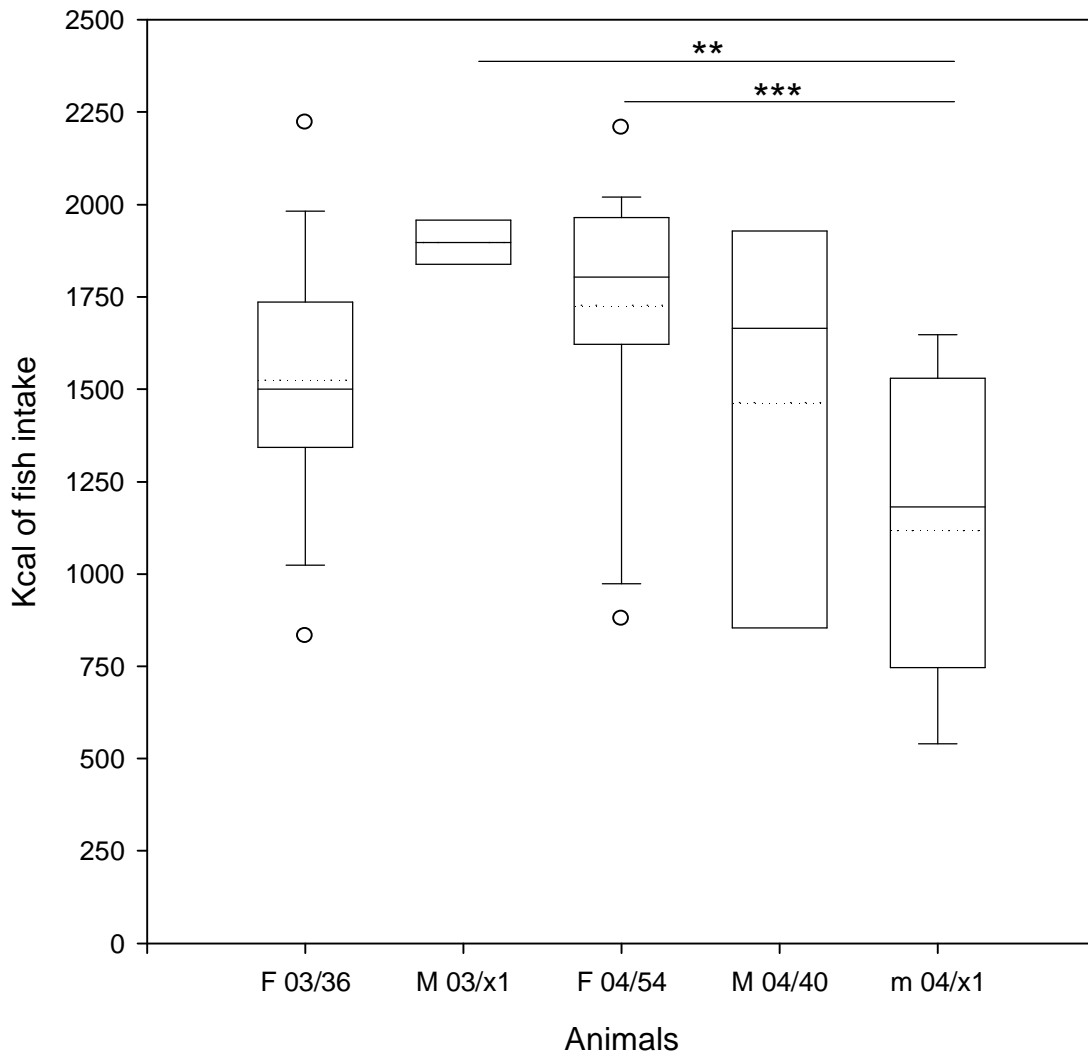


Fig. 2.3.4: Daily kcal intake of all southern river otters. F = adult female; M = adult male; m = juvenile male; followed by year of capture; behind / frequency of transmitter or x = died before operation. ** $p < 0.01$, *** $p < 0.001$.

In Fig. 2.3.4 the average fish eaten per day in captivity are shown as box-plots. The normality test failed ($p < 0.05$); therefore the Kruskal-Wallis One-Way-Analysis of Variance on Ranks was performed. The result indicates that the differences in the median values among the groups are greater than would be expected by chance. A statistically significant difference was found ($H=19.42$; $df=4$; $p < 0.001$). The post hoc Dunn's Method (a pairwise multiple comparison procedure) did find

significant differences between M 03/x1 vs. m 04/x1 and F 04/54 vs. M 04/x1. The median for F 03/36 is 1500 kcal (1361.56/1691.88), for M 03/x1: 1896.25 kcal (1841.88/1953.75), for F 04/54: 1802.50 kcal (1638.44/1961.25), for M 04/40: 1664.06 kcal (1024.13/1903.00) and for m 04/x1: 1181.25 kcal (774.38/1489.06).

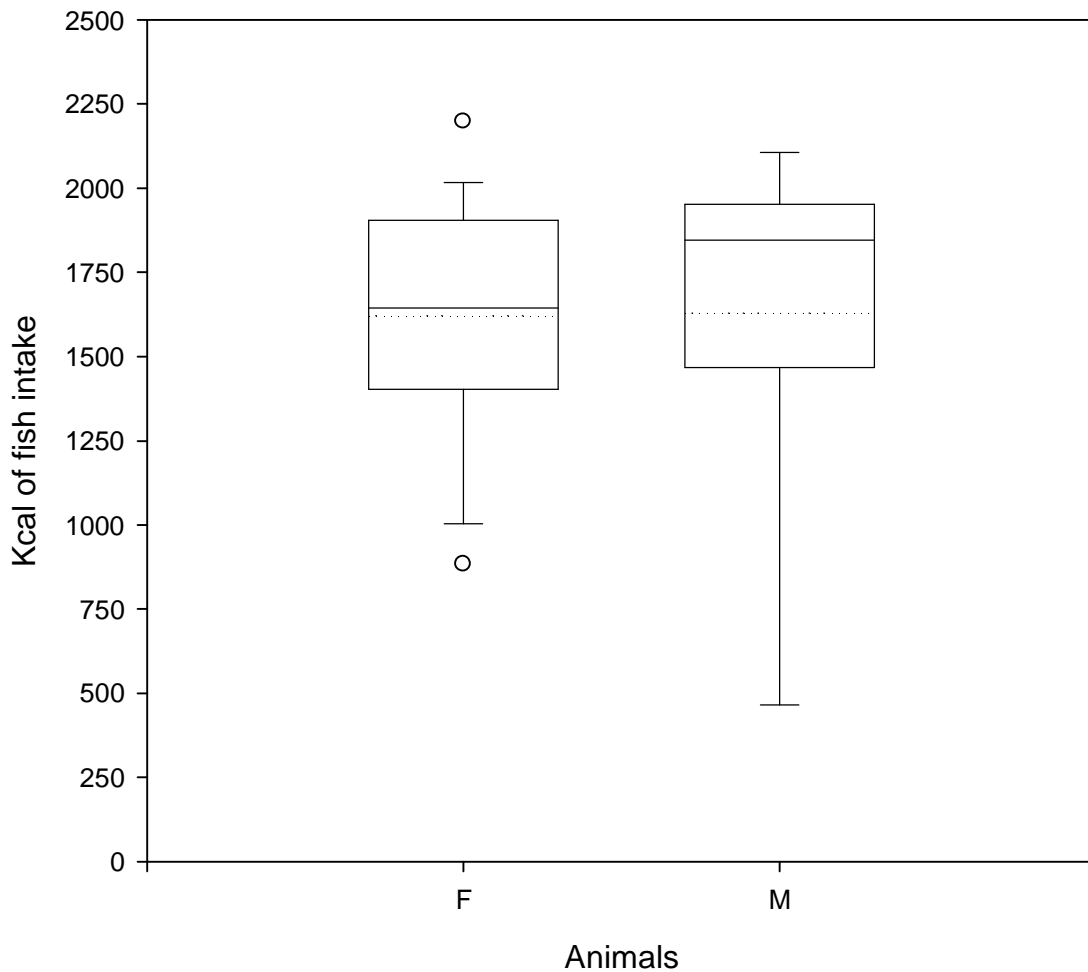


Fig. 2.3.5: Average kcal intake compared among the sex (only adults animals), F = adult female (n=2); M = adult male (n=2)

To test the two sexes for significant differences in average fish eaten (Fig. 2.3.5), a t-test was performed since the tests of normality were successful. The results do not show any significant difference between the two compared groups ($t=-0.07$; $p=0.943$). For the group of females the median of daily eaten fish was 1643.75 kcal (1413.75/1897.50) and for the males it was 1846.25 kcal (1518.53/1951.06).

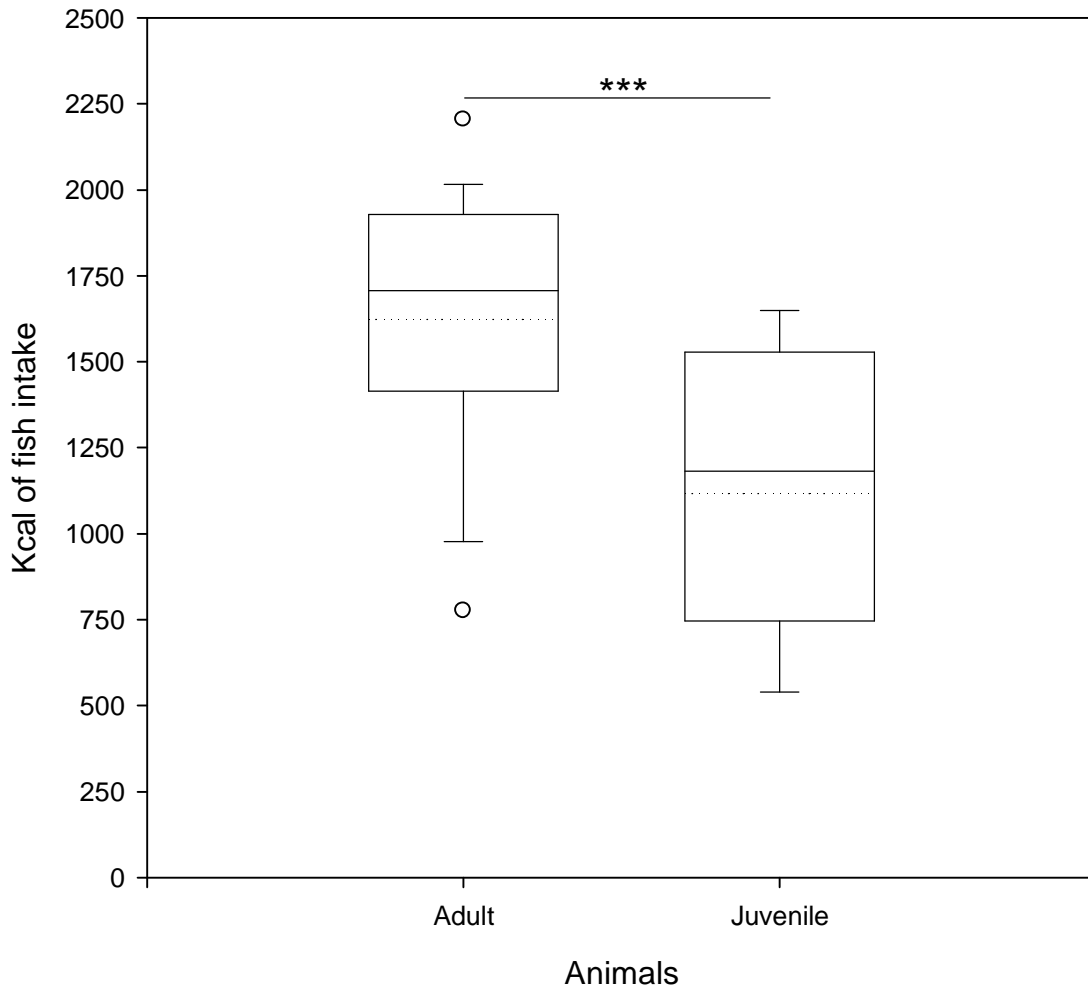


Fig. 2.3.6: Average kcal intake compared among adults (n=4) and the juvenile (n=1) (***) $p < 0,001$

By comparing the fish intake between adults and the juvenile animal (Fig. 2.3.6) a highly statistically significant difference was found ($t = 3.80$; $p = < 0.001$). A t-test was performed because the normal distribution and equal variance conditions were both successfully met. The median for kcal intake for the adults is 1707.50 (1425.63/1919.69) and for the juveniles is 1181.25 (774.38/1489.06).

The food consumption, before and after the operation is shown in Fig. 2.3.7. All groups were tested for normal distribution and a t-test run if the condition was met. If the condition was not met and the distribution was not normal, then a Mann-Whitney Rank Sum test was performed instead. Between the fish consumed before and after the operation there is no statistically significant difference for the

animals except for the males. (F 03/36 (t-test): $t=0.64$; $df=19$; $p=0.531$; F 04/54 (Mann-Whitney Rank Sum Test): $T=70.5$; $p=0.380$; M 04/40(t-test): $t=-5.44$; $df=6$; $p= 0.002$). This significant difference is an exception and results due to the low number of days he was in captivity and fed before his operation (2 days).

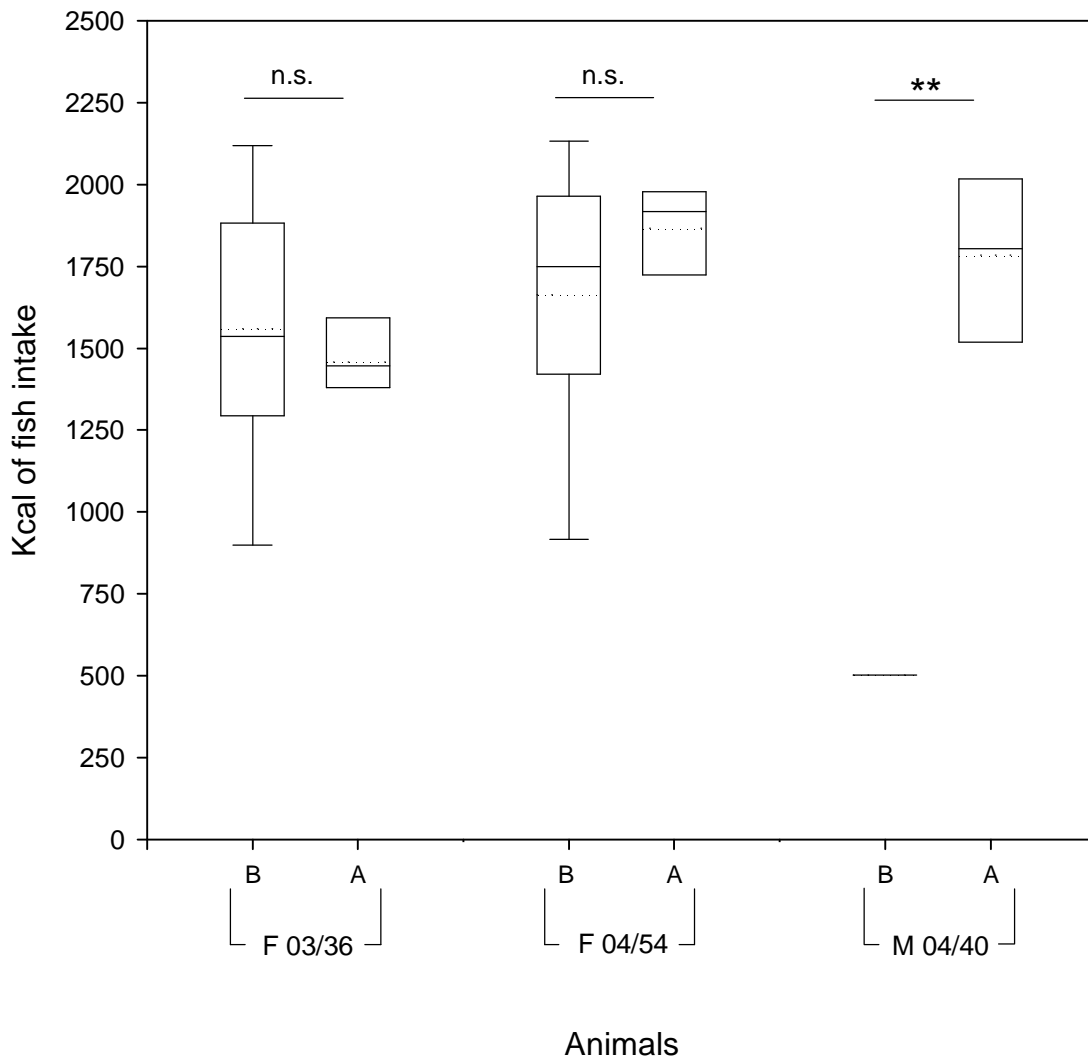


Fig. 2.3.7: Average kcal intake before and after operation (B = before operation; A = after operation; F = adult female; M = adult male; m = juvenile male; followed by year of capture; behind / frequency of transmitter; n.s. = not significant; ** $p < 0.01$)

The calculated kcal per feeding and per day is shown in Tab. 2.3.2. The energy content of the gutted silverside fish was measured as 125 kcal/100g.

Tab. 2.3.2: Calculated average kcal intake for all animals (sorted by sex)

ID	kcal / per feeding	SD \pm	kcal / per day	SD \pm
F 03/36	384.15	79.74	1525.24	334.53
F 04/54	424.94	100.88	1726.38	351.88
M 03/x1	461.93	33.22	1897.25	60.55
M 04/40	385.60	143.30	1463.13	649.94
m 04/x1	347.94	89.44	1117.61	393.91

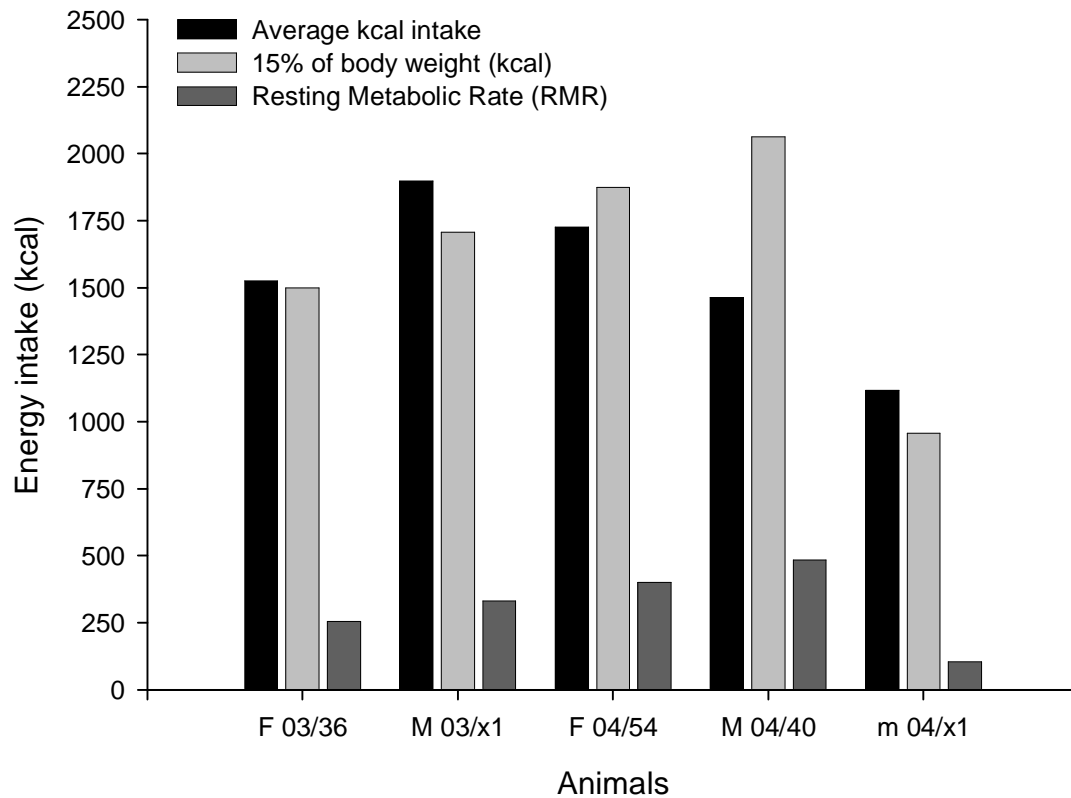


Fig. 2.3.8: Mean daily kcal intake and metabolic rates for all fed animals

For the juvenile m 04/x1 and the animals captured in 2003, the average kcal intake was higher than the value 15 % of body weight (in kcal). The adult animals captured in 2004, on the other hand, had a lower average kcal intake than the 15 %. All animals had a significantly lower RMR (Tab. 2.3.8).

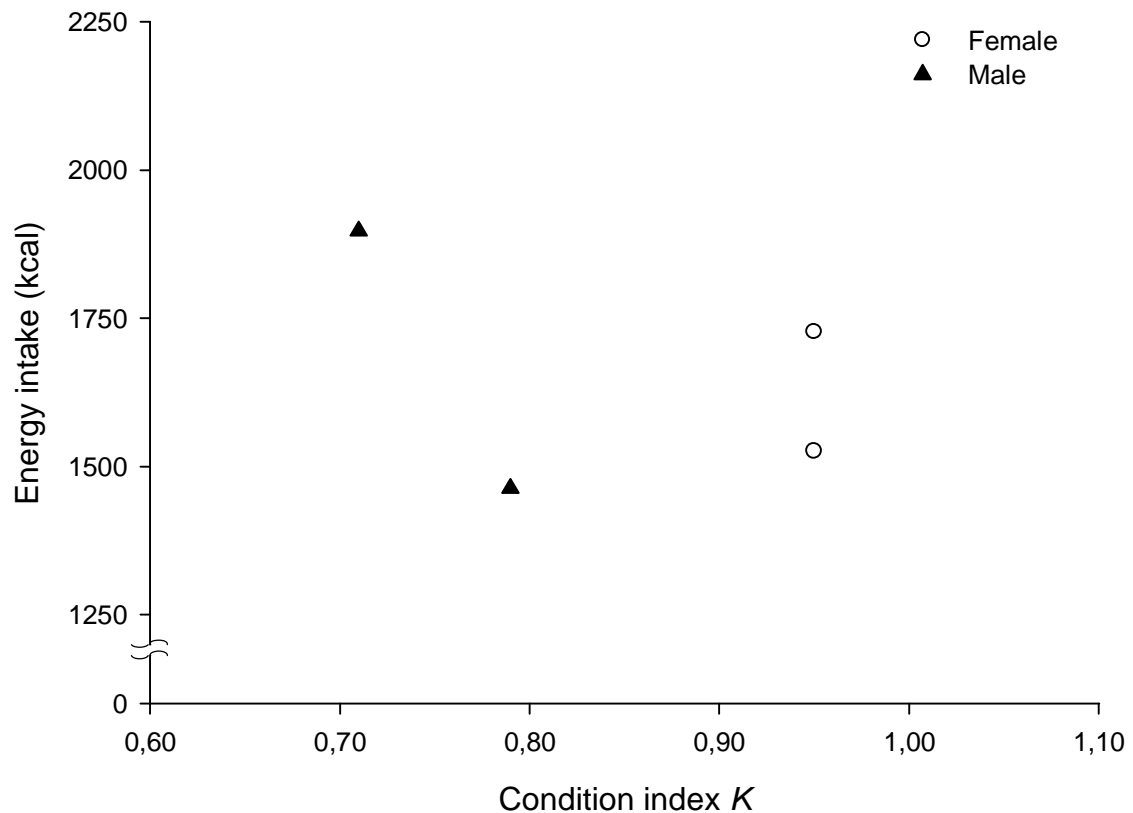


Fig. 2.3.9: Relation between kcal intake and condition index K for four adult animals

In contrast, the female southern river otters, which had approximately the same condition index regardless of the level of energy intake, the males had different condition indices for different energy intake levels. Specifically, a male otter with a low condition index had a higher energy intake than a male otter with a high condition index (Fig. 2.3.9).

2.3.4 Discussion

Condition Index

The condition index K was calculated for the southern river otters using only adult animals and no recaptures. Due to the limited morphometric and demographic data on these animals, only 12 individuals could be used in the calculations. In contrast to KRUUK (1995), no southern river otter from road mortality could be used for K -index calculation because values for dead otters found on the road have never been reported. It seems that this otter species is very restricted to the water. Therefore only adult, apparently healthy animals were used.

Both females (F 03/36; F 04/54) have the same condition index ($K = 0.95$) and were close to the category of healthy normal otter, in contrast to the adult male otters, of which only the male southern river otter M 04/x2 was healthy ($K \geq 1$). The condition index of the recaptured animal M 03/x1 was low and in comparison to previous years, had decreased (2000, $K = 1.13$; 2001: $K = 0.78$; 2003: $K = 0.71$). I took into consideration that this animal already reached his age limit, which could also have been a reason for his death while in captivity. The K -Index for the juvenile m 04/x1 ($K = 0.68$) and for the subadult southern river otter M 04/40 ($K = 0.79$) are very low, probably because of age, since they were not full-grown. The result is that the calculations for the K -index of southern river otters must here be restricted to adult animals.

Energy intake

Days when otters were not fed four times a day, like the day of operation or the day of release, were not included in the calculations. In all cases, more fresh food was provided to the caged animals than was consumed.

The only significant difference of kcal intake found in the captured southern rivers otters was between the adults and juvenile otters. However, the juvenile southern river otter already shows an average kcal intake of 76 % of the average adult energy intake. The juvenile otter (m 04/x1) age was estimated as being between seven and nine months old.

Due to the lack of data on energy intake available for the southern river otter, data from the northern river otter *Lontra canadensis* and the Eurasian otter *Lutra lutra* were used instead.

HARRIS (1968) describes a daily fish intake by *Lontra canadensis* of 700 – 900 g which corresponds approximately to the 752 – 970 kcal that I calculated. In observations conducted in the Netherlands, the Eurasian otter had an average daily energy intake of 781 kcal (NIEWOLD *et al.*, 2003).

In the present study, the average kcal intake was 1546 kcal per day and was commensurate with (14.8 ± 2.2) % of the animals' body weight. Even though the kcal intake for the southern river is much higher it is similar to the findings of NIEWOLD *et al.* (2003) and KRUIK (1995) who calculated 13.5 % and 15 % kcal (as a conservative estimate) intake of the otters body weight, respectively.

Due to the limited field facilities it was not possible to measure the resting metabolic rate (RMR) of the southern river otter. Therefore the values of KRUIK (1995) have been used for comparison. All otters showed a much higher kcal intake than resting RMR. VAN ADRICHEM *et al.* (2004) suggest that RMR also varies on season and therefore may be much higher in winter than during summer. Thus show MELISSEN (2000), for a housed female European otter, that energy requirement in winter have been more than twice as high as in summer.

Requirements of kcal intake also depend on life circumstances. Animals in reproduction or growth need more kcal than those who only eat for maintenance (HAUFLER & SERVELLO, 1996). KRUIK (1995) estimated a total intake per day for a lactating female with one cub in Shetland at about 28 % of body weight and postulate that the energy consumption in the wild is probably even greater than in captivity.

In contrast to VAN ADRICHEM (2004), who reports that animals do not eat after an operation, in our study the operation appeared without any apparent negative consequences on the feeding consumption in all captured otters, since no animal showed a significant difference. The same findings were observed in previously captured southern river otters (pers. comm., MEDINA-VOGEL). The male adult otter M 04/40 was the one exception, but he had had no time for acclimatisation since his operation was shortly after his capture. However, no negative bias

appeared, since it ate much more after the operation and his average intake was about 1463 kcal per day.

NIEWOLD *et al.* (2003) found a significant negative correlation between the kcal intake and *K*-Index. Specifically, they found that the lower the *K*-Index is, the higher the kcal intake by captured otters is. This finding can also be seen in the data on the male southern river otters, though not in the females, which had the same *K*-Index but different kcal intake. Moreover, the number of observed animals was not big enough to allow a significant conclusion.

Given the difficulty of trapping this rare animal, the data set on nutritional requirements is very small and therefore provides only basic information or a trend. Nevertheless, MEDINA-VOGEL (pers. comm.) reports about the same amount of fish eaten by *L. provocax* which were captured between 2000 and 2002.

Additional information / behaviour observations

Behaviour in cage

All animals accepted the artificial den (the PVC-tube) and the jute cloth. Animals which were recaptured from the previous season showed more quickly exhibited a calm behaviour when placed in the enclosure. This was the case for F 03/36 and M 04/x1. These animals rested in the daytime on the side of the pool from their first day in captivity. The other animals, on the other hand, were very shy and, when humans were present, were not seen outside of the tube in the daytime until the third to fifth day of captivity. However, the otters all slept strictly in the back part of their tube.

The pool was used by all captured animals. Newly captured animals primarily used the pool at night.

While cleaning the enclosure, animals were kept in their tubes by closing the wooden sliding door. Animals tried to escape from the tube by scratching the wooden door. After about ten minutes and after refilling the cleaned pool, the tube was reopened. The southern river otters usually took the opportunity to have a

bath, so the tube was then likewise cleaned and the jute cloth changed for a fresh one. The new jute cloth was always accepted.

The newly captured animals hissed more frequently than the experienced ones. After some days the hissing became more rare, but after the operation and wound treatment (iodine on wounds), the animals hissed continuously. The juvenile animals did not show any different behaviour as compared to the adults.

Faeces were not deposited in latrines, in other words, all places except for the tube and the pool were used for defecation. The faeces were much more fluid than usual, which was likely a matter of the diet we fed them, since they are normally accustomed to a diet of crustaceans (MEDINA, 1998).

Feeding

The otters F 03/36 and M 03/x1 were accustomed to the feedings because of their experience during previous captures and ate the presented fish without problems. The low amount of eaten fish on the first day by M 03/x1 is due to the late capture of the otter and the late feeding at 22:00. The otters F 04/54 and m 04/x1 ate the fish after we offered it a second time. The male adult otter M 04/40 refused the fish on the first day. He smelled it, but left it untouched on the cage wire where it was offered. On the following day fresh fish was offered by hand through the cage wire. The otter M 04/40 tried to bite us through the cage wire, and in doing so, bit into the offered fish. The animal then ate it between loud snarls. In the following days the other offered fish was taken without showing aggressive behaviour and was eaten immediately. In contrast to other otters, such as *L. lutra*, the southern river otter always ate the fish from the tail to the head while holding it with its forepaws. Mostly the head was left uneaten, but never the tail.

Mortality

M 03/x1

When captured in the winter of 2003, the male otter M 03/x1 had lost weight in comparison to previous captures (see above) and was not in good condition. Even though he ate all the provided fish, he was found drowned in the pool in the morning on the seventh day.

On the day before it died, we observed that the animal had physical problems indicated by unknown behaviour. For example, his lower jaw, shivered and cramped very intensely for approximately 40sec, at which point it subsided. Afterwards, the otter displayed normal behaviour and ate without any apparent problems.

m 04/x1

Until 4 hours before his death, this animal's behaviour was normal and there was no evidence of any difference in behaviour or appearance. However, shortly before it died, it was apathetic and did not eat the offered fish anymore, though he did react on acoustic signals. 30 minutes before the otter m 04/x1 died, it had problems leaving the pool and died in spite of medical treatment. The post-mortem examination of the lymph nodes indicated that the otter most likely died of a bacterial infection.

M 04/x2

This male southern river otter was, with a weight of 14.5 kg, the heaviest animal we caught. While immobilized in the trap, no complications were observed. However, after applying the antidote to the tranquilizer in the enclosure, the animal's cardiovascular system failed and it died. A post-mortem examination showed that this animal had an abnormal, barrel-shaped heart and on account of this probably had problems with the antidote.

3 Home range and activity patterns of the southern river otter

3.1 Introduction

3.1.1 Home Range

Each animal is in an alternating relationship with its environment and other organisms and shows a behaviour pattern which is dependant upon both time and place. To understand and gain insight into an animal's behaviour pattern like habitat utilisation and movements, it is important to know its home range. The term home range was first defined by BURT (1943; MEDINA, 1998) as the "area traversed by the individual animal in its normal activities of food gathering, mating, and caring for young".

Home range size is a basic ecological parameter that is regularly described for a species (HERFINDAL *et al.*, 2005). Whereby territory is distinct from this definition as it is a part of the home range, is defended against conspecifics, and is therefore an area of exclusive use (BURT, 1943; EWER, 1973). This exclusive use often implies defence through aggression (BURT, 1943; POWELL, 1979) or marking behaviour (PETERS & MECH, 1975; RALLS, 1971; WOODMANSEE *et al.*, 1991). However, territory is difficult to determine (MACDONALD, 1980) and is less useful as a measure than home range (GITTLEMAN & HARVEY, 1982).

That carnivore home range size is contingent on metabolic needs has been addressed by several authors (GITTLEMAN & HARVEY, 1982; GOMPPER & GITTLEMAN, 1991; GRANT *et al.*, 1992; HERFINDAL *et al.*, 2005; MCNAB, 1963; 1980; POWELL, 1979; SANDELL, 1989; SOMERS & NEL, 2004). Due to metabolic needs, carnivores inhabit a larger home range in contrast to herbivores of similar size (SWIHART *et al.*, 1988). However, home range size can also vary greatly between species (GOMPPER & GITTLEMAN, 1991). Some variation can be explained in terms of body mass and feeding style as well as food availability (HERFINDAL *et al.*, 2005), but many species deviate highly from predicted values (FERGUSON *et al.*, 1999).

Multiple factors may influence home range size, including habitat quality, habitat composition (MACDONALD, 1983), topography (POWELL & MITCHELL, 1998),

season (DE VILLIERS & KOK, 1997), climate (LINDSTEDT *et al.*, 1986), sexual activity (PAYER *et al.*, 2004; POWELL, 1979), reproductive status or rather maternal care (SAID *et al.*, 2005) and interspecific and intraspecific competition (GOMPPER & GITTLEMAN, 1991).

In the present study, home ranges of the southern river otters *Lontra provocax* are described by means of the minimum convex and fixed kernel methods in order to facilitate comparisons with other studies in the literature and to highlight and discuss any intra-study differences.

3.1.2 Habitat preferences

To assess a species' needs one usually looks at habitat use and from this infers selection and preference. Presumably, species should reproduce or survive better, i.e., their fitness should be higher, in habitats that they tend to prefer (GARSHELIS, 2000). Thus, once habitats can be ordered by their relative preference, they can be evaluated as to their relative importance in terms of fitness.

An animal's home range usually contains a number of different habitat types, and the availability of resources (generally food) varies between habitats, both spatially and temporally. Optimal foraging theory predicts that an animal will "maximise the net caloric intake ...per unit time" (EMLEN, 1966), which suggests that an animal would spend disproportionately greater amount of its time in the most profitable habitat types. However, optimality is not restricted to foraging and can apply to a number of other constraints on an animal's reproductive success as well (Stephens & Krebs, 1986), including the avoidance of predators (KUMMER, 1968); the search for mates (BAILEY, 1974); and proximity to resting sites (DONCASTER & WOODROFFE, 1993; MOORHOUSE, 1988). The evaluation of habitat use is central to an understanding of the ecology of an animal.

Preference for habitats is determined by comparing use with availability and identifying those habitats which are used disproportionately (JOHNSON, 1980). The most common method for measuring utilization is radio-telemetry, but counts of holts (KRUUK *et al.*, 1989) and spraints for otters as well as spools and line techniques for small mammals (BOONSTRA & CRAINE, 1986) are also effective.

Another possible constraint on river habitat utilisation is the distribution of resting sites or dens. Within this study, for the first time, it will be possible to get a better understanding of what kind of resting sites or dens the southern river otter uses and what kind of vegetation they require.

Since spraint distribution has often been used to determine riparian habitat preference, the locations of marking sites were investigated. The home range of individual otter for locations of spraint sites was thus surveyed.

3.1.3 Activity patterns

Various species have evolved different circadian activity cycles to cope with the time structure of their environments (DAAN & ASCHOFF, 1982). The circadian timing mechanism in mammals is located in the suprachiasmatic nuclei (SCN) of the anterior hypothalamus and is composed of numerous clock cells which manipulate the circadian programme (REPPERT & WEAVER, 2001). Light plays an important role in circadian rhythms as the SCN receives light information by a direct retinohypothalamic tract to synchronize the clock to a 24-h day and to ultimately generate output rhythms in physiology and behaviour (REPPERT & WEAVER, 2002). Activity patterns are in general related with photoperiodism and therefore species can be assigned to one of the three following basic activity pattern groups: diurnal, i.e. activity occurs only when light is present; nocturnal, i.e. activity bouts occur at night; or crepuscular, i.e. the daily activity peaks are around dusk and dawn, which is multimodal (polyphasic or ultradian). These activity rhythms give the animal the opportunity to predict environmental changes and to choose the time for a given reaction (ARONSON *et al.*, 2003).

Most animals are strictly affiliated to one of these groups because of ecological and physiological trade-offs and this has profound consequences for an animal's ecology and social behaviour (ENRIGHT, 1970; HALLE, 2000) since most nocturnal species are solitary, and most group-living species are diurnal (e.g. CLARKE *et al.*, 1995). However, some species are cathemeral. This term was proposed by TATERSALL (1979) which describes animals whose activity pattern is arrhythmically around the 24-h day (KAPPELER & ERKERT, 2003; ZIELINSKI,

2000) and their activity bouts have no relation to photoperiodism (ENRIGHT, 1970).

Activity patterns are not only driven by circadian clock, they are also affected by both physiological and exogenous factors, like environmental stimuli, which can influence endogenous rhythms (UNDERWOOD, 1992). The environmental stimuli can suppress or increase the activity of an animal, examples of which include the adaptation of the eye to bright and dim light (KAVANAU & RAMOS, 1975), high as well as low temperatures (KÖRTNER & GEISER, 2000; PORTER *et al.*, 1973), dehydration (PORTER *et al.*, 1973), and hunger and prey availability respectively (LODÉ, 1995; METCALFE & STEELE, 2001; NIELSEN, 1983; PRICE, 1971)

Some species have a flexible activity pattern, including the redfronted lemur *Eulemur fulvus rufus*; owl monkey *Aotus azarai* (FERNANDEZ-DUQUE, 2003); fossa *Cryptoprocta ferox* (DOLLAR, 1999); red fox *Vulpes vulpes* (ABLES, 1969); binturong *Arctictis binturong* (GRASSMAN *et al.*, 2005) and European polecat *Mustela putorius* (MARCELLI *et al.*, 2003).

Such a flexibility in activity patterns is not generally expected, since adaptations to activity at either day or night require strong structural adaptations (VAN SCHAIK & KAPPELER, 1996). However, the activity pattern of the American marten *Martes americana* correlates with the activity of its prey, and therefore includes hunting at night during the winter, and during the day in the summer (ZIELINSKI *et al.*, 1983).

Likewise, there are many different activity patterns within the subfamily *Lutrinae* and even within the genus of otters. For example, the sea otter *Enhydra lutris* displays diurnal activity (MASS & SUPIN, 2000), whereas Asian clawless otters *Amblonyx cinereus* are cathemeral (BALLIET & SCHUSTERMAN, 1971). But different activity patterns were reported even in species like the European otter *Lutra lutra*. The European otter seems to be nocturnal in temperate fresh water habitats (e.g. CARSS *et al.*, 1990; GREEN *et al.*, 1984) but are diurnal in marine habitats (e.g. KRUIK, 1995). However, other authors reported that *L. lutra* was observed in freshwater habitats at daytime (e.g. TÜZÜN & ALBAYRAK, 2005; UMAPATHY, 2000). In conclusion, the nature of endogenous and exogenous factors that govern these activity patterns are still poorly understood (KAPPELER & ERKERT, 2003).

The southern river otter is described by PARERA (1996) as primary nocturnal, but occasionally active during the daytime (SIELFELD, 1983).

Precise details about the activity patterns of *L. provocax* are still limited and to some extent contradictory, primarily due to the difficulties of recording activity over 24 hours and by reason of the highly cryptic life of this animal.

3.1.4 Aims

The general purposes of this chapter are to examine: (1) the area three individual southern river otters use, (2) the preferences for habitat use and (3) to reveal the activity pattern and movements of each animal.

For the examination of the area used by southern river otters, especially the total range, the home range and core length will be determined. Furthermore the activity patterns will be examined, especially frequency of movement and inactivity occurrence for each individual. Specifically, the aims for habitat use are to determine preferences for hunting areas, den sites and marking sites.

3.2 Methods

3.2.1 Home Range

3.2.1.1 Telemetry

Sender and receiver

For radio telemetry a TR-4 receiver (TELONICS Inc., USA), radio transmitters (Sirtrack Ltd., Havelock North 4201, New Zealand), sensitive to movements and a hand-held three-element folding Yagi antenna (Sirtrack Ltd., Havelock North 4201, New Zealand) were used. The size of the radio transmitter was approximate 15 mm x 110 mm and was completely covered in latex. It had a weight of about 40 g, including the battery, and therefore was significantly below the tolerance level of five percent of the body mass (KENWARD, 1987; SAMUEL & FULLER, 1996). The life expectancy of the transmitters was indicated as 12 month and their frequencies lay between 150.360 MHz and 150.540 MHz. The radio transmitters were activated by a magnet held over a marked silver spot. Deactivation of the sender was possible via the same procedure.

The range of the transmitters depended upon the vegetation and topography of the area. Variations from 50 m up to 500 m were observed. If the animal was situated in a den, the signal could decline to a range of less than 10 m.

To minimize and determine the bearing errors, two methods were performed. On one hand a beacon was used to train and for identifying the error of individual observers, and on the other hand, radio-tracking the animal bearing was carried out from three to five locations, every time the animal paused, at least every hour. The bearing error depends on the distance to the sender (KAUHALA & TIILIKAINEN, 2002). Therefore the deviation is between 0 m and 25 m.

Radio tracking

Between 2003 and 2004, three southern river otters were equipped with intraperitoneal movement-sensitive radio transmitters. After eight days of recovery from surgery, animals were released at the former trapping spot. For control, animals were tracked immediately for one hour after releasing, but this data set was not used for investigation of the home range. It is assumed that animals

released after a period in captivity have to re-establish their home range or demonstrate different behaviour (DEMERS *et al.*, 2003), but this has only been reported for animals with external transmitters (WHITE & GARROT, 1990). Furthermore it is possible that the released, formerly trapped animals do not return to the capture area for several days (DEMERS *et al.*, 2003; SAMUEL & FULLER, 1996). To avoid errors on avoidance of locations and non-normal behaviour and allowing the southern river otters to acclimatise, only data from the 10th day on has been taken into account for the calculation of home range and activity pattern analysis.

The female southern river otter (F 03/36) was tracked from April 2003 through November 2003 and in 2004 two animals were tracked from March through August 2004 (F 04/54: March 2004 through August 2004; M 04/40: April 2004 through July 2004).

In the following time, the radio-equipped animals were radio tracked for three consecutive days, each time for eight hours, in such a way as to complete a 24 h cycle (00:00 – 08:00; 08:00 – 16:00; 16:00 – 24:00) at least once per month. During the two-week stay in the field, further radio tracking bearings were taken daily.

To radio track an otter, the area was searched two and a half hours before officially beginning by a car with a roof fixed military antenna with a speed of 5 - 15 km/h. The distance for the vehicle-fixed antenna was approximately about 800m. When the signal was captured, the first team with a Yagi antenna drove out. The second team took position so that the animal was always kept between the two teams and such that the angle between the two teams formed 60° to 120° for cross bearing as recommend by WHITE & GARROTT (1990).

Once the animal was located, it was followed on foot for an eight-hour shift. The visible and audible presence of the trackers was minimized and a minimum distance of 20 m was maintained between the animal and observer in order to not influence the animals' behaviour, which could bias the study.

Location fixes and behaviour data of animals were taken in five minutes intervals. In preliminary observations in this studies it was pointed out that ten-minute intervals were insufficient, because within 10 minutes the southern river otter could

moved out of its den, hunt and return to the same den before the second data point would be taken. Both teams used a digital five-minute timer with auto-repeat function (Casio Computer Co., LTD, Japan). It was thereby guaranteed that the observations for triangulation were made simultaneously. The direction of the radio-tracked animal was acquired by the strongest audible signal and with the bearing of a compass (Recta DS 50, Suisse). The intersection point, which is found with transmitter location, was determined by each team. Information about location station, measured via Global Positioning System (GPS, Garmin, GPS 12 Personal Navigator, USA), compass bearing, activity status and direction of movement (up- or downstream) were noted on a data sheet. Additional information on traffic and observed behaviour were also noted.

Home Range estimates

In order to delineate the range an animal uses, MOHR (1947) developed a non-statistical approach called the minimum convex method (MCP). THE MCP is a link-distance method using a two-dimensional model of uniform use enclosed by its outermost sightings (POWELL, 2000; WHITE & GARROT, 1990). The MCP method is descriptive and not dependent upon the independence of collected locations. Polygons are generated by the connections of the outermost locations such that the inner angles of the polygon do not exceed 180°. The resulting area is then interpreted as the home range of an animal.

MCP 100 thus includes all location fixes and therefore describes the total area the animal used (total range). A standard method is that 5 % of location fixes are treated as non typical movements, like sallies, and therefore are excluded from home-range calculations (WHITE & GARROT, 1990). Consequently, minimum convex polygon home range estimate (MCP 95) includes 95 % of all independent location fixes closest to the harmonic mean centre.

In contrast to parametric estimators, the kernel method can identify intensively used areas. The kernel method is a nonparametric estimator of the variation in observation densities within the area an individual animal is using (SEAMAN *et al.*, 1999; WHITE & GARROT, 1990). This probability distribution of relative use of space is termed 'utilization distribution' (FIEBERG & KOCHANNY, 2005; KATAJISTO & MOILANEN, 2006) and is of great importance in home range

studies (WORTON, 1989). With the kernel method it is possible to illustrate areas with different utility distributions as probability contours (isopleths).

Kernel calculations are based on the following equation:

$$f(x) = 1/nh \sum_{i=1}^n K[(x - X_i)/h], \quad (\text{SILVERMAN, 1994})$$

where $f(x)$ = describes the density estimator for the location (x);

h = the bandwidth,

$K[(x - X_i)/h]$ stands for the used kernel function.

The method is based upon the calculation of the distance between successive observed locations (x), which are located within a distance h from (x). The assumed kernel function K will be calculated from the number of locations within h and their distance to (x). When this procedure is carried out for all locations in an observed region, kernel areas can be defined with specific densities of observations.

For the most accurate linear home-range estimate, fixed kernel is used including 95 % of all independent location fixes (FK 95) with smoothing factor h_{ref} as recommended by BLUNDELL (2001).

The innermost 50 % of all independent location fixes (MCP 50, FK 50, and FK 25) were considered as a core area estimate. For best results in the linear home range estimate, FK 50 and FK 25 were calculated with the smoothing factor selected by least-squared cross validation (BLUNDELL *et al.*, 2001).

Autocorrelation

To avoid autocorrelation of location fixes a “range span method” is used due to the fact that software packages would have calculated untrue independent data points as the animal only uses linear travel routes. *Lontra provocax* seems to be restrained to water as they were never seen crossing dry ground. Average travel speed from all location fixes and the maximum distance of location fixes in the home range of each individual were calculated and the data set was thus resampled.

Home range asymptotes

Home range analysis should encompass the wide variation in moving behaviour related to sex and age differences (HARRIS *et al.*, 1990). Only a representative sample for the entire sampling duration conforms to these requirements. To assure that the sampling period contained the whole range of behaviour exhibited by the animal, asymptotes for home range were required (LAVIER, 2005). The number of location fixes needed to calculate home range size was determined by plotting the number of location fixes against home-range size until home-range size reached an asymptote (HARRIS *et al.*, 1990). Calculations for the asymptote of the southern river otter's home range had to be done manually since software package analyses only in hectares the area which was used by an animal. In this case the southern river otter used the river almost exclusively and no terrestrial parts. Therefore the home range was linear. To determine the linear home range, each successive distance of location fixes was measured manually in ArcView™ and the increase in home range was thus calculated.

3.2.1.2 Data evaluation

Tracking data

The triangulation data were calculated using the computer program LOAS (Version 4.0, Ecological Software Solution). LOAS estimates locations using two or more bearings and the output data can be used for further analyses. The further processing and analyses of the data were realised by using the software package "ArcView™" (Version 3.2, ESRI, Environmental System Research Institute) and the extension "Animal movement" (HOOGE & EICHENLAUB, 2000b). For the fixed-kernel home range with smoothing factor h_{ref} the extension "Home range analyses" by RODGERS & CARR (1998) was used.

Map

In order to measure location stations and calculate intersection points of bearings, the metric map coordinate system Universal Transverse Mercator was selected (UTM) because of its ability to calculate distances between locations and simplify calculations in telemetry (WHITE & GARROT, 1990).

In the field, maps of the area Tolten (No. 3900 – 7300), Comuy (No. 3900 – 7245) and Lanco (No. 3915 – 7245) with a scale of 1: 50.000 were used and for computer analysis digitized maps, both provided by the INSTITUTO GEOGRAFICO MILITARY de CHILE.

Home range

Home range estimates by fixed kernel were measured to the maximum location fix within the home range contours and not to the contour line of the home range. This was done to not overestimate the 'real' home range.

3.2.2 Habitat preferences

Vegetation analysis was carried out within the home range of the female southern river otter F 03/36, as only this area was completely accessible in contrast to the other areas of the otters. However, the male M 04/40 also used a wide range of the habitat of F 03/36 and the habitat of F 04/54 was situated in the impenetrable ombrophilous swamp forest.

To determine which vegetation type was associated with the occurrence of prey (hunting areas) and dens of the southern river otter, all aquatic habitats of the investigation area were determined and categorized by the following characteristics at 200 m intervals within an area of 10 m width:

- depth and width of water, current, left and right bank angle ($< 15^\circ$, $15^\circ - 45^\circ$, $> 45^\circ$, 90°);
- river bed structure: Sand, Gravel, Stones, Rocks, subsurface Woody debris, Trees/Roots, Aquatic plants;
- riparian vegetation structure: Sand/Stones, Grass/Herbs, Bushes, Trees (< 10 m), Big trees (> 10 m), Roots, Overhanging roots, Quila *Chusquea quila* (Poaceae), Dead trees.

Marking sites were searched within the home range and were revisited daily during the time in the field. Sites with positive spraint occurrence were classified in terms of:

- distance from water to faeces (horizontal/ vertical);
- bank angle (< 15°, 15° - 45°, > 45°, 90°);
- surrounding vegetation: Soil/Stone, Grass/Herbs, Bushes, Trees (< 10 m), Big trees (> 10 m), Roots, Overhanging roots, Dead trees.

3.2.3 Activity patterns

In this study implantable movement-sensitive radio transmitters were used to measure the activity pattern of *Lontra provocax*. Due to the design of the radio transmitters, it was possible to categorize the behaviour in terms of active and inactive phases. When the signal occurred once per second, the animal was 'active' and when it occurred every 1.5 seconds, the animal was considered 'inactive'. In combination with the bearing it was possible to classify the activity pattern in the following three different categories:

- Inactivity = bearing with two Yagi antennae did not indicate change of location within the next data fix and the signal of the radio transmitter pulsed every 1.5 seconds (inactive);
- Stationary activity = bearing indicated no change of the location within the next data fix, but the signal of the radio transmitter pulsed every 1.0 second (active);
- Movement = bearing indicate change of the location within the next data fix and signal of the radio transmitter pulsed every 1.0 second (active).

Hunting behaviour was sometimes also measurable; represented by a change in the loudness/strength of the signal or by the signal disappearing for a few seconds. However, this method was vulnerable to bias, due to the different interpretation by each team. Therefore this behaviour pattern was not analysed further.

Data was collected every five minutes and noted on the spreadsheet by each team individually when after 10 seconds the signal of the 5-minute timer stopped. Activity patterns which were noted differently between the two teams were excluded from the calculations.

Due to limitations of man power, poor climate conditions and the difficulty in following the animal through impassable rough terrain, continuous 24-hour tracking was divided into consecutive 8 h shifts for three consecutive days. It was attempted to do continuous tracking for 24 hours at least once for each animal.

Only bouts which were recorded continuously were used for calculation, incomplete data was not considered (i.e. if no signal was obtained after five minutes, whole data set was ignored until the activity pattern changed).

In order to calculate velocity, fixed 5 minute intervals were used. The distance between two bearings on the map was measured using ArcView™ 3.2 (ESRI, 1996).

3.2.4 Statistical analysis

All data were tested for normal distribution and equality of variances. When the assumptions did not fulfil the criteria, non-parametric tests were applied. Detailed information on the applied statistical test is specified in the results section. For statistical analysis the software package STATISTICA (Version 5.0, Statsoft, Inc.) was used. The significance level of $P < 0.5$ was assumed for all statistical tests. Box-plot diagrams are illustrated with mean (dotted line), median (solid line), 5 and 95 percentile, as well as 25 and 75 quartiles. Values in brackets display 25 and 75 percentiles i.e. (25/75).

Average linkage cluster with unweighted pair-group method was used to display the relationship between the river bed variables of hunting areas and den sites and for the aggregation of marking sites.

For the calculation of preferred habitat types or habitat structure elements AEBISCHER *et al.* (1993a) recommend the composition analysis as it eludes many pitfalls compared to alternative methodologies. To analyse which structure elements for den and hunting areas are most important the program "Compos Analysis" by SMITH (2004) was used. The composition analysis is a non-parametric analysis which ranks habitat elements according to their utilization or, in this case, to their importance.

Beside errors which emerged from data collection, systematic and random errors can arise during the data input process. Measurement errors in home range length can appear as well, since river length had to be measured manually in the software package ArcView™ by following the course of the river with the track ball.

3.3 Results

3.3.1 Home Range

3.3.1.1 Accessibility

The area in which the home range of the southern river otter was studied was not of a homogeneous shape. Therefore there was not equal accessibility to locations within this study area (Tab. 3.3.1). Less time was generally spent searching for animals whose home range was more accessible by car. Besides animal F 03/36, which occupied an area which was not possible to access at night due to the danger of rocks, steep hills and deep canyons, all other home ranges were accessible by car or by foot at any time.

Tab. 3.3.1: Accessibility of home ranges of three otters

ID	Total Range MCP 100 (m.)	Possible by car (m)	%	only by foot (m)	%	not possible at night (m)	%
F 03/36	16894	9118	53.97	7776	46.03	4629	27.40
F 04/54	18663	14348	76.88	4315	23.12	--	--
M 04/40	17608	7075	40.18	10533	59.82	--	--

The average time spent to initially locate an animal was 1:58 hours (SD = 1.44 min) (Tab. 3.3.2). Most of the home range of M 04/40 was only accessible by foot and therefore most search time was spent on this animal (00:30 h – 11:30 h), followed by F 03/36 and F 04/54.

Tab. 3.3.2: Time spent for first location on animal

ID	General		positive search		negative search	
	Average (hh:mm)	Range (hh:mm)	Average (hh:mm)	Range (hh:mm)	Average (hh:mm)	Range (hh:mm)
F 03/36	02:38	00:24 – 06:30	02:00	00:24 – 05:30	04:41	03:00 – 08:00
F 04/54	02:18	00:50 – 04:05	01:57	00:50 – 03:50	03:26	02:10 – 04:05
M 04/40	03:48	00:30 – 11:30	01:57	00:30 – 08:20	05:30	01:00 – 11:30
Average	02:55		01:58		04:32	

3.3.1.2 Home Range, Core Areas, Autocorrelation

The range span and independent data points were calculated for the southern river otters with radio transmitters. The average velocity was calculated by dividing the total distance travelled by individual animals, as measured by telemetry, by the total time of observation (Tab. 3.3.3). The female southern river otters F 03/36 and F 04/54 showed almost the same velocity, whereas the male M 04/40 was approximately 9 % slower. The average speed was 589.80 meters per hour.

The range span, calculated within FK 95, was highest for M 04/40 (22.3 % higher than average) and F 03/36 (16.0 % higher than average) which also results in the highest time interval for the next independent location fix. In contrast to the otters mentioned previously, the range span and time intervals for independent data points for F 04/54 were a lot lower (47.7 % lower than average for the range span).

Tab. 3.3.3: Range span and intervals for independent data fixes

ID	N	Average velocity (m/h)	SD (\pm)	Range Span (m)	Independent data point (hh:mm)
F 03/36	240	608.26	540.40	11375	18:42
F 04/54	140	607.99	531.52	4996	08:13
M 04/40	27	553.14	473.61	12287	22:13
Average		589.80	31.75	9552.67	16:23

The manually calculated cumulative area curves for the two female (F 03/36; F 04/54) and one male (M 04/40) radio tracked southern river otters illustrate diverse rates of home range stabilisation (Fig. 3.3.1). Only the asymptotes for the two females were attained. The fix number for range stabilisation for F 03/36 was reached after 19 (and 59 respectively) and for female F 04/54 it was reached after 51 location fixes. Although the male southern river otter did not reach the asymptote it was kept in calculations for comparison with data from literature.

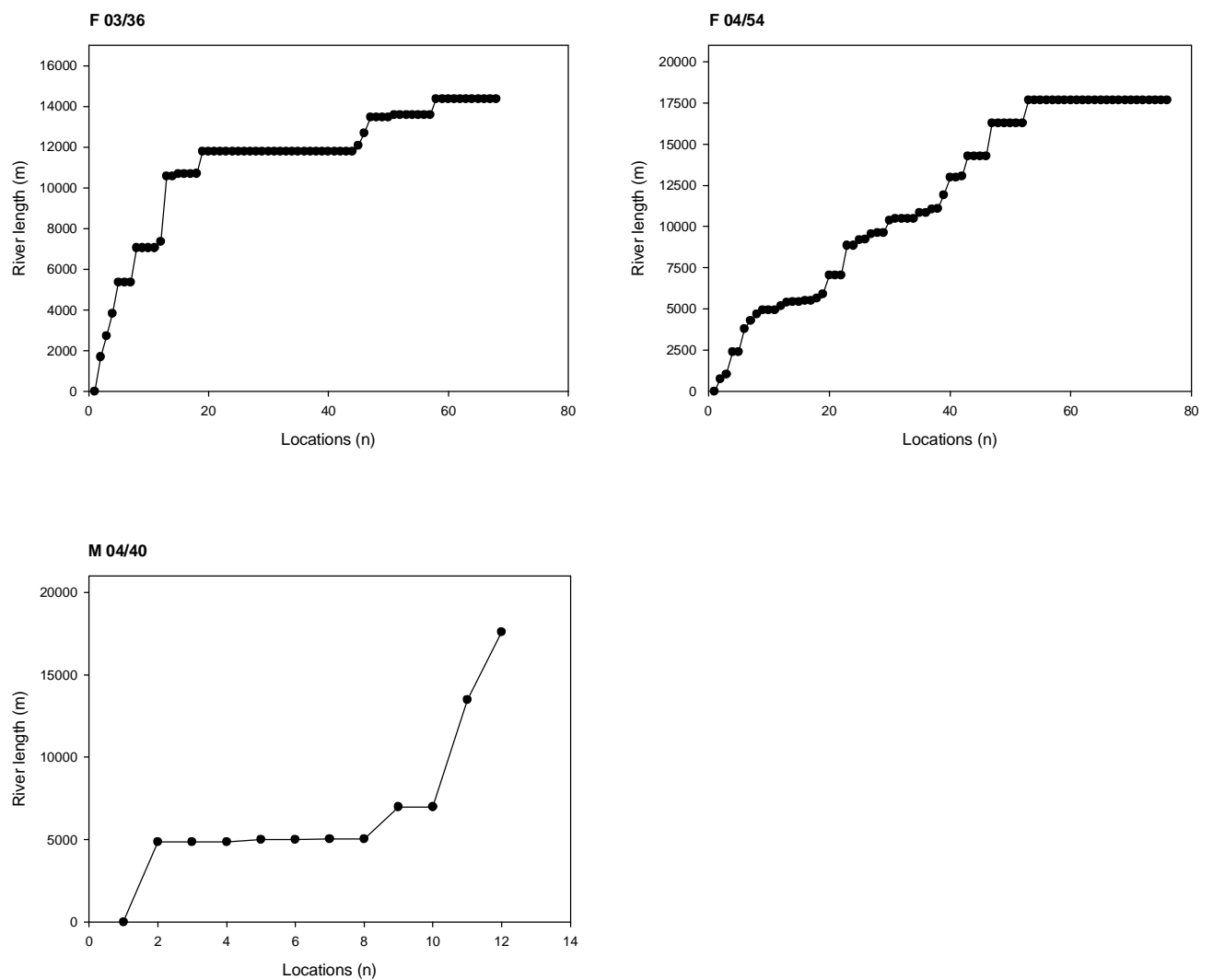


Fig. 3.3.1: Kernel density asymptote analysis (FK 95) for three radio tracked southern river otters

Total ranges (Fig. 3.3.2) were calculated for all three radio equipped southern river otters using MCP 100 which includes all location fixes (Tab. 3.3.4). Home range estimates were analysed by using MCP 95 and FK 95 and core areas were measured using the minimum convex polygon and fixed kernel that includes 50 % of location fixes (MCP 50, FK 50). Additionally the core area with 25 % of location fixes was quantified by using fixed kernel (FK 25) (Fig. 3.3.3; 3.3.4; 3.3.5).

MCP 95 and FK 95 were used as they are widely considered the best for home range delineation (HARRIS *et al.*, 1990; WHITE & GARROT, 1990) and the results can be compared with data from the literature.

MCP 95 reduced the home range estimates by 20.0 % to 29.8 % compared with MCP 100, whereas the reduction was lower in FK 95 (0.0 % to 15 %). Core area estimates using MCP 50 represent a range from 6.6 % to 30.8 % of MCP 95 home range areas. The fixed kernel core areas (FK 50) correspond to 5.4 % to 33.1 % of FK 95 home range estimates. The additional home range with 25 % of independent data fixes display approximately 7.7 % of FK 95 home range estimates (range 5.4 % - 11.2 %). Although MCP and FK method display different results, there was no significant disparity between the home ranges MCP 95 and FK 95 or core areas MCP 50 and FK 50 (paired t-test: home ranges MCP/FK 95; $t = -2.454$, $P > 0.05$; core areas MCP/FK 50; $t = 0.161$, $P > 0.05$).

Tab. 3.3.4: River length used by three southern river otters (total range, home range and core area)

ID	Fixes	Total range (m)	Fixes	Home range estimate (m)		Core area estimate (m)			Kernel h factor
	all	MCP 100	independent	MCP 95	FK 95	MCP 50	FK 50	FK 25	LSCV
F 03/36	2945	16894	68	13514	14358	4163	4749	1606	362
F 04/54	1558	18663	76	14397	17675	3594	3057	1165	241
M 04/40	663	17608	12	12365	17608	1162	952	952	608
Average		17722		13425	16547	2973	2919	1241	
SD		890		832	1548	1594	1902	334	

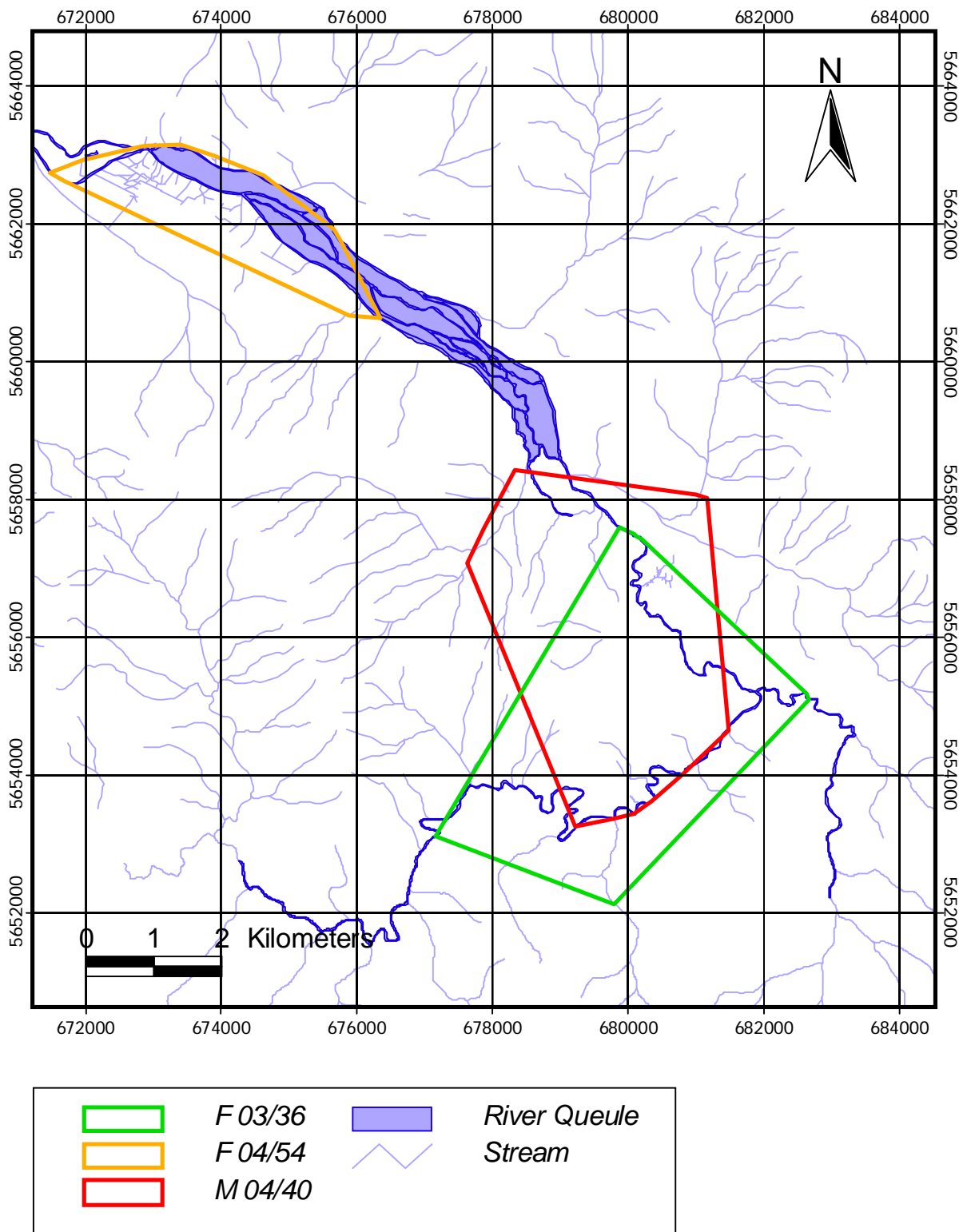


Fig. 3.3.2: Total range (MCP 100; all location fixes) for three radio tracked southern river otters in 2003 and 2004 in the Upper Queule River

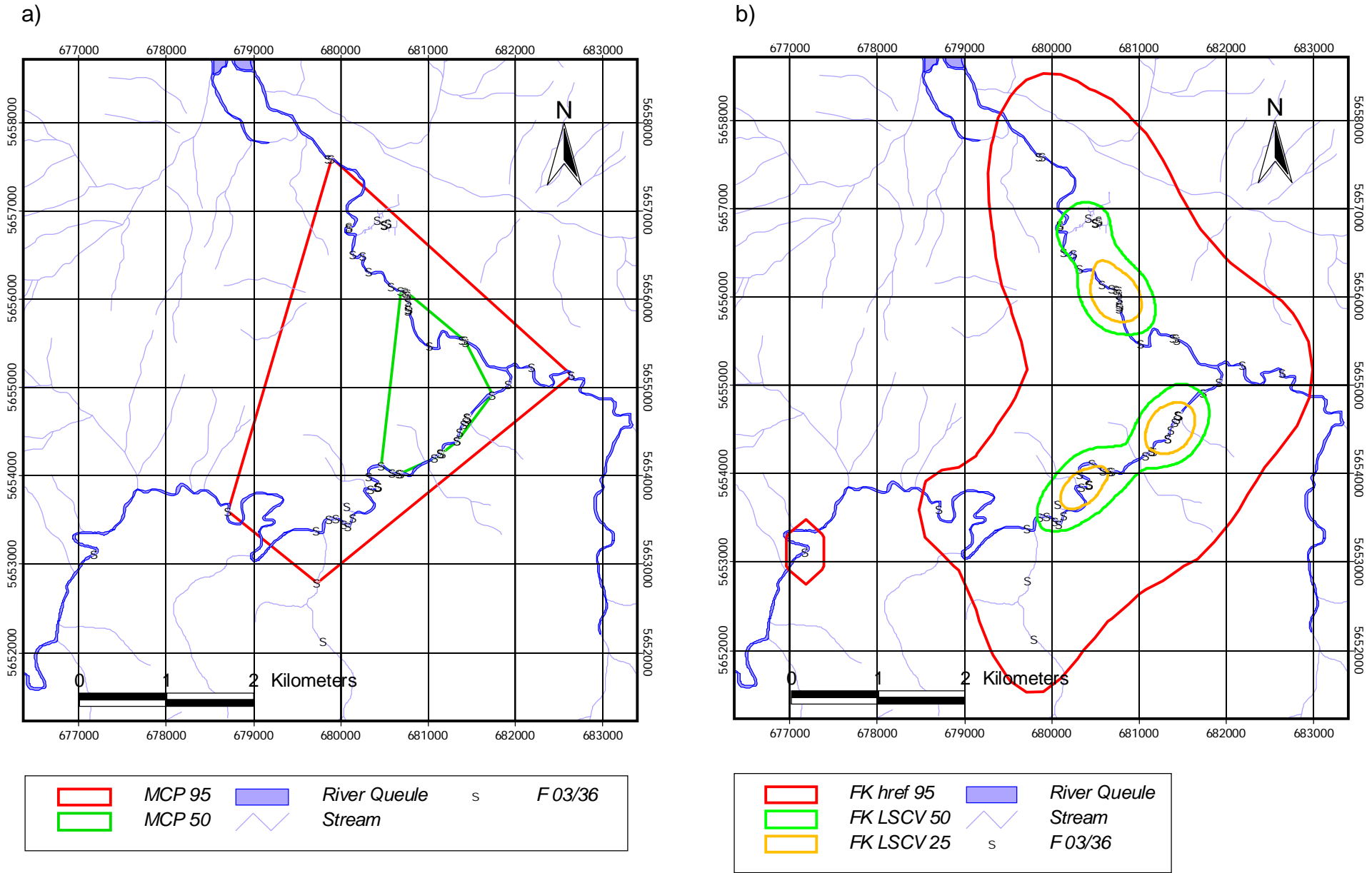


Fig. 3.3.3: Map of Queule area. Displaying (a) minimum convex polygon home range (MCP 95); core area (MCP 50) and (b) fixed kernel home range (FK 95) and core area (FK 50, FK 25) estimates of animal F 03/36

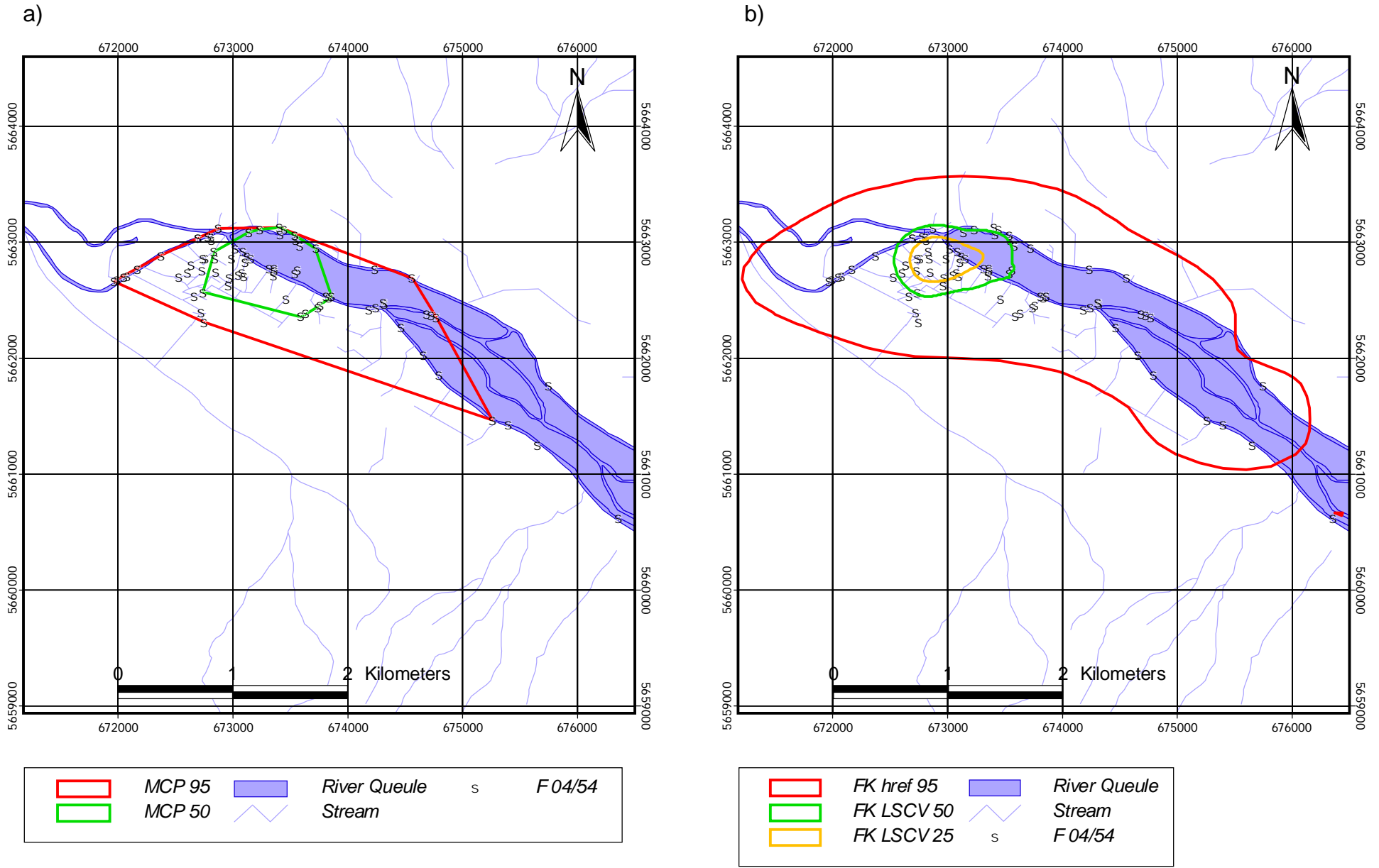


Fig. 3.3.4: Map of Queule area. Displaying (a) minimum convex polygon home range (MCP 95); core area (MCP 50) and (b) fixed kernel home range (FK 95) and core area (FK 50, FK 25) estimates of animal F 04/54

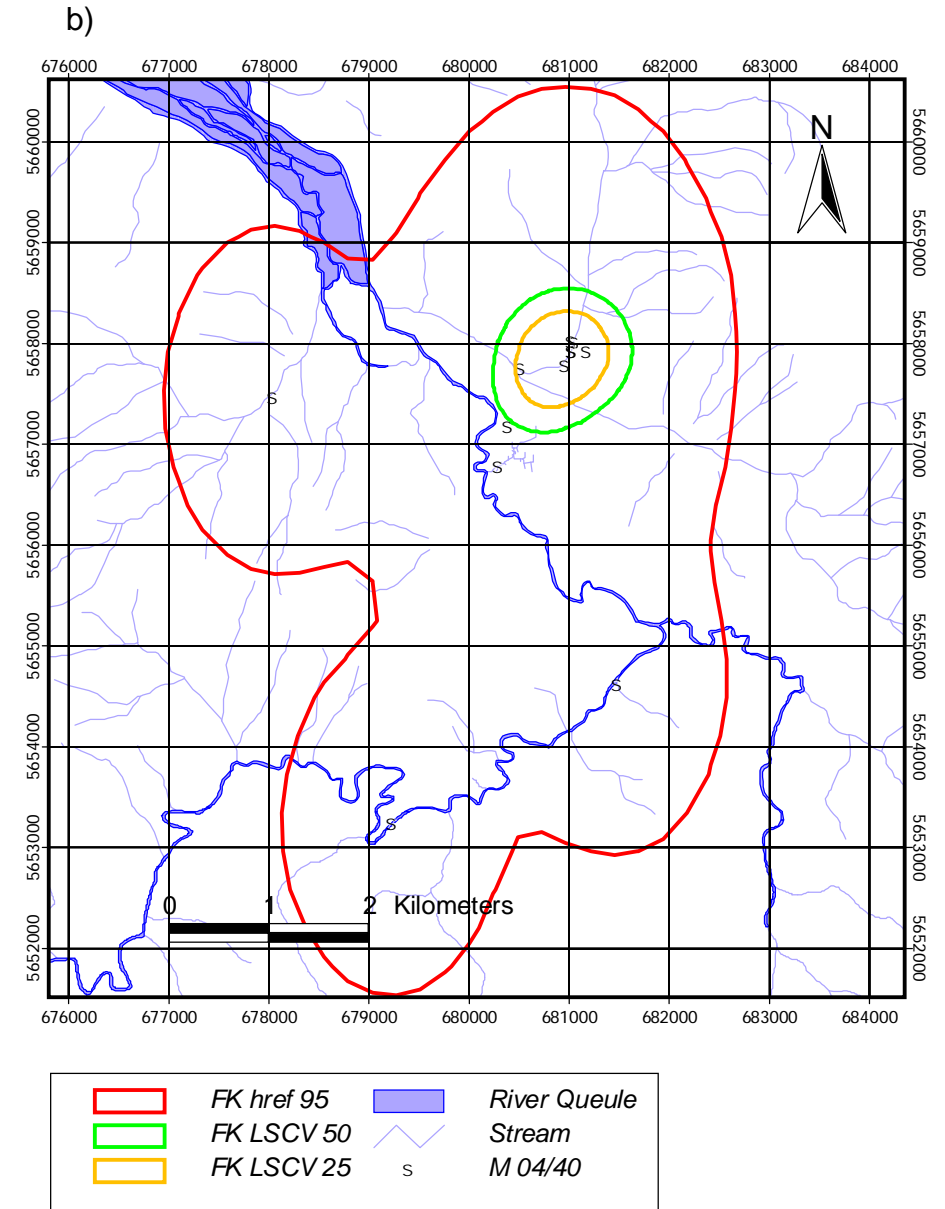
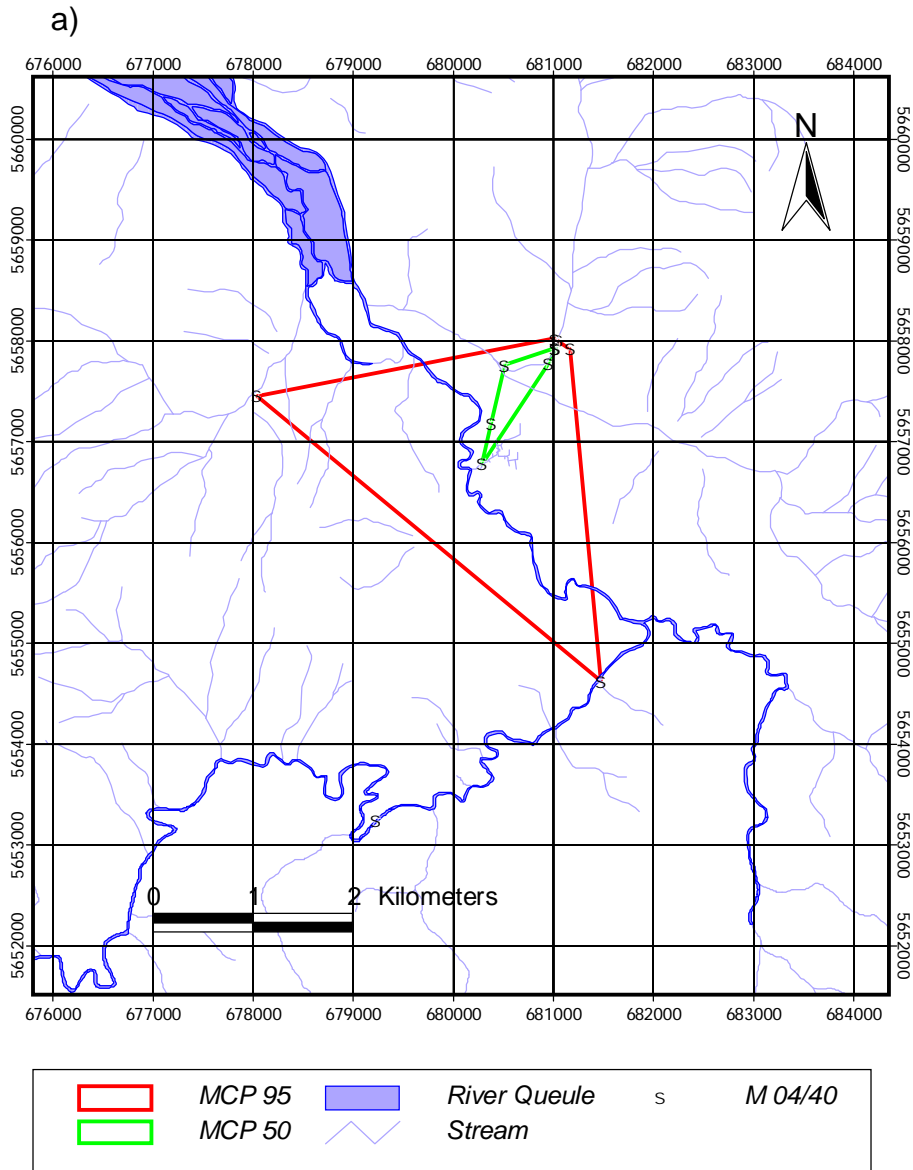


Fig. 3.3.5: Map of Queule area. Displaying (a) minimum convex polygon home range (MCP 95); core area (MCP 50) and (b) fixed kernel home range (FK 95) and core area (FK 50, FK 25) estimates of animal M 04/40

3.3.2 Habitat preferences

3.3.2.1 Habitat composition of F 03/36

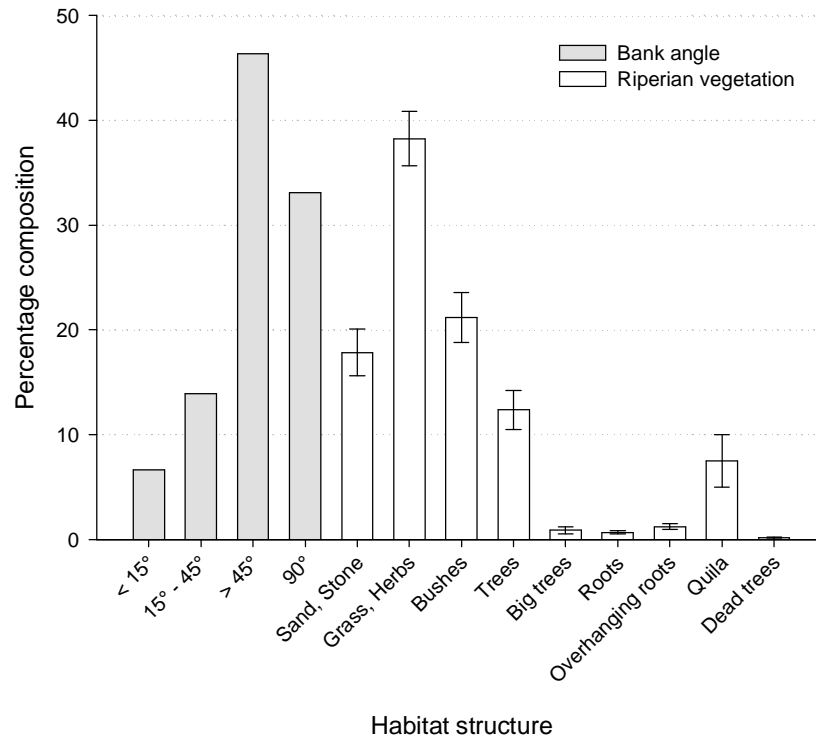


Fig. 3.3.6: Habitat composition of the home range of female southern river otter F 03/36. Mean values and standard errors for vegetation structure are shown (n=76)

As only the home range of F 03/36 was accessible, this home range was used for examinations of habitat preferences.

Bank angles of >45 degrees (46.4 %) represent the most frequently occurring riparian inclination followed by 90° bank angles (33.1 %) (Fig. 3.3.6). The vegetation structure Grass/Herbs (38.2 %; SE = 2.59) is salient and is building a group with the variables Bushes (29.2 %; SE = 2.37) and Sand/Stones (17.8 %; SE = 2.24). The variables Trees and Quila are represented with 12.4 % (SE = 1.86) and 7.5 % (SE = 2.51) respectively. Big trees (0.8 %; SE = 0.33), Roots (0.66 %; SE = 0.16), Overhanging roots (1.2 %; SE = 0.30) and Dead trees (0.1 %; SE = 0.10) occurred infrequently in the investigated home range of F 03/36.

As the normality test failed the Kruskal-Wallis ANOVA on Ranks was performed. The vegetation variables are significantly different (H= 361.734; df=8; p<0.001).

The possible correlations of bank angle and riparian vegetation structure are summarised in an overview table (Tab. 3.3.5 a, b). Interestingly Quila is negatively correlated with the variables Sand/Stones, Grass/Herbs and Bushes on the right bank site. It is not surprising that roots are positively correlated with Big trees and Overhanging roots with the variable Roots, thus these results validate the test. Surprisingly only one vegetation variable (Overhanging roots) is correlated positively with the bank angle (90°). The right side vegetation structure shows a very similar correlation for the variable Quila. This variable is again negatively correlated with Sand/Stones, Grass/Herbs and Bushes. A bank angle of <15° is positively correlated with the vegetation structure variable Sand/Stones, and a bank angle of 90° with Grass/Herbs. Additional Bushes are positively correlated on the right side with the variable Big trees and Roots. When both sides are correlated, Quila shows a highly significant positive correlation ($r_s=0.449$, $t=4.323$, $p<0.001$) (Appendix 10.2; Tab. C).

Tab. 3.3.5: Correlation of left (a) and right (b) side riparian vegetation structure and bank angle. Significant values are shown in bold numeric. (+ = positive significant; - = negative significant; + (-) = $p<0.05$; ++(--)= $p<0.01$; +++(---) = $p<0.001$). Specified are r_s , $t(n-2)$, and p values

a)

Variable	Bank angle				Riparian vegetation structure								
	<15°	15° -45°	>45°	90°	Sand, Stones	Grass, Herbs	Bushes	Trees	Big trees	Roots	Overh. roots	Quila	
Bank angle	<15°		-0.122 -1.052 0.296	-0.307 -2.755 0.007	-0.172 -1.490 0.141	0.216 1.888 0.063	-0.010 -0.088 0.930	-0.032 -0.270 0.788	-0.080 -0.683 0.497	-0.060 -0.515 0.608	-0.122 -1.050 0.297	-0.158 -1.369 0.175	-0.087 -0.745 0.459
	15° -45°			-0.432 -4.087 0.000	-0.241 -2.126 0.037	0.226 1.978 0.052	-0.066 -0.569 0.571	-0.069 -0.569 0.587	0.097 0.834 0.407	-0.085 -0.726 0.470	-0.078 -0.668 0.506	-0.222 -1.949 0.055	-0.122 -1.051 0.297
	>45°	---	---		-0.606 -6.514 0.000	-0.192 -1.675 0.098	-0.119 -1.023 0.310	0.047 0.402 0.689	-0.010 -0.082 0.935	-0.074 -0.638 0.526	-0.050 -0.429 0.669	0.008 0.072 0.943	0.181 1.571 0.121
	90°		-	---		-0.097 -0.834 0.407	0.197 1.717 0.090	0.018 0.150 0.881	-0.018 -0.156 0.876	0.192 1.670 0.099	0.197 1.717 0.090	0.270 2.395 0.019	-0.054 -0.464 0.644
Riparian vegetation structure	Sand, Stones					-0.069 -0.594 0.554	-0.210 -1.852 0.068	-0.143 -1.240 0.219	0.157 1.372 0.174	0.244 2.169 0.033	0.064 0.549 0.585	-0.283 -2.535 0.013	
	Grass, Herbs						-0.231 -2.042 0.045	-0.224 -1.975 0.052	0.111 0.964 0.338	0.029 0.253 0.801	0.131 1.136 0.260	-0.402 -3.774 0.000	
	Bushes						-	0.048 0.410 0.683	-0.079 -0.678 0.500	0.065 0.561 0.576	0.157 1.365 0.176	-0.344 -3.157 0.002	
	Trees								-0.155 -1.347 0.182	0.048 0.416 0.679	-0.041 -0.355 0.724	-0.203 -0.779 0.079	
	Big trees									0.302 2.729 0.008	0.195 1.707 0.092	-0.064 -0.556 0.580	
	Roots					+				++	0.372 3.448 0.001	-0.131 -1.132 0.261	
	Overh. roots				+						++	-0.169 -1.477 0.144	
	Quila					-	---	--					

b)

Variable	Bank angle				Riparian vegetation structure										
	<15°	15° -45°	>45°	90°	Sand, Stones	Grass, Herbs	Bushes	Trees	Big trees	Roots	Overh. roots	Quila	Dead trees		
Bank angle	<15°		-0.092 -0.793 .431	-1.196 -0.716 0.090	-1.196 -0.716 0.090	0.352 3.240 0.002	-0.213 -1.876 0.065	-0.038 -0.328 0.744	-0.093 -0.803 0.424	-0.069 -0.594 0.519	-0.075 -0.647 0.592	-0.063 -0.539 0.592	-0.039 -0.334 0.740		
	15° -45°			-0.323 -2.937 0.004	-0.323 -2.937 0.004	0.117 1.012 0.315	-0.078 -0.669 0.506	0.083 0.715 0.477	0.167 1.458 0.149	-0.114 -0.986 0.327	0.009 0.076 0.940	-0.103 -0.893 0.375	-0.064 -0.552 0.583		
	>45°		--		-0.689 -8.175 0.000	-0.011 -0.093 0.926	-0.099 -0.853 0.396	-0.003 -0.028 0.978	-0.030 -0.262 0.794	-0.050 -0.427 0.670	-0.173 -1.510 0.135	-0.107 -0.921 0.360	0.209 1.836 0.070	0.029 0.246 0.806	
	90°		--	---		-0.230 -2.030 0.046	0.249 2.210 0.030	-0.037 -0.314 0.754	-0.042 -0.364 0.717	0.159 1.387 0.169	0.201 1.764 0.082	0.206 1.810 0.074	-0.109 -0.946 0.347	0.033 0.284 0.777	
Riparian vegetation structure	Sand, Stones	++			-		-0.237 -2.097 0.039	-0.148 -1.289 0.201	-0.192 -1.687 0.279	-0.126 -1.091 0.181	-0.155 -0.839 0.404	-0.097 -0.839 0.404	-0.272 -2.429 0.018	0.144 1.254 0.214	
	Grass Herbs				+	-		-0.224 -1.229 0.051	-0.141 -0.997 0.223	-0.115 -0.348 0.322	0.040 0.294 0.770	0.034 0.294 0.770	-0.382 -3.561 0.001	0.005 0.046 0.964	
	Bushes								0.096 0.828 0.410	0.263 2.341 0.022	0.247 2.195 0.031	0.009 0.077 0.939	-0.267 -2.379 0.020	-0.086 -0.739 0.462	
	Trees									0.210 1.851 0.068	0.175 1.533 0.129	0.099 0.852 0.397	-0.062 -0.537 0.593	-0.128 -1.106 0.272	
	Big trees								+		0.222 1.958 0.054	0.326 2.965 0.004	-0.078 -0.669 0.505	-0.075 -0.647 0.519	
	Roots								+			0.263 2.346 0.022	-0.084 -0.729 0.468	-0.052 -0.451 0.653	
	Overh. roots										++	+		-0.070 -0.375 0.708	
	Quila						-	--	-						-0.044 -0.375 0.708
	Dead trees														

3.3.2.2 Den sites of F 03/36 and M 04/40

As no den sites have been located in the previous recorded vegetation sections, den sites were noted additionally. Thus 87 (76+11) sections were taken into the analysis to detect significant variables for den sites. The habitat composition of den versus non-den sites is displayed in Fig. 3.3.7. Only the den site variable Quila and Trees show an increasing trend towards occurrence of dens (D), while the other variables like Grass/Herbs and Bushes are clearly decreasing. The trend of the other den occurrence variables is negligibly small. Significant differences between non-den area and den area exist in three variables (Sand/Stones: Mann-Whitney Rank Sum Test: $T=331$, $df=87$, $p=0.028$; Grass/Herbs: t-test: $t=2.466$; $df=87$; $p=0.016$; Quila: Mann-Whitney Rank Sum Test: $T=737.00$; $df=87$, $p=0.001$). The vegetation structure Sand/Stones and Grass/Herbs occur more frequently in non-den areas as in den areas (Sand/Stone: 17.6%/6.4%; Grass/Herbs: 38.1%/20.5%). Quila is the most frequent vegetation variable with 44.1% of the den area (non-den area: 7.5%).

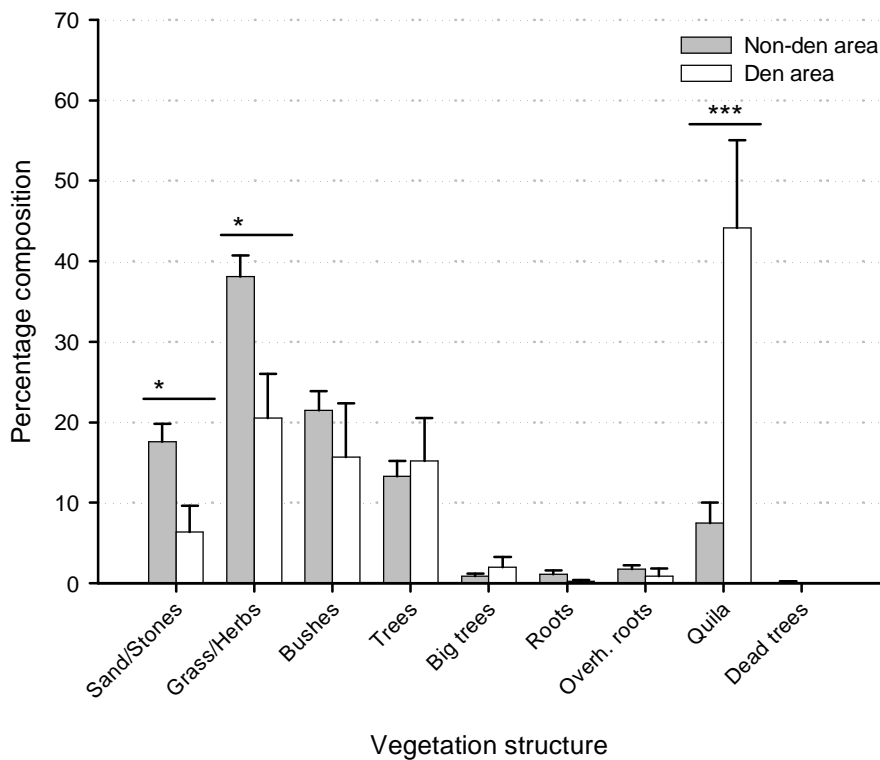


Fig. 3.3.7: Percentage composition of non-den and den area variables. Mean values and standard errors are shown. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (non-den area, $n=76$; den area, $n=11$)

Positive significant correlation between den vegetation variables exist for Sand, Stone/Roots ($r_s=0.313$, $t=3.021$, $p=0.003$) and Roots/Overhanging roots ($r_s=0.251$, $t=2.39$, $p=0.02$). The variable Quila shows a significant negative correlation for four out of eight variables (Quila/Sand, Stones: $r_s=-0.468$, $t=-4.89$, $p<0.001$; Quila/Grass, Herbs: $r_s=-0.380$, $t=-3.78$, $p<0.001$; Quila/Bushes: $r_s=-0.400$, $t=-3.40$, $p<0.001$; Quila/Overhanging roots: $r_s=-0.281$, $t=-2.70$, $p=0.008$). The dendrogram (Fig. 3.3.8) displays the subsumption of the 87 riparian vegetation sections. Only one cluster is of note in this figure, as it clearly demonstrates correlation with the variables Overhanging roots, Roots, Dead trees, Big trees and Trees. This cluster has a high Euclidean distance to the other variables. All other variables create a cluster of their own.

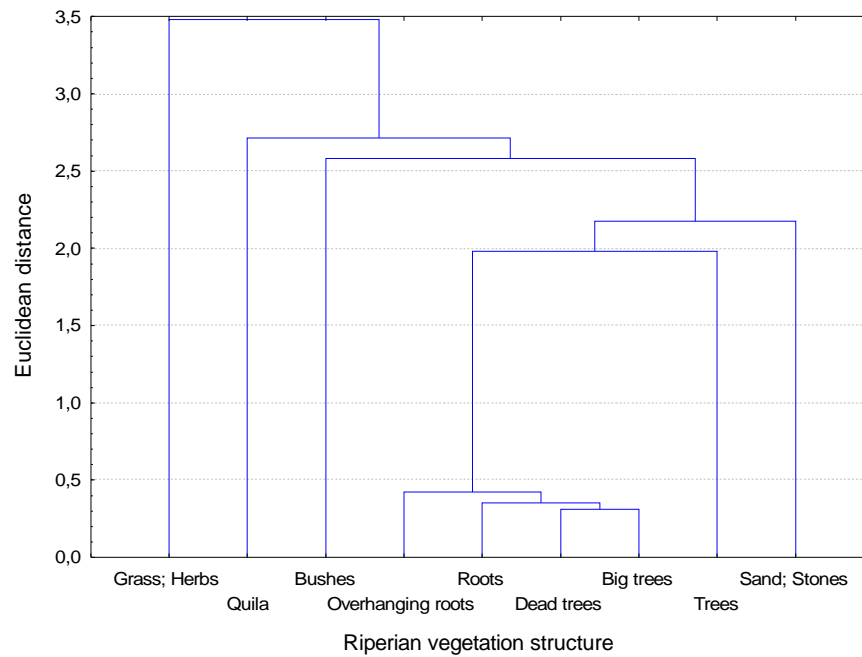


Fig. 3.3.8: The dendrogram displays the relationship of riparian vegetation variables out of 87 sections

Comparison of non-den area and den area revealed that Quila, ranked first, followed by Trees, Big Trees, Roots, Overhanging Roots, Bushes, Grass/Herbs, Sand/Stones (Tab. 3.3.6). Quila, Trees and Big trees were significantly selected over the other variables.

Tab. 3.3.6: Simplified ranking matrix with ranked variable sequence (most to least used); >>> = denotes a significant difference between two consecutively ranked variables

Variables	Sand; Stones	Grass; Herbs	Bushes	Trees	Big trees	Roots	Overh. Roots	Quila	Rank
Sand; Stones		-	-	---	---	---	---	---	0
Grass; Herbs	+		---	-	---	- (---)	---	---	1
Bushes	+	+++		-	-	-	-	--- (-)	2
Trees	+++	+	+		+	+	+	-	6
Big trees	+++	+++	+	-		+++	+	---	5
Roots	+++	+(+++)	+	-	---		+	---	4
Overh. Roots	+++	+++	+	-	-	-		-	3
Quila	+++	+++	+++ (+)	+	+++	+++	+		7

Quila > Trees > Big Trees >>>

Roots > Overh. Roots > Bushes >>>

Grass; Herbs > Sand; Stones

3.3.2.3 Hunting Area

Most of the river bed structure variables of the investigated hunting areas are influenced by river current, river width and river depth, only the variable woody debris does not show any significant correlation to the river properties (Tab. 3.3.7).

Tab. 3.3.7: Correlation of river properties and river bed structures. Significant values are shown in bold numeric

Variable		River bed structure				
		Sand	Gravel	Stones	Rocks	Woody debris
River properties	Current	-0.402	0.145	0.209	0.124	-0.004
		-3.703	1.238	0.928	1.052	-0.033
		0.000	0.220	0.356	0.296	0.974
	Width	0.268	-0.045	-0.282	-0.242	0.130
		2.374	-0.389	-2.516	-2.239	1.119
		0.020	0.699	0.014	0.037	0.267
	Depth	0.295	-0.419	-0.232	-0.184	0.064
		2.642	-3.943	-2.042	-1.595	0.552
		0.010	0.000	0.045	0.115	0.583

Out of 76 investigated sections, 18 were recorded as hunting areas as a result of radio tracking sessions. The river bed composition divided into non-hunting and hunting area is displayed in Fig. 3.3.9. The most recorded variable in the non-hunting sections is sand with 46 %. All other variables have been smaller than 25 %. The hunting area is also dominated by the variable Sand (42 %). However, Woody debris also plays an important role (40.3 %). While the variables for Sand, Gravel, Stones and Rocks declines towards the hunting area (H), only the variable Woody debris increases. A significant difference between non-hunting and hunting area was found for Stones and Woody debris (Mann-Whitney Rank Sum Test: Stones $T = 496.00$, $p=0.016$; Woody debris: $T=1056.00$, $p<0.001$). No statistically significant differences were found for the variables river current, river width and depth between non-hunting and hunting areas, (Mann-Whitney Rank Sum Test: Current: $T=814.50$, $df=75$ $p=0.676$; Width: $T=901.50$, $df=76$, $p=0.593$; Depth: $T=838.00$, $df=76$, $p=0.942$).

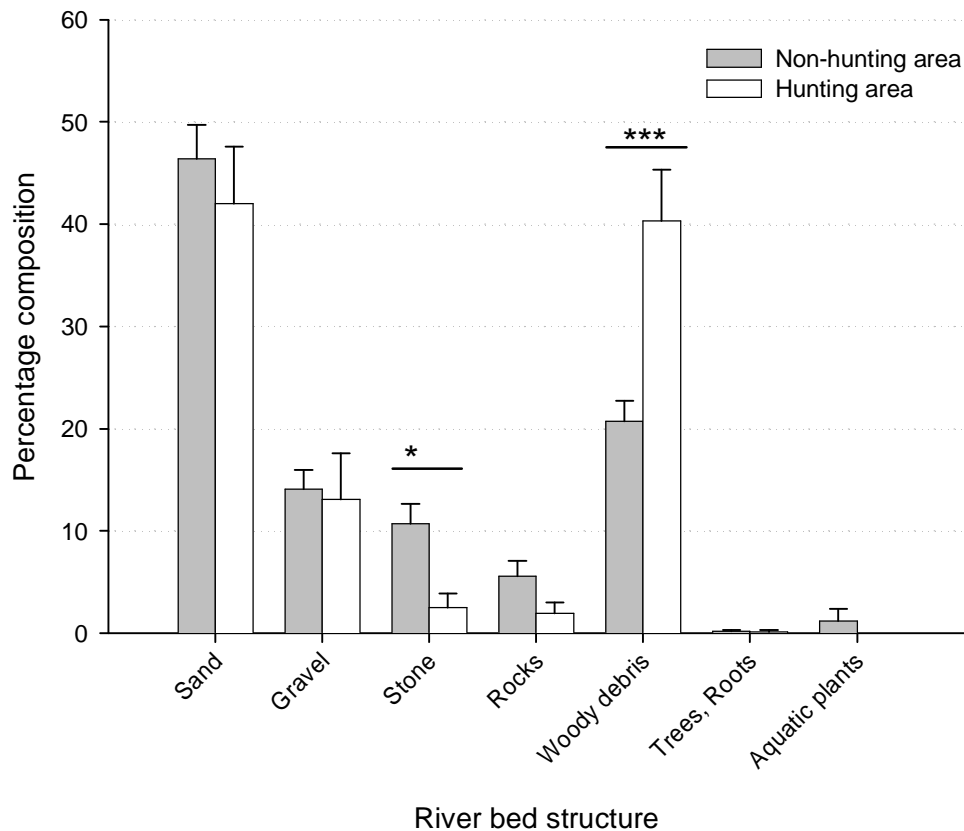


Fig. 3.3.9: Percentage composition of the river bed structure variables. Mean values and standard errors are shown. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (non-hunting area, $n=58$; hunting area, $n=18$)

Significant negative correlations exist between sand and all other variables (Spearman-Correlation: Sand/Gravel: $r_s = -0.38$, $t = -3.51$, $p = 0.001$; Sand/Stones: $r_s = -0.44$, $t = -4.17$, $p < 0.001$; Sand/Rocks: $r_s = -0.40$, $t = -3.77$, $p < 0.001$; Sand/Woody debris: $r_s = -0.35$, $t = -3.18$, $p = 0.002$). In contrast a highly positive correlation exist between the variables Stone/Rocks ($r_s = 0.68$, $t = 7.82$, $p < 0.001$). The two variables (Gravel/Woody debris) are also positive correlated ($r_s = 0.23$, $t = 2.01$, $p = 0.048$). With the help of the cluster analysis the variables can be arranged in three groups (Fig. 3.3.10). Cluster 1 displays the “heavier river bed material” stones and rocks which can be found together, likewise the “medium river bed material” woody debris and gravel which forms the cluster 2. Only the cluster 3 “light river bed material” (Sand) stands alone and is not related to other variables.

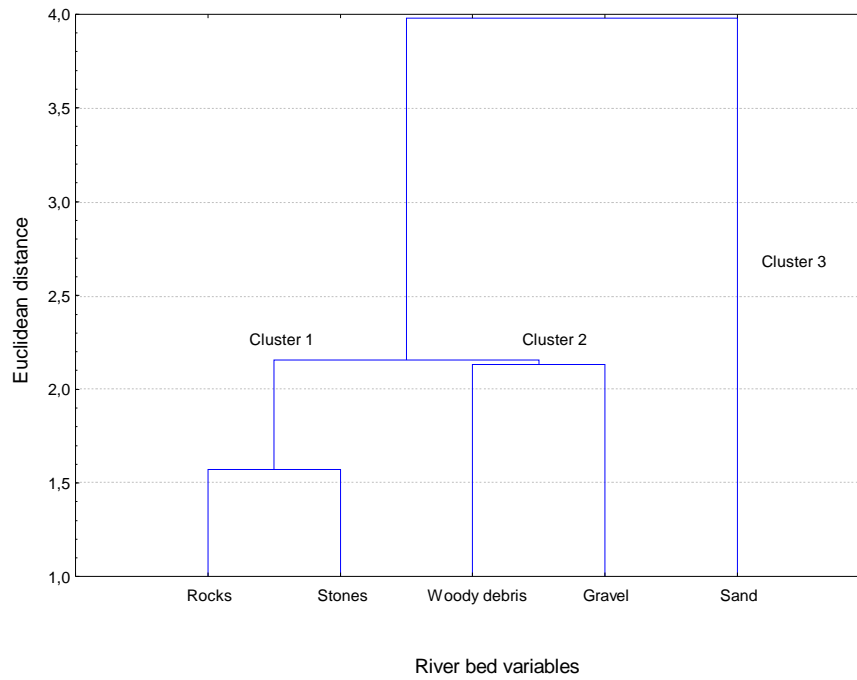


Fig. 3.3.10: The dendrogram displays the relationship of river bed variables out of 76 river bed structure sections in three clusters. Cluster 1: heavy; Cluster 2: medium; Cluster 3: light river bed material

The composition analysis revealed that woody debris ranked first, followed by sand, gravel, rocks and stones in hunting areas (Tab. 3.3.8). Woody debris was significantly selected over the other variables.

Tab. 3.3.8: Simplified ranking matrix with ranked variable sequence (most to least used); >>> = denotes a significant difference between two consecutively ranked variables

Variables	Sand	Gravel	Stones	Rocks	Woody debris	Rank
Sand		+	+++	+++	--- (-)	3
Gravel	-		+++	+++	---	2
Stones	---	---		---	---	0
Rocks	---	---	+++		---	1
Woody debris	+++ (+)	+++	+++	+++		4

Woody debris >>>

Sand > Gravel >>>

Rocks >>>

Stones

3.3.2.4 Distance to human constructions

Figure 3.3.11 displays the home range, divided into 50 m sections, of southern river otter F03/36 and its relationship to human constructions. 54.4 % of its home range is located closer than 150 m to human constructions. Only 19.2 % is more than 450 m away from human constructions. The section at a distance of 100 - 150 m was most frequently used (35.1 %), and the animal was found more frequently during day time (20.3 %) than at night (14.9 %) in this section. The animal was present in the first section (0 - 50 m) for 27.6 % of total time observed (14.2 % at day and 13.4 % at night). The five sections from 200 - 450 m were used for 26.4 % of the time and the farthest section was visited during day time for 8.5 % of the time and 1.6 % at night.

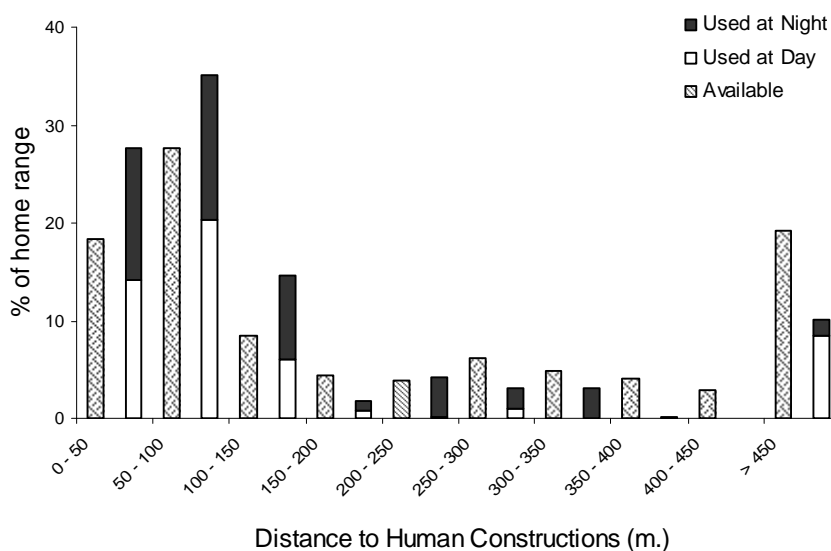


Fig. 3.3.11: Home range versus used sections by F03/36

The home range of F04/54 was mainly located far from human constructions (Fig. 3.3.12). The farthest section was used 53.1 %, with 31.2 % during the day and 36.9 % at night. The section 0 - 350 m was only visited for 23.7 % of all time monitored. This area was mainly used at night (15.4 %) in contrast to 5.2 % during the day. The southern river otter F04/54 was never found in the first section which was the closest to human constructions (0 - 50 m).

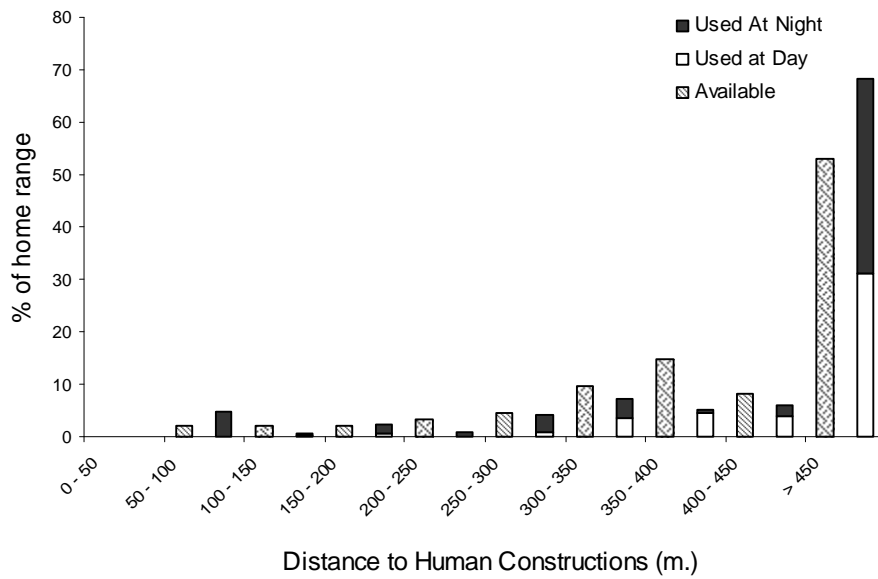


Fig. 3.3.12: Home range versus used sections by F04/54

48.0 % of the home range of M04/40 is located close to human constructions (0 - 200 m), where the animal was observed for 54.6 % of its time, with 20.8 % during the day and 33.8 % at night (Fig. 3.3.13). 14.6 % of the time the animal was monitored in the section 300 - 350 m (daytime 2.5 %; night time 12.1 %). The southern river otter M04/40 was monitored for 28.1 % of its time (15.9 % during the day; 12.2 % at night) in the farthest section (> 450 m) which constitutes 27.2 % of its home range.

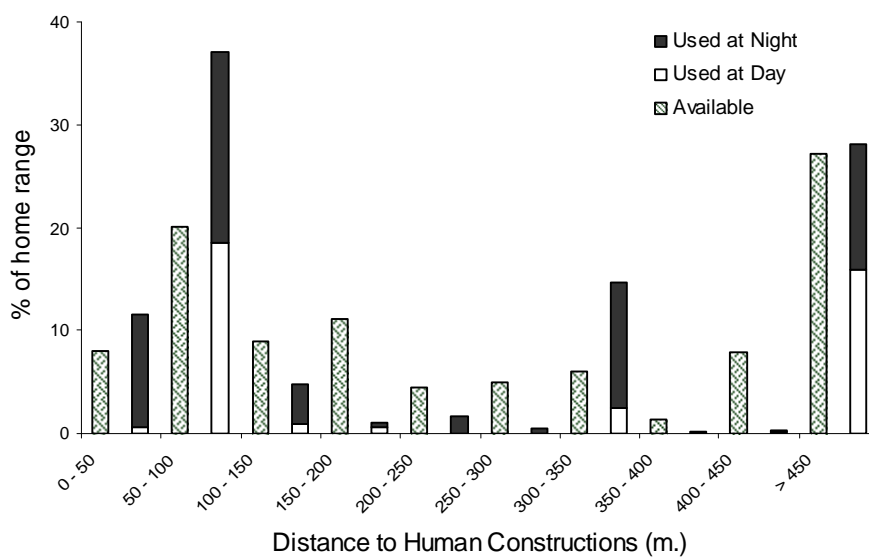


Fig. 3.3.13: Home range versus used sections by M04/40

3.3.2.5 Marking site

Fig. 3.3.14 displays the averages for marking sites. The mean average for bank angle was 46.3° (SE = 4.5). Spraints were deposited at an average height of 78.6 cm from water level (SE=14.1) and at a horizontal distance from the water line of 68.7 cm (SE = 10.1). The vegetation Soil/Stone with a proportion of 60.7 % (SE = 6.6), followed by Grass/Herbs with 28.9 % (SE = 6.4) were most present at average marking sites. The vegetation variables Bushes, Trees, Big trees, Roots, Overhanging roots and Dead trees were each present for less than 5 %.

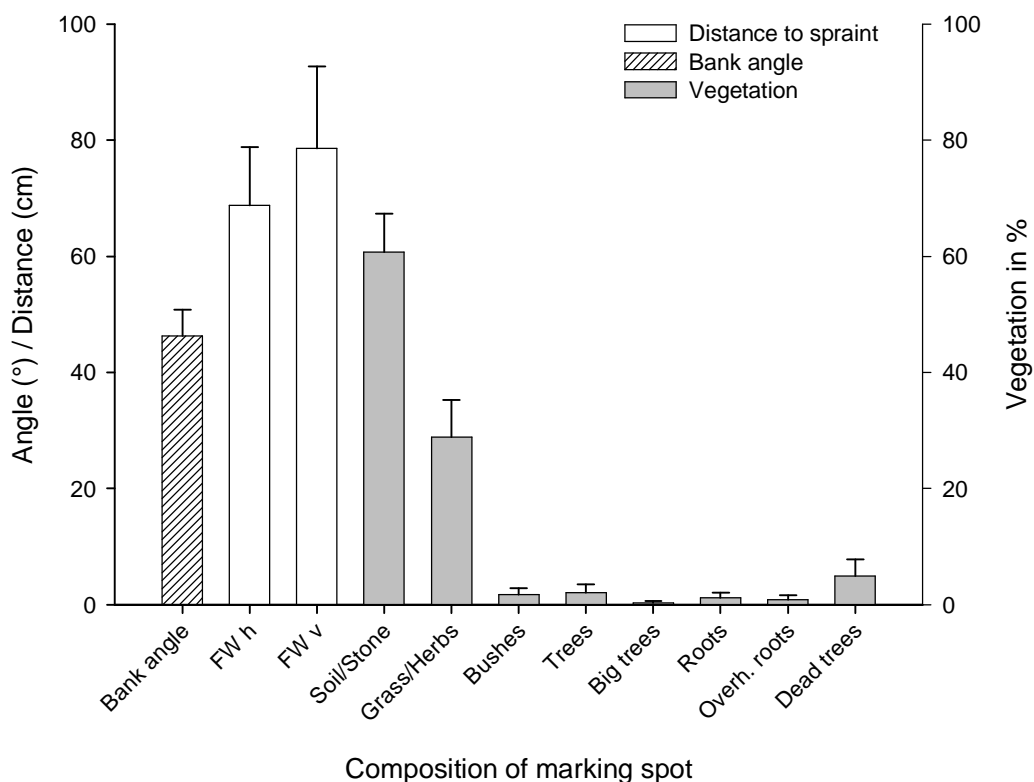


Fig. 3.3.14: Average composition of 36 marking spots. FW h = Horizontal distance of faeces to water; FW v = Vertical distance of faeces to water

A positive significant correlation exists between the variable 'horizontal distance of faeces to water/vertical distance of faeces to water' (FWh/FWv: $r_s=0.45$, $t=2.93$, $p=0.006$). The variables Soil, Stone/Grass, Herbs are negatively correlated ($r_s=-0.86$, $t=-9.71$, $p<0.001$). With the help of the cluster analysis the 36 mapped sections were summarised in groups, which are characterised by special combinations of structure variables (Fig. 3.3.15). In general two clusters, displayed as cluster 1 and cluster 2, with a high Euclidean distance can be noted.

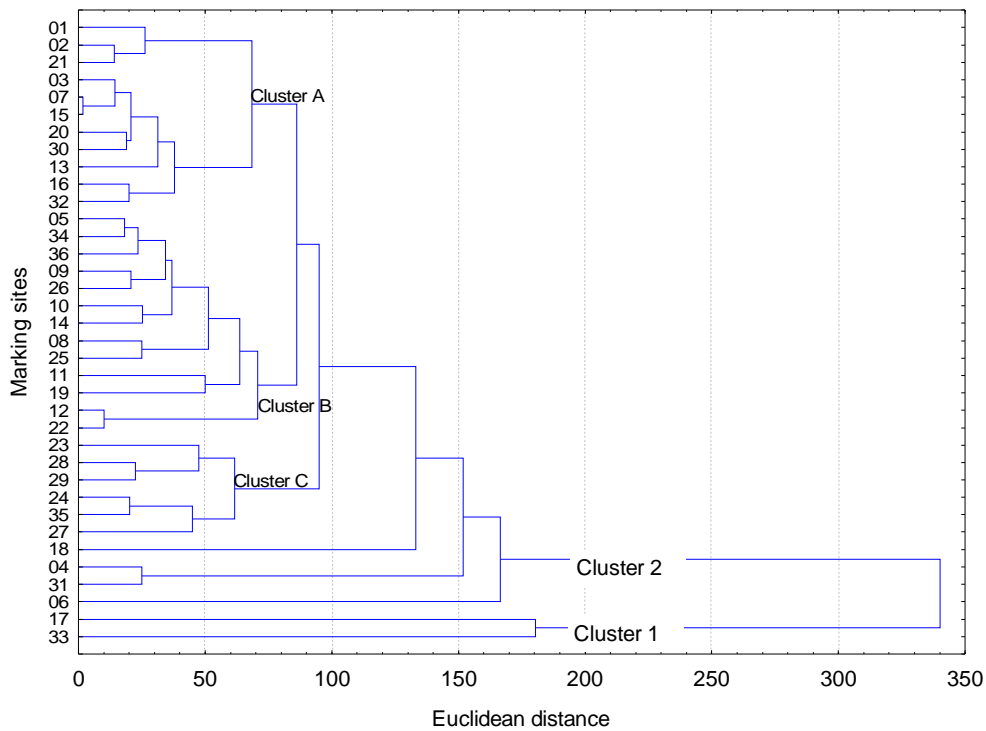


Fig. 3.3.15: The dendrogram displays the aggregation of 36 marking site sections

Cluster 1 is characterized by only two marking size with a general high distance to water; horizontal and vertical (Tab 3.3.9). The differences within cluster 2 are not as high as the previous cluster but are also mainly grouped by the variable “Distance – Faeces to water (horizontal and vertical)”. Cluster 2 shows several clusters, but more details are described only for the clusters with more than five marking sites. In contrast to cluster 1, cluster 2 A, B, C shows marking sites, which are closer to the water line. Only 34 % of the cluster 2 is located within 100 cm to the river, horizontal and vertical. Whereas the remaining marking sites of cluster 2 shows maximum distances up to 150 cm (vertical or horizontal).

Tab. 3.3.9: Cluster characteristics of marking sites

	# of sites	FW v (cm)	FW h (cm)	bank angle (°)
Cluster 1	2	> 200	> 200	30 – 45
Cluster 2 A	11	10 – 40	15 – 60	30 – 45
Cluster 2 B	13	50 – 150	30 – 90	15 – 90
Cluster 2 C	6	0 – 60	80 – 140	45 – 90

3.3.3 Activity patterns

3.3.3.1 General and individual behaviour patterns of southern river otters

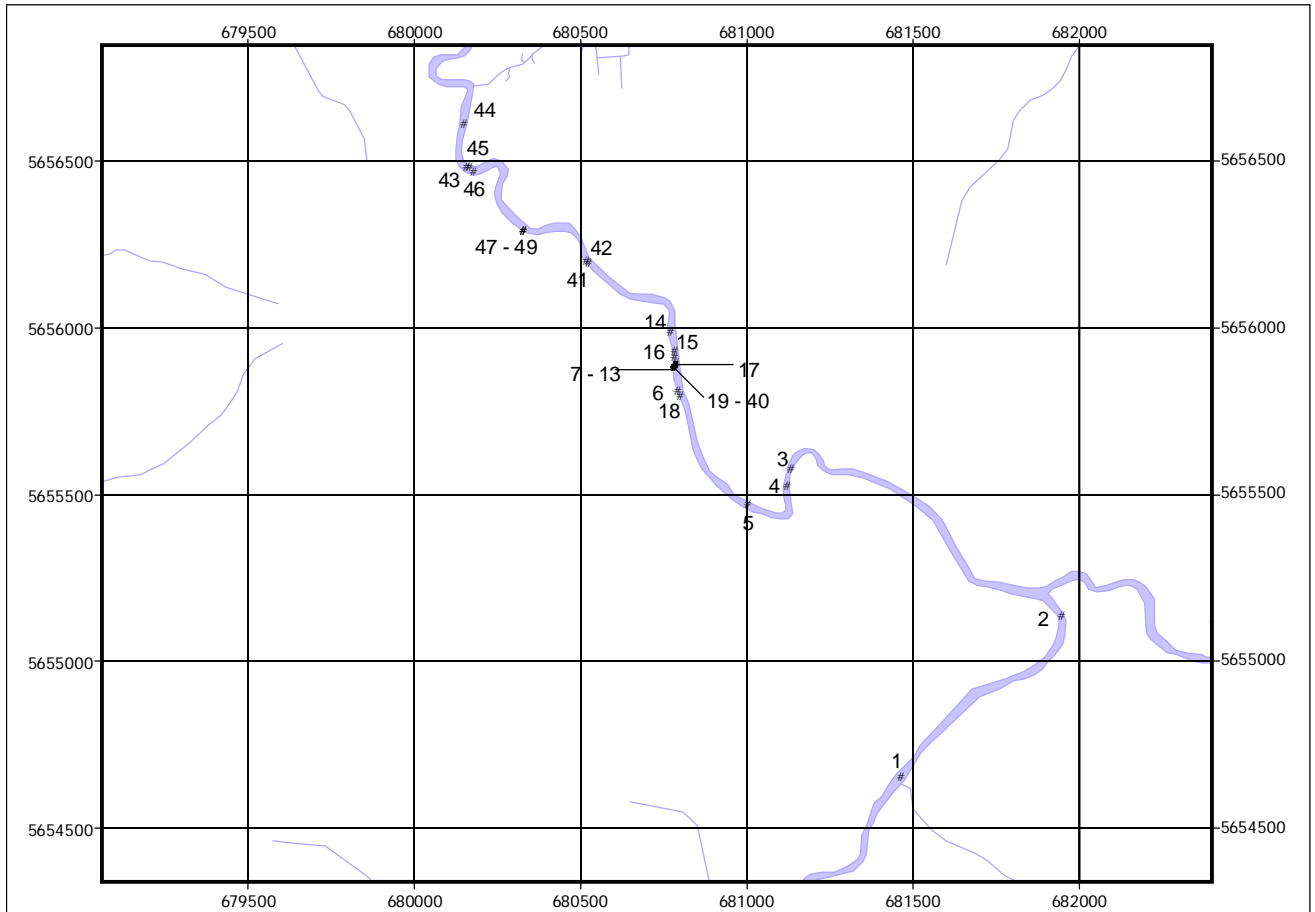
By radio tracking the southern river otter, 5379 data fixes were recorded in the Upper Queule River, of which 1190 fixes are movement behaviour samples (Tab. 3.3.10). The movement behaviour was strictly limited to the waterways (river or streams). Fig. 3.3.16 illustrates an example of the movement pattern of the animal F 03/36 on 27th November 2003 during a 24-hour radio tracking survey accomplished by two teams.

Radio tracked southern river otters display an average daily movement behaviour of 26 %. In contrast, the time of inactivity was much higher, reaching an average of 55 %. Both movement behaviour and inactivity behaviour are almost identical during the day and at night. Stationary activity behaviour demonstrated the same finding with only small differences between daylight (21.1 %) and night (17.2 %) behaviour.

Tab. 3.3.10: Southern river otter movement, stationary activity and inactivity by three individuals, and duration of activity from activity sensitive radio transmitters for 24 hours (2003 – 2004)

Variable	Whole day		Daylight		Night	
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
Movement fixes (%)	25.6	12.3	23.7	10.5	27.3	14.5
Movement (h)	6.6	2.4	2.9	0.9	3.7	1.6
Stationary activity fixes (%)	19.1	3.2	21.1	5.3	17.2	1.0
Stationary activity (h)	4.9	0.5	2.6	0.4	2.3	0.1
Inactivity fixes (%)	55.3	12.2	55.2	15.4	55.5	10.4
Inactivity (h)	14.3	5.2	6.7	3.1	7.6	2.3
Length of movement bouts (h)	1.9	0.3	1.9	0.3	2.0	0.4
Length of inactivity bouts (h)	2.5	0.4	2.2	0.6	2.7	0.5
Number of movement fixes	1190		519		671	

Consistent with the findings of movement fixes compared with inactivity fixes, the length of movement bouts were smaller (24 %) than the length of inactivity bouts. Likewise the lengths of behaviour bouts do not show wide differences between day and night. There are no statistical differences between the two groups daylight and night (Mann-Whitney Rank Sum Test: T=25, n=5/5, p=0.690).



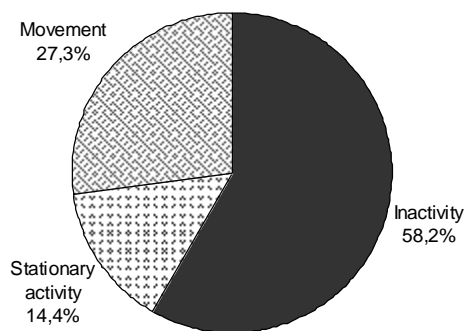
Time of fixes:

1: 00:00	12: 05:30	23: 11:00	34: 16:30	45: 22:00
2: 00:30	13: 06:00	24: 11:30	35: 17:00	46: 22:30
3: 01:00	14: 06:30	25: 12:00	36: 17:30	47: 23:00
4: 01:30	15: 07:00	26: 12:30	37: 18:00	48: 23:30
5: 02:00	16: 07:30	27: 13:00	38: 18:30	49: 00:00
6: 02:30	17: 08:00	28: 13:30	39: 19:00	
7: 03:00	18: 08:30	29: 14:00	40: 19:30	
8: 03:30	19: 09:00	30: 14:30	41: 20:00	
9: 04:00	20: 09:30	31: 15:00	42: 20:30	
10: 04:30	21: 10:00	32: 15:30	43: 21:00	
11: 05:00	22: 10:30	33: 16:00	44: 21:30	

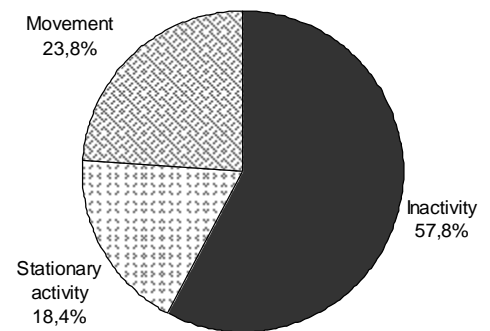
Fig. 3.3.16: Movement behaviour and distances travelled by southern river otter F 03/36 during a 24-hour radio tracking on 27th November 2003. Movement fixes are highlighted bold numerals in the table

All three radio tracked animals show in general a similar percentage of observed behaviours (Fig. 3.3.17) and no significant differences were found (One - Way ANOVA: $F=1.67$; $df=2$; $p=0.265$). The percentage of movement behaviour in particular is very similar, where the span is not very large and embraces the range from 22.3 % up to 27.3 %. However the inactivity behaviour for the male southern river otter is an average of 16.4 % smaller than for the female southern river otters. The female animals display a similar amount for stationary activity behaviour (14.4 % and 18.4 %). However, in contrast to the female animals, the male otter show almost the double amount of stationary activity behaviour (36.1 %).

F 03/36



F 04/54



M 04/40

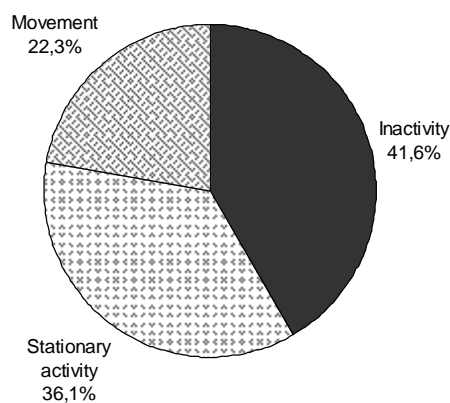


Fig. 3.3.17: Percentage of displayed behaviours (movement, stationary activity and inactivity) by three southern river otters

Movement behaviour was recorded throughout the 24 hour period during the radio tracking study. However, the average distribution of movement behaviour was uneven. Between 00:00 – 03:00 (30.3 %), 06:00 – 12:00 (32.0 %; 28.8 %) and 18:00 – 21:00 (32.5 %) the southern river otters showed more activity than during the early morning 03:00 – 06:00 (19.8 %), afternoon 15:00 – 18:00 (17.4 %) and 21:00 – 24:00 (23.0 %) time periods (Fig. 3.3.18). Remarkably, the southern river otters' movement behaviour from 03:00 - 09:00 hours corresponds to 15:00 - 21:00 hours.

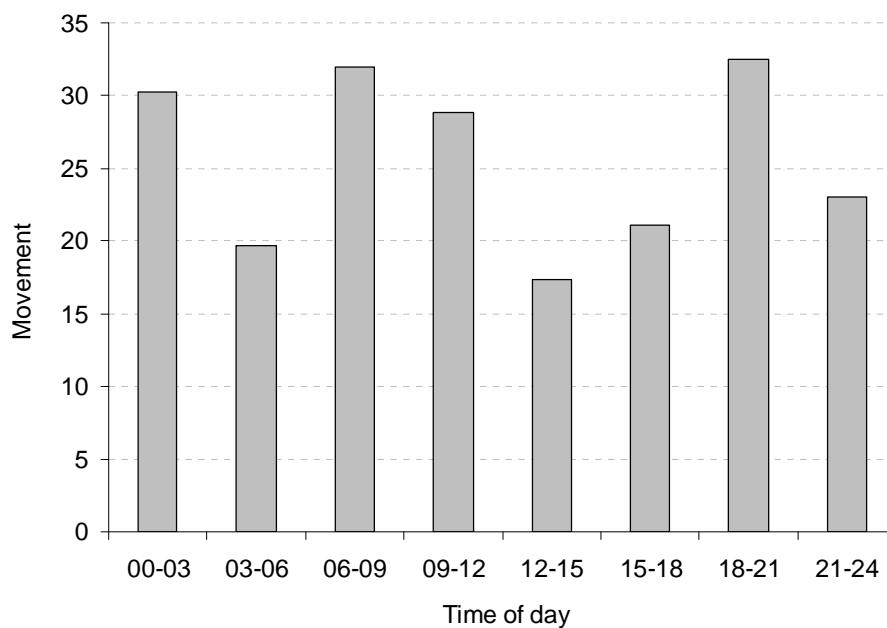


Fig. 3.3.18: Distribution of the average daily movement behaviour of three southern river otters throughout 24 h radio tracking (divided into 3-hour intervals)

The time an individual is sheltering in den or stayed out of the den in a 24-hour cycle is displayed in Figure 3.3.19. The female southern river otter spent 67 % of its time in a den; this finding is almost similar to the female animal F 04/54 which stayed in den for 62 % of its radio tracked time. The male southern river otter M 04/40 sheltered for the highest proportion of time in den (73 %). On average, the observed animals shelter in their dens for most of the time ($\bar{x} = 67.3\%$) and have been recorded outside of den for only 32.7 %.

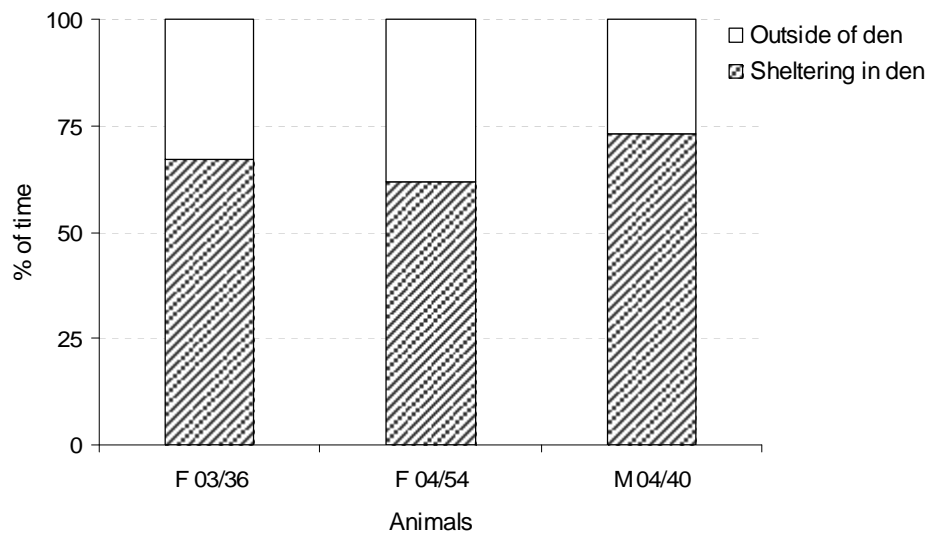


Fig. 3.3.19: Percentage of time radio tracked southern river otter spent sheltering in den or outside of den

Regardless of time of day or night all types of behaviour were displayed (Fig. 3.3.20). Only small and no significant variation in the proportion of daylight and night behaviour occurred in the individual animal ($t=-0.591$, $df=16$, $p=0.563$).

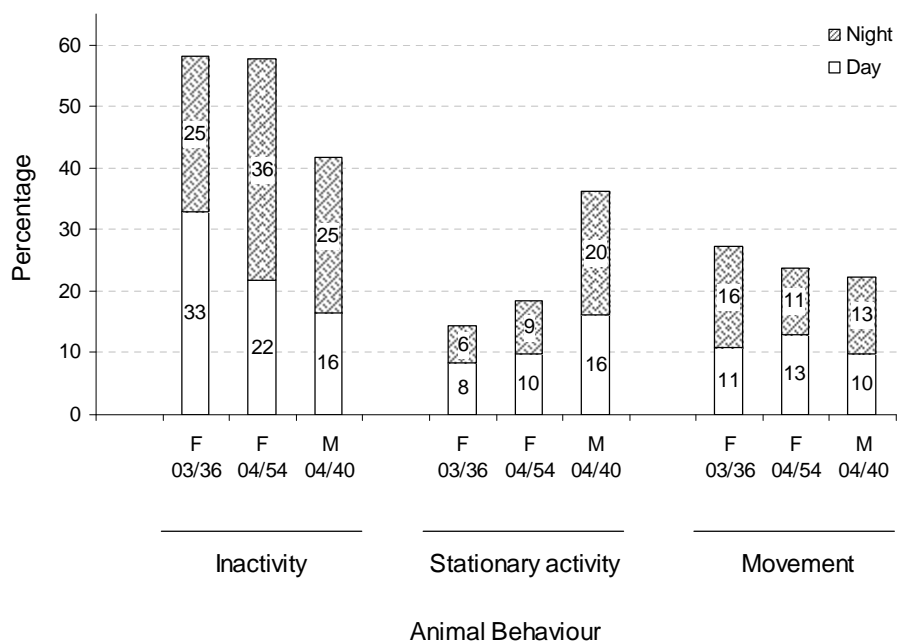


Fig. 3.3.20: Frequency distribution of inactivity, stationary activity and movement behaviour of all fixes on radio tracked animals during day and night

On an individual scale the animals show different movement patterns. The female southern river otter F 03/36 displays a lack of movement behaviour in the afternoon with most movement behaviour at night and antemeridian, whereas the animal F 04/54 displays a mostly bell shaped curve which reaches its maximum of movement behaviour at noon, decreasing towards the night. Movement behaviour of the male M 04/40 took place in the afternoon until night and was less frequent at antemeridian (Fig. 3.3.21).

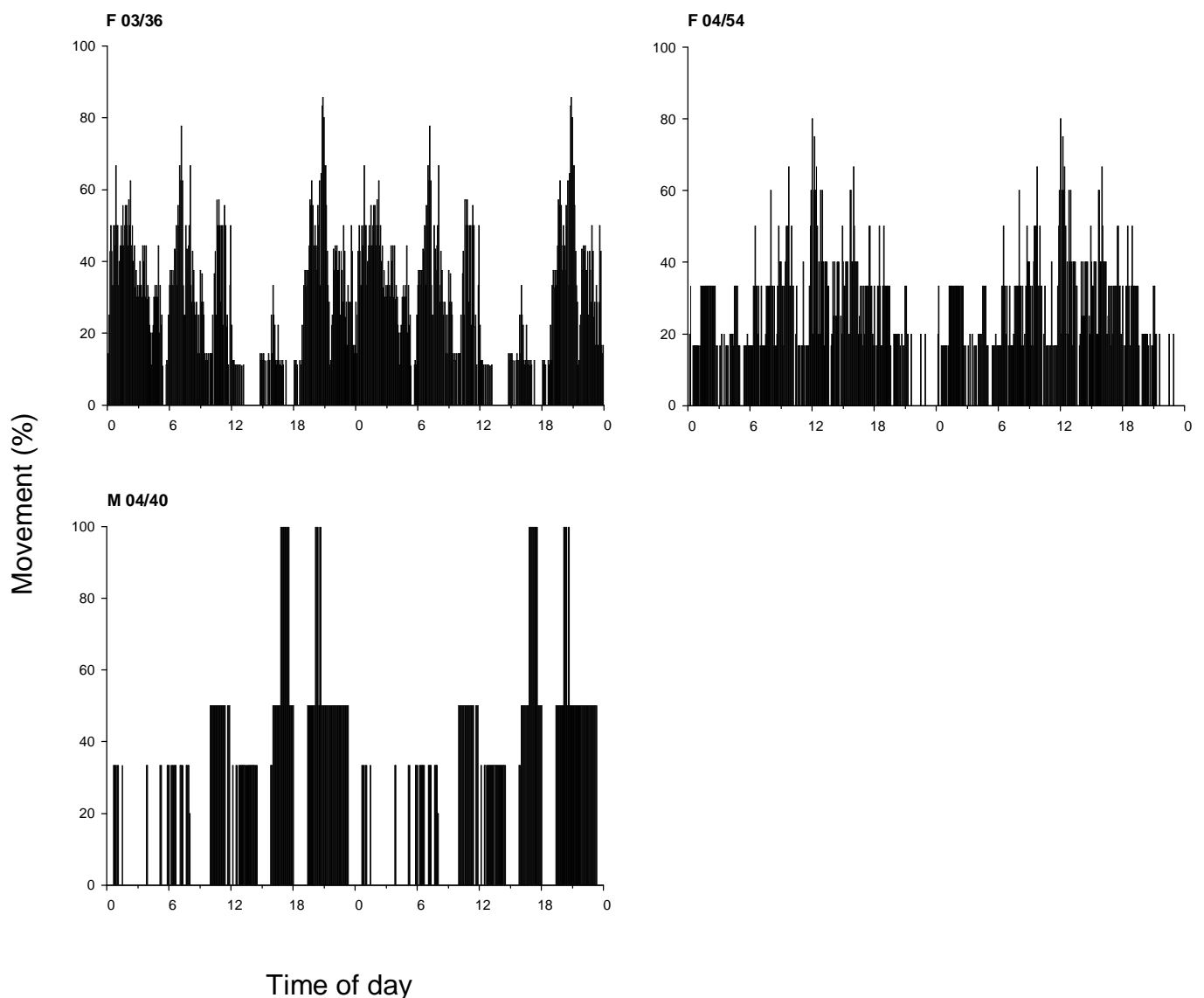


Fig. 3.3.21: Ordinate dates represent average values in % of the total amount of movement counts per day. On the abscissa the 24-hour movement results are displayed for two days for a better overview on nocturnal movements

Fig. 3.3.22 displays an example of behaviour data obtained by one of the 24-hour radio tracking sessions on three southern river otters. The activity pattern bands show in general that all animals in this example had different time ranges and bouts for their activities.

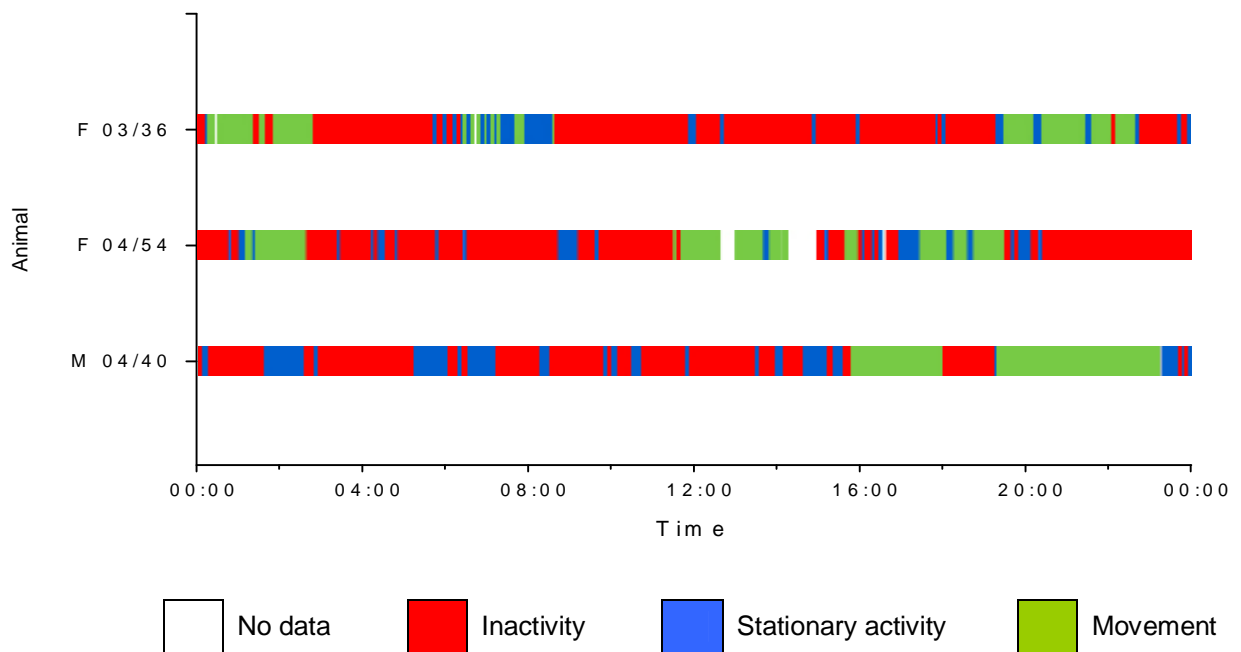


Fig. 3.3.22: Example for activity patterns of radio-implanted southern river otters, based on 24-h radio-tracking session with locations taken at five minutes intervals

The animal F 03/36 exhibits three main subdivisions of movement behaviour, with a short section of inactivity taking place in the early morning and an extended phase of inactivity occurring within the daytime. The southern river otter F 04/54 displays a similar division of movement behaviour. However, its inactivity phase is located antemeridian and at night. In this example the male animal M 04/40 has an extensive inactivity phase during the morning and afternoon changing to movement behaviour in afternoon until night. The southern river otter F 03/36 demonstrates a higher frequency of stationary activity in the movement phase as between the inactivity phase. The stationary activity behaviour of F 04/54 is more equally dispersed within the movement and inactivity phases, whereas the male southern river otter M 04/40 shows more stationary inactivity behaviour within the inactivity phase.

3.3.3.2 Movements and distance travelled

The travelled distance between inactive periods for all southern river otters is shown in Figure 3.3.23 and averages 913.7 meters, with the mean of 664.1 m, being lowest for F 03/36 ($\tilde{x} = 248.4; 134.8/1089.1$), followed by F 04/54 with 1383.6 m ($\tilde{x} = 1287.1; 612.3/2077.1$), having travelled more than twice the average distance than F 03/36.

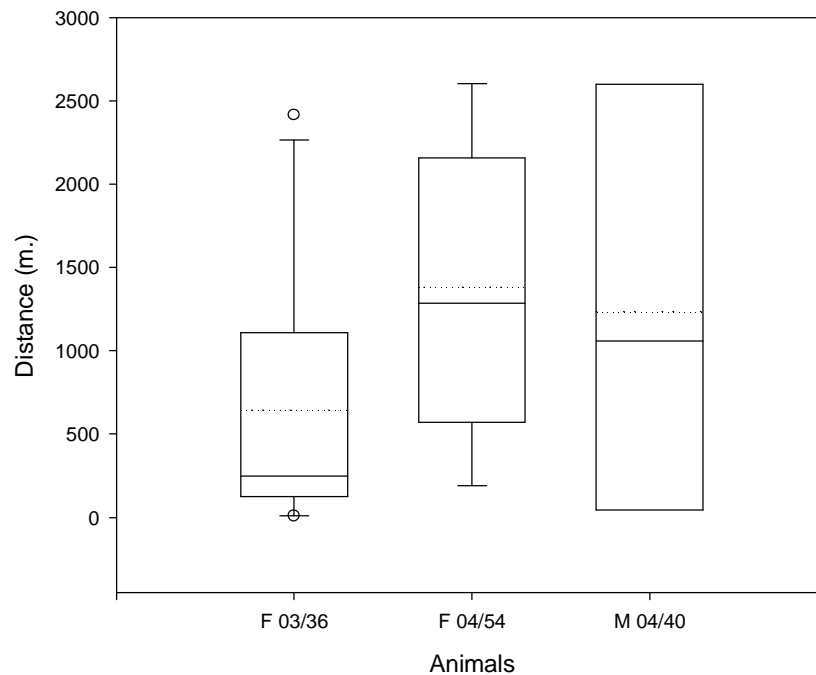


Fig. 3.3.23: Distance travelled by individual animals between inactive phases

The male southern river otter M 04/40 travelled almost the same distances as F 04/40 (1235.1 m), with the median being $\tilde{x} = 1060.2$ (134.8/1089.1). The Kruskal-Wallis One Way Analysis of Variance on Ranks resulted in no significant differences between the individuals ($H=5; df=2; p=0.082$).

The longest uninterrupted time of movement behaviour was observed in the female F 04/54 (5.7 hours). The mean time for movement behaviour is lowest for F 03/36 with 1.8 hours ($\tilde{x} = 1.78; 0.88/2.46$). The time for movement behaviour for F 04/54 averages 3.2 hours ($\tilde{x} = 2.75; 1.92/4.58$), which is similar to the time of movement behaviour noted for M 04/40 ($\bar{x} = 2.9$ hours; $\tilde{x} = 2.42; 1.60/4.42$) (Fig. 3.3.24).

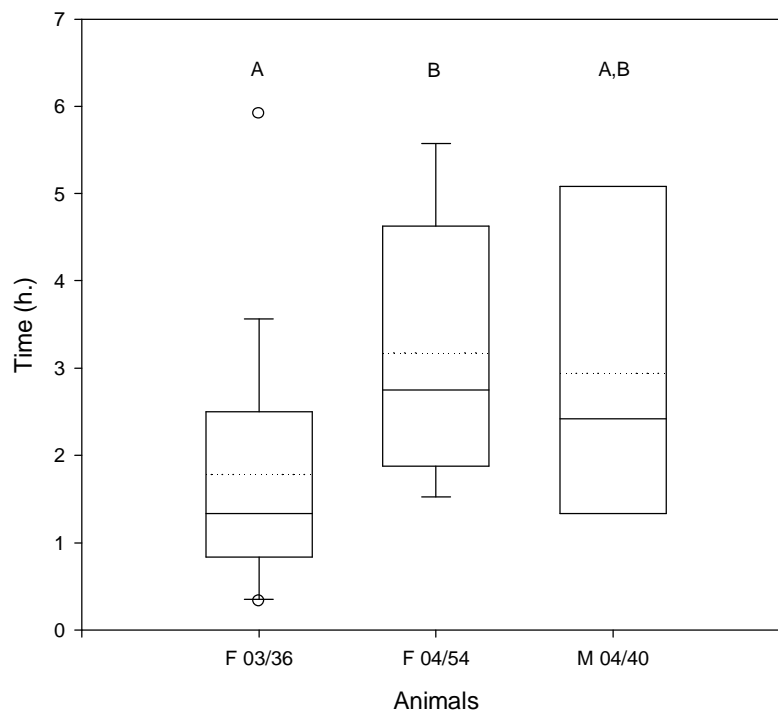


Fig. 3.3.24: Time range of movement per 24h; same letter per animals = no significant difference; different letter per animal = significant difference

ANOVA was performed and a significant difference between the times of movement behaviour was found ($H=7.24$; $df=2$; $p=0.027$). The subsequent pairwise multiple comparison procedures (Dunn's Method) show a statistical difference between F 03/36 and M 04/40 (Difference of Ranks = 9.8; $Q=2.6$; $p<0.05$). The average movement velocity and maximum velocity a southern river otter swam during the study period was highest for female F 04/54 with 1.59 km/h and 12.70 km/h respectively (Tab. 3.3.11).

Tab. 3.3.11: Calculated velocity of radio tracked southern river otter

ID	Velocity (km/h)		Maximum velocity (km/h)
	\bar{x}	SE	
F 03/36	1.08	0.05	11.25
F 04/54	1.59	0.10	12.70
M 04/40	1.24	0.10	6.28
Average (\bar{x})	1.49	0.05	10.08

3.4 Discussion

A significant part of the present research looked at the animals' habitat use and preference of an area, as well as the amount of time the southern river otter spent on different activities. It would not be possible to make a meaningful statement as to whether the southern river otter has special habitat requirements or shows a typical circadian cycle without the information about home range, activity patterns and habitat preferences.

3.4.1 Methodology

Telemetry

Animals such as *Lontra provocax* are extremely difficult to study by direct observation alone because of their shyness, and due to their agile movements. Tracking animals which have a transmitter is therefore a useful technique to find out about the activity patterns, behaviour, habitat use and movements of these animals or about animals in general. Furthermore conclusions regarding habitat preference can be drawn (WHITE & GARROT, 1990).

The first use of wildlife transmitters was on heart rates on chipmunks in 1959 by LE MUNYAN (1959). Later studies on radio tracking have been conducted primarily on terrestrial animals due to the problem of attaching the transmitter to an aquatic or semi-aquatic animal. On otters, especially *Lutra lutra*, several methods to attach external radio transmitters have been attempted, including collars and harness (GREEN *et al.*, 1984), but these are problematic, not only because of the high danger they pose the otter in getting it caught under water and causing it to drown (MASON & MCDONALD, 1986), but also because of the difficulty in fitting the collar as the neck of an otter is thicker than its head. Furthermore, the lifespan of collar or harness is shortened by its frequent rubbing behaviour to keep its fur dry and clean (HERNANDEZ-DIVERS *et al.*, 2001). However, MELQUIST & HORNOCKER (1979) developed implantable radio transmitters for otters, which were used first on *Lontra canadensis* by implanting into the intraperitoneal cavity. The surgery for implanting radio transmitters appears to be safe, as further operations on *Lontra canadensis* (ERICKSON & MCCULLOUGH, 1987; HERNANDEZ-DIVERS *et al.*, 2001; HOOVER, 1984; POLECHLA, 1988), *Enhydra lutris* (WILLIAMS & SINIFF, 1983) and on *Lutra lutra* (ARNEMO, 1990; RUIZ-

OLMO *et al.*, 1992) did not show significant problems. This is consistent with observations on *L. provocax* in this study, as the female otter F 03/36 gave birth to two cubs, even though she received the intraperitoneal radio transmitter approximately 20 weeks before.

Two different methods can be used in radio tracking: 1) sequential and 2) continuously tracking of radio equipped animals, which have advantages and disadvantages. By using sequential tracking it is possible to locate several different animals within a short time. Therefore it is possible to compare the animals' activity directly, as abiotic factors like temperature and precipitation, which may change activity patterns, are equal. On the other hand, it is not possible to accurately ascertain the actual time an animal spent travelling, resting or feeding, or the travel distance or habitat preference.

In this study the accessibility to the areas and time spent on first location for radio tracked southern river otters were different (Tab. 3.3.1; p. 55). Therefore the results could show the investigators accessibility to an area rather than the animal's true home range, this bias is often ignored (MELQUIST & HORNOCKER, 1983). However, this kind of bias does not exist when focused on only one animal by using the continuous tracking method. It is assumed that a more realistic description of spacing and activity patterns is possible using this method, as more data points will be obtained and the investigator also can follow the animal in areas which are difficult to access. However this method is time consuming and the problem of data independence arises. Both methods were used in this study. Continuous tracking was used primarily to obtain data for activity patterns and sequential tracking was used to obtain additional data for the home range estimation for *L. provocax*.

Two teams located the animal and noted the activity status in order to obtain data regarding home range and activity patterns. Personal abilities may have, to a certain degree, influenced the accuracy of telemetry and the identification of the activity status. Furthermore technical problems occurred twice and may have biased the radio tracking results in some respects. On one occasion solar winds produced strong static noises causing a very weak radio tracking signal and it is assumed that this resulted in some bearing errors; therefore this data was not used. Furthermore the lifetime of the transmitter was shorter than declared and the

transmitting signal stopped after 9 months instead of 12 months. Thus data collection was not maintained over all seasons.

Bearing error

Bearing errors are caused by manifold aspects like terrain, observer, and physical factors. In weald and plain landscape, errors on bearings for radio-tracked animals are usually low, but dense vegetation and difficult terrain, like slopes, hills or mountains, can produce systematic bearing errors by bouncing, bending and refracting the radio waves, resulting in misinterpretation of the location of the radio-tracked animal (SCHOBER, 1986; WHITE & GARROT, 1990). To reduce this kind of error, bearings from multiple elevated locations were taken (GARROTT *et al.*, 1986). Roads and fields in the study area were mostly higher than the river where the radio tracked animal occurred, but there were still difficulties in receiving signals due to the complexity of the terrain. Furthermore, there were errors caused by animal movement which resulted from the velocity and distance to the animal (WHITE & GARROT, 1990).

Home Range estimation

The size and utilization of an animal's home range can be determined by analyses of telemetry data (AEBISCHER *et al.*, 1993b; HARRIS *et al.*, 1990; KENWARD *et al.*, 2001; WHITE & GARROT, 1990). Numerous home-range models can be found in the literature, which describe methods for defining the area used by an animal. In general the available home range estimation programs can be classified into two groups: (1) models that connect the area between locations and (2) nonparametric models, which analyse the location density.

The minimum-convex-polygon (MOHR, 1947), and the minimum-concave-polygon (HARVEY & BARBOUR, 1965) can both be placed in the former group. These models are descriptive and non-statistical.

The second group of programs is based on location density, and includes the harmonic mean (DIXON & CHAPMAN, 1980), Fourier series (ANDERSON, 1982), bivariate normal (JENNRICH & TURNER, 1969), adaptive and fixed kernel (WORTON, 1989), and the time-kernel (KATAJISTO & MOILANEN, 2006).

The MCP (minimum-convex-polygon) is the most commonly used method for describing the total area used by the animal as well as the overlapping of home ranges (BELANT & FOLLMANN, 2002; HORNER & POWELL, 1990). Therefore the MCP method is widely used for comparison on intra-studies.

Weaknesses of the MCP method include a lack of consideration for the density distribution of the locations, sensitivity to sample sizes, and especially to outliers far from the centre of activity (HARRIS *et al.*, 1990; SEAMAN *et al.*, 1999; WHITE & GARROT, 1990). When the outer location sightings form a convex shape, then the estimates are highly accurate since they do not include unused areas. However, if the shape formed by the outer locations is not convex, then unused areas, which normally do not form a part of the home range, will be incorporated into the model and the resulting estimate will be too large (ANDERSON, 1982).

The kernel method uses a smoothing parameter (h), which is also referred to as 'bandwidth', or 'smoothing width', in order to improve the fit of the contours to the data. As the value of the smoothing factor is increased, the accuracy of the fit onto the samples decreases. According to SILVERMAN (1994), the adjustment settings of the smoothing factor are the most important adjustments in the kernel method because they have such a large influence on the results. There are two different possible approaches for dealing with these adjustments: the fixed kernel model and the adaptive kernel model. The fixed kernel method uses a single smoothing factor for a given data set, and the adaptive kernel method calculates a new smoothing factor for each area with a different density, such that the area with fewer location fixes receive higher h values (e.g. greater smoothing) and areas with a greater number of location fixes are calculated with a smaller h value (SILVERMAN, 1994).

The smoothing factor can be derived by trial and error through multiple analyses, where the best results are used (KERNOHAN *et al.*, 2001). However, such a selection is not statistically reliable. Two statistical methods are presented by the reference method (WORTON, 1995) and the least squares cross validation method (SILVERMAN, 1994). When using the reference method it is important to bear in mind that this method is only optimal for bivariate normal distributions. As home ranges are usually not normal distributed, they can be greatly overestimated by using the reference method (SEAMAN *et al.*, 1998). The least square cross

validation method, on the other hand, is nearly free of bias. The nonparametric fixed kernel method with least square cross validation is therefore considered to be the best choice for unbiased home range estimation and therefore was used in the present study (BELANT & FOLLMANN, 2002; SEAMAN *et al.*, 1998; SEAMAN & POWELL, 1996; WORTON, 1995). However, all these methods were developed using animals that occupy a two-dimensional range (measured in square meters) and can move without restraint anywhere in their landscape (BLUNDELL *et al.*, 2001). In contrast, otters often use linear home ranges (measured in meters), which is bound to the course of a water way.

BLUNDELL *et al.* (2001) who evaluated the effects of smoothing parameter, sample size and independences of data points on kernel estimates for linear home ranges, suggested that fixed kernel h_{ref} with 95 % contours for home range provides more reliable and consistent estimates and these were used in the present study.

Core Areas

To evaluate the use of habitat within the home range, it is necessary to calculate the use of space (BELANT & FOLLMANN, 2002). Because resources are normally not homogeneously distributed in an area, but rather occur in clumps, the area used by the animal is usually heterogeneous. The area within the home range, which contains a higher activity or density of locations, is termed the core area (SAMUEL *et al.*, 1985; WORTON, 1989). POWELL (2000) postulates that core areas are of ecological importance because in these areas, which include breeding areas, resting places and hunting areas, there is a higher accumulation of resources and a higher density of nutrients than in peripheral areas. Therefore not all parts of a home range are equally important for an individual.

The kernel method provides a good method for identifying and analysing core areas, where a higher density of locations exist, (KENWARD *et al.*, 2001) since the utility distribution is displayed as percentage used areas with specified probabilities (POWELL, 2000). However, it is assumed that for an assessment of the habitat utilization, both the number of individuals and the number of locations are required (OTIS & WHITE, 1999).

Core areas should not merely describe regions in which the animal is likely to be, but rather should also be tested for biological meaning as regards the nature of the

terrain, since this can sometimes indicate social interactions on an intra- and interspecific level (HARRIS *et al.*, 1990).

In several studies FK 50 and MCP 50 are used to describe core areas. However a general conclusion towards which is the most suitable method is not possible as MCP 50 in general does not show higher or lower values in relation to FK 50 in the present study. Core area estimates by MCP 50 or FK 50 may not describe the real core area, as they may overestimate the centre of activity in a linear system. Thus river sections without any special features of ecological importance are included in this study. By using FK 25 the core areas are reduced in length, but display the more ecologically important areas, such as den areas, as supposed by POWELL (2000).

Autocorrelation

Nonparametric models of home range, such as the kernel model, assume that the locations used have been sampled independently (HARRIS *et al.*, 1990). When the time intervals between the location samples of the animal are too short, autocorrelation occurs and the resulting data do not represent an independent fix of the animal's movement and may instead be underestimated (SWIHART & SLADE, 1985; WORTON, 1989).

Several methods have been developed to verify the independence of data points (SWIHART & SLADE, 1985). However, there are multiple methods available for statistical analysis of autocorrelation and these can produce a wide range of possible results leading to a variety of different interpretations.

An increase in the time intervals between location samples in order to achieve statistical independence will most likely result in an underestimation of the home range and a loss of biologically relevant information (ROONEY *et al.*, 1998). Furthermore, the independence of the data is affected by the biological conditions (LAIR, 1987).

The independence of locations can also be calculated by the maximum distance between two fixes within the home range, also known as "range span," and the average velocity. As a result, the location fixes will be interpreted as independent when the time interval between two successive locations potentially allows an animal to reach any location in his home range (SWIHART & SLADE, 1985; WHITE & GARROT, 1990). Range span was calculated for all three animals.

However, due to the different range span, particularly for F 04/54 the independent data points between the three radio tracked southern river otters differed highly. As the animal F 04/54 was situated in the ombrophilous swamp forest, where a lot of streams were parallel and crosslinked, range span and time for independent data points were smaller.

Beside the selection of the home range estimator, the selection of the software program is important. A comparative study by LAWSON & RODGERS (1997) pointed out that similar programs of home range estimation resulted in significant differences concerning the size of the home range and the core areas.

3.4.2 Home Range

Fidelity to a specific home range is beneficial for individuals since they are familiar with the local prey, resting sites, shelter, and mates. It also reduces competition for resources (O'DOHERTY *et al.*, 1997; mentioned in PAYER *et al.* 2004; POWELL, 1994). Furthermore, the risk of mortality is reduced since the animals are not wandering into unknown habitats (THOMPSON & COLGAN, 1987).

Home range stabilisation and size

Both female southern river otter meet the asymptote for home range stabilization. This is in contrast to the male individual. According to POWELL (1979), who classifies individual mustelides into three groups: (1) 'transients', which are animals who simply pass through an area; (2) 'temporary residents', which are individuals who stay for a short period of time, and (3) 'residents', which stay for a prolonged time or for their entire life in an area, the female southern river otter should be classified as resident. The female F 03/36 feature more than one range stabilisation. This is due to the different fixes found between the antenatal and postnatal periods for this animal.

It is assumed that the female F 03/36 reached the asymptote earlier than F 04/54 since the home range of F 03/36 is more linear, having no interconnections between streams as was the case for F 04/54. In the case of M 04/40 it seems that the animal is a temporary resident, as it did not attain the asymptote and radio contact was lost after four months of radio tracking. Furthermore, animal M 04/40

was aged as a sub-adult and may have searched for an area to occupy in order to establish its territory. However, taken into consideration must be the fact that the transmitter was defective. The calculated data still can serve as an approximate value for future research.

Home range size varied between female southern river otters. The estimated home range for F 03/36 was 18.8 % smaller than the others. Finding intra-sexual differences in home range sizes is consistent with previous studies on *L. provocax* (SEPULVEDA TERÁN, 2003) , and was also reported for other species, such as *L. lutra* (GREEN *et al.*, 1984).

If the male home range is larger than that of females, it may be possible to attribute this to the fact that the sub-adult male southern river otter M 04/40 is not a resident animal. However, previous studies on male home ranges of *L. provocax* show large variations (SEPULVEDA TERÁN, 2003).

The female F 03/36 was captured in 2000, 2002 and 2003 and equipped with a radio transmitter. In 2000 the animal was classified as juvenile and the calculated home range averaged 11298m (SEPULVEDA TERÁN, 2003). In 2002 the female southern river otter already reached the adult status and occupied a home range of 8922m (unpublished data). With data taken in 2003 a home range of 14358m (FK 95) was calculated. However, by excluding the time were F 03/36 was travelling with cubs, almost same home range size as recorded in 2002 was estimate for the animal (FK 95 = 8490 m). As this female used always the same upper section of the Queule River, it is assumed that she established its home range most likely in 2000 and maintained it at least until end of November 2003 when last radio contact was recorded.

Factors influencing home range size

The size of home ranges depends on a multitude of factors; such as body size, den sites, food resources and mating partners (e.g. GOMPPER & GITTLEMAN, 1991; HERFINDAL *et al.*, 2005; POWELL, 1979).

MCNAB (1963) showed that home range size increases with metabolic needs, and that it also varies with body mass (MACE & HARVEY, 1983). However, even in animals with similar body weight, home ranges can vary by factors from 6 to 1400 (GITTLEMAN & HARVEY, 1982) . In this study, it was not possible to conclude that there exists a relationship of body size to home range size because the

number of radio-tracked otters was too low. Also, previous work on the home ranges of the southern river otter does not provide sufficient data to make these conclusions. However, as shown in Chapter 2, the sexual dimorphism in *L. provocax* is low; therefore, an intra-specific difference, based on metabolic needs, is not assumed for this species.

MCCLOUGHLIN & FERGUSON (2000) suggest that home range size is primarily related to prey availability and habitat productivity; and, therefore, home ranges where there are fewer prey productive patches have to be larger in order to meet individual needs. This relationship is also reported for different species, such as mule deer *Odocoileus hemionus crooki* (RELYEA *et al.*, 2000), red squirrels *Sciurus vulgaris* (WAUTERS & DHONDT, 1992), red fox *Vulpes vulpes* (LUCHEBINI & LOVARI, 1996), Cape clawless otter *Aonyx capensis*, (SOMERS & NEL, 2004) and northern river otter *Lontra canadensis* (BLUNDELL *et al.*, 2000).

There is, however, a relationship between the home range size and prey availability for the southern river otter that can be assumed, but is difficult to test as the productive areas are too complicated to investigate. Thus, the results in this study seem to have conflicting outcomes. F 04/54 has a home range area located in the ombrophilous swamp forest. This is assumed to be a highly productive area, but shows a higher FK 95 as F 03/36 where the patches of food were of lower densities.

Seasonal changes in home range size during the mating season, and postnatally, are known for several species; for example, the male brown bear *Ursus arctos* (DAHLE & SWENSON, 2003), black-faced impalas *Aepyceros melampus petersi* (MATSON *et al.*, 2007) and stoats *Mustela erminea* (ERLINGE & SANDELL, 1986). A postnatal change in home range size was also noted for F 03/36, but is discussed in detail in Chapter 4.

When a male otter die, its territorial vacancy has to be filled; and, sub-adult animals may be the ones to occupy this area. POWELL (1979) noted that sub-adult, *L. lutra* (two year old), showed territorial activity in the autumn; that is, they seem to establish territories during this time. This may also be the case of M 04/40; the animal was classified as a sub-adult and during the period of radio-tracking it disappeared several times. This can be explained as a period of time where the animal was surveying (travelling) in search of vacant territories. It is assumed that temporary resident male southern river otters do not influence the

spacing pattern of resident animals. This was also reported by HAWLEY & NEWBY (1957; cited in POWELL 1979) for transients or temporary residents least weasel *Mustela nivalis*.

Human disturbances are assumed to have influence on the home range size of otters since they are altered environments (SOMERS & NEL, 2004). Most of the F 03/36 home range was located close to human construction sites. However, even within her home range there existed sections that were further away from human construction areas. These areas were used less frequently, but they did provide den and hunting sites. Furthermore, southern river otters were seen swimming close to fishermen who were fishing in the river. They were also seen in areas where the riparian trees had been cut with motor saws. (pers. obs.). Therefore, it seems that the F 03/36 is, to a certain degree, tolerant to anthropogenic disturbances such as those reported for the European otter, *Lutra lutra* (KRUUK, 1995). It is possible, however, that the female southern river otter had to choose a suboptimal habitat because no other habitat was available. Animal F 04/54 shows a different activity pattern in relation to its distance from human construction sites. Travelling through sections that were close to human construction sites was carried out exclusively during the night time. The male southern river otter M 04/40 seemed to avoid travelling during the day time through sections which were close to human construction sites. This may be the result of avoiding human activity and traffic that were highest during the day time.

Spacing pattern

Mustelides generally demonstrate intrasexual territoriality. However this is determined by resources. For example, females occupy a home range that provides enough prey in which to rear offspring, and males inhabit a home range wherein they can maximize their reproductive success and is therefore only partially influenced by prey availability (JOHNSON *et al.*, 2000). However, there is a wide variation in the spacing patterns within species. Thus, even though weasels *Mustela nivalis* and stoats *Mustela erminea* have an intersexual and intrasexual overlap of home ranges, there is spatio-temporal separation between and within the sexes (ERLINGE, 1974; KING, 1975).

ERLINGE & SANDELL (1986) have shown that male *Mustela erminea* changed home range size in response to competition with females over resources. The data

on home range should therefore be related to the season during which they were conducted (JOHNSON *et al.*, 2000), particularly since habitat requirements can be different in winter versus summer (BUSKIRK & LINDSTEDT, 1989).

Likewise, variation in spacing patterns and intrasexual territoriality has been reported in the subfamily *Lutrinae*. For example, a strong intrasexual territoriality has been described for the European otter *Lutra lutra* (ERLINGE, 1967, 1968, mentioned in POWELL, 1979), whereas the northern river otter *Lontra canadensis* does not show territoriality and there is an intra- and intersexual overlap of their ranges (BOWYER *et al.*, 1995; MELQUIST & HORNOCKER, 1983). The Cape clawless otter *Aonyx capensis* spacing pattern seems to be similar to *Lontra canadensis*, except that there is a temporal instead of spatial avoidance (SOMERS & NEL, 2004; VAN DER ZEE, 1982). Although sea otters *Enhydra lutris* normally exhibit intrasexual territoriality, during the breeding season adult males occupy territories that overlap with female territories (ESTES, 1980; GARSHELIS *et al.*, 1984; JAMESON, 1989). An intersexual home range overlap is assumed in *L. provocax* as the male southern river otter M 03/x1 was captured in the home range of the female F 03/36 (for details see Chapter 2), which is consistent with the results of SEPULVEDA TERÁN (2003). Furthermore dens of F 03/36 were used by male southern river otters in 2002 and 2004.

3.4.3 Habitat preferences

Den sites

In contrast to the home range of F 04/54, which is located in the ombrophilous swamp forest, the home ranges of F 03/36 and M04/40 are anthropogenic influenced. The anthropogenically modified area is characterized by low numbers of big and dead trees, roots, and overhanging roots; in here the natural vegetation was replaced by grass and bushes which dominated the area.

However, the southern river otter depends upon special vegetation structure such as Quila *Chusquea quila*, trees and big trees, as these structures provide den sites and resultant good protection. This is similar to the findings for several other otter species, such as neotropical otter *Lontra longicaudis* (QUADROS & DE ARAÚJO MONTEIRO-FILO, 2002), Cape clawless otter *Aonyx capensis* (PERRIN &

CARUGATI, 2000), and the European otter *Lutra lutra* (ANDREWS, 1989) where dens were built in sites of dense vegetation.

Den sites are frequently found in areas where Quila is abundant. The bamboo Quila is very dense and an aggressive coloniser (LUSK, 2001), allowing no access, or visibility into the entrance of the den, as it covers the whole riparian section up to the water line. However, Quila is seen as a pest plant by farmers as it grows very fast inland and is therefore regularly burned down. As the results show (Tab. 3.3.5 a, b; p. 64, 65) Quila is negatively correlated to anthropogenic favoured vegetation and therefore den locations are limited in the home range of F 03/36.

FK 25 shows three core areas in the home range of F 03/36, representing the most used den sites, and in these areas Quila was the dominant vegetation type. Interestingly the core area (FK 25) of the female F 04/54 was situated in an anthropogenically modified part, in a canalized area. The core area of the male otter M 04/40 was also located in an anthropogenically modified area and furthermore the animal utilized dens which were used in the previous year by the female southern river otter F 03/36. This is consistent with the findings of SEPULVEDA-TERÁN who found that male southern river otters used the same dens as females, but never at the same time.

Most dens were initially found by telemetry and two accidentally in the ombrophilous swamp forest. As Quila does not seem to grow under the tree canopy (LUSK, 2001), big trees and overhanging roots may play an important part for den sites in anthropogenic undisturbed areas. Therefore it may be concluded that dense and copious vegetation is most important for dens on bank sides in an anthropogenically changed area, whereas in natural, unchanged areas, big trees and overhanging roots are used by *L. provocax* for den sites.

Hunting areas

The composition of river bed structures in the hunting areas of the southern river otters F 03/36 and M 04/40 demonstrates significantly more woody debris compared with non-hunting areas. Woody debris offers protection from predators for many aquatic animals (e.g. ANGERMEIER & KARR, 1984; EVERETT & RUIZ, 1993). Investigations regarding prey availability (Chapter 5) demonstrate that the main prey of *L. provocax*, the crayfish *S. spinifrons* uses woody debris for

sheltering. The vegetation structures trees/roots were also used by *S. spinifrons* (Chapter 5), however as these structures were mostly absent, only woody debris provides hunting areas for the southern river otter in the anthropogenic modified area.

Woody debris was not correlated to river properties and therefore is randomly spread along the river used by F 03/36 and M 04/46. As pine plantation has replaced original forest in this area, woody debris occurrence in the river depends upon clear cutting activity. Forest workers leave roots and some trunks which are flushed into the river by flooding. These new habitat structures are colonised by aquatic invertebrates (DRURY & KELSO, 2004) and fish within a short time (pers. obs.). The occurrence of woody debris is positively correlated with the river bed structure gravel; which is used as a shelter by the crustacean species *Aegla obtao* (see Chapter 5). This correlation means that the southern river otter will find two crustacean prey species within the hunting area and in addition will find fish which shelter in the woody debris (ANGERMEIER & KARR, 1984).

Marking sites

Most of the marking sites were close to the water line (horizontal and vertical) and vegetation selected for marking was comprised of mainly soil/stones or grass/herbs, there was no high vegetation.

It is assumed that conspicuous and open structure types of vegetation were selected as these let other southern river otters easily find the faecal deposits. Contrary to the findings of CHANIN (1985), where *L. lutra* formed sign heaps, no such behaviour was recorded for *L. provocax*. The southern river otter only used existing riverbank and vegetation structures, and faeces were sometimes positioned in elevated dominant places. In one case a faecal sample was found in a fork of a branch 25 cm above ground, but it was still conspicuous.

The suggestion of KRUUK (1992) that scent marks signal the use of resources may not be transferable to the southern river otter, as in some cases two relatively fresh spraints were found on the same marking site (with an assumption that these were from two different individuals) and additionally, marking sites were infrequent in hunting areas.

In contrast to other mustelides, otters show anal glands and proctodeal glands (CHANIN, 1985). Thus scent is always deposited on faeces which may provide a

chemical fingerprint for the otter (TROWBRIDGE, 1983) and therefore, according to KRUIK (1995), faeces with gland secretion may serve for intrasexual communications.

That faeces serve for communication is also suggested for the southern river otter, as three large collections of faeces were accidentally found in a branch of the den, which apparently served as a latrine and may identify the resident otter to other otters. Furthermore, one southern river otter was seen inspecting older faeces with his nose, before depositing faeces itself on the marking site.

3.4.4 Activity patterns

The southern river otter showed, according to the definition of TATTERSALL (1979), cathemerality throughout the time of radio tracking. This is consistent with observations made whilst trapping the southern river otter, as otter signs like foot prints were detected during the day and at night when traps were checked (Chapter 2) and when animals were caught in traps.

Minimizing interspecific competition and predation pressure as well as gaining thermoregulation and nutritional benefits are proposed as the main advantages of cathemerality as animals are more flexible to extend their activity into diurnal or nocturnal phases (HILL, 2006).

OVERDORFF (1988) suggests that the change from diurnal to cathemeral activity is a strategy to evade predation by diurnal predators. However, avoidance of predation cannot be conferred to the southern river otter, as *L. provocax* is on the top of the nutrition pyramid. No other predators, except humans, are known for the southern river otter. As the puma *Puma concolor*, which also occurs in the investigated area, is shy of water and *L. provocax* did only leave the river for marking, it is assumed that the southern river otter is not preyed upon by the puma. Several authors show that activity patterns of predators are related to prey activity pattern. For example LODÉ suggests (1995) that the activity pattern of polecats *Mustela putorius* is synchronized with the activity of their main prey and BELTRÁN & DELIBES (1994) note that the Mediterranean rabbit influences the circadian activity of the Iberian lynx *Lynx pardinus*. Likewise the fossa *Cryptoprocta ferox*, according to FERNANDEZ-DUQUE (2003), shows cathemerality, similar to

lemur prey species activity patterns (CURTIS & RASMUSSEN, 2006). An advantage of year around cathemeral predators is that they can prey upon diurnal, nocturnal and cathemeral species (DOLLAR, 1999).

The cathemerality of *L. provocax* seems not to be related to prey activity pattern, as the main prey, *Samastacus spinifrons* show nocturnal activity and hide in shelters during the day (pers. obs.). However, *L. provocax* also preyed upon *S. spinifrons* during the day by digging with the forepaw to reveal crustaceans. It is assumed that *L. provocax* also has to consume fish to attain its metabolic requirements, but it is not known if the fish activity is predominantly nocturnal or diurnal. The fish species *Salmon salar* can detect food more easily during the day, but the risk of predation is greater, therefore they show a predominantly nocturnal behaviour. However, they were diurnal when risk of starvation was greater (METCALFE *et al.*, 1998).

Furthermore, cathemerality can avoid interspecific competition, as, for example, top feeding hours can be different during night-active and day-active periods (RASMUSSEN, 1999; cited in CURTIS & RASMUSSEN, 2006). For *L. provocax* there are no known species for interspecific competition. Only the American mink *Mustela vison*, as an introduced species, occurs in the same area, however competition is not assumed (see Chapter 4). Furthermore *M. vison* also shows cathemeral activity in this region (pers. obs.).

It is also suggested that an advantage of cathemeral activity may be the avoidance of unfavourable temperatures (see CURTIS & RASMUSSEN, 2006). However, thermoregulation does not seem to play a major role in the activity pattern of the southern river otter, as a large difference of water temperature was only noted between seasons and not within 24 hours.

Southern river otters time budget for movements is almost similar to the findings for the European otter *Lutra lutra* in Scotland (DURBIN, 1993). However, it has to be considered that only nightly movements were considered in the study of European otter's time budget and therefore it might be higher by collecting data on a 24-hour cycle. MELQUIST & HORNOCKER (1983) show that the northern river otter *Lontra canadensis* spent more than 60 % of its time searching for prey. Also the giant otter *Pteronura brasiliensis* used 58 % of its time for foraging (STAIB,

2002). Lower values for movement activity are reported for the marine otter *Lontra felina*, where it amounted to only 19 % (MEDINA-VOGEL *et al.*, 2007).

Prey availability and metabolic requirements are the factors which influence the time an animal spends on hunting (e.g. GESE *et al.*, 1996; GITTLEMAN & HARVEY, 1982). ESTES *et al.* (1982) suggest that sea otters *Enhydra lutris*, which were introduced into a new area and spent only 16 - 17 % of time on feeding, stayed in an area with a high prey availability and the population was below equilibrium density.

It is assumed that these suggestions can be transferred to the situation in the study area and the southern river otter inhabited an area with high prey availability or populations were below equilibrium density.

The increase of activity pattern from 03-06 to 06-09 hours, which corresponds to 15-18 to 18-21 hours is interesting. However, a general conclusion about an activity cycle is not possible as it could be an artefact due to the low number of animals which were radio tracked. Furthermore the individual's cycle shows different top activity hours. By intersexual comparison the male southern river otter M 04/40 differs in the proportion of behaviour showing a lower inactivity phase, and higher stationary activity phase. However, it has been shown that like the other radio tracked animals he spent more than 60 % of the time sheltering in dens. The slightly different activity pattern may be due to his age or due to his classification as a temporary resident animal. As only a few studies provide data on activity budget over a 24-h cycle, no comparison can be made.

Only dens and no resting sites were detected for radio tracked animals, which is contrary to other otter species, like *Lontra longicaudis* (WALDEMARIN & COLARES, 2000) *Lutra lutra* (MASON & MCDONALD, 1986) and *Lontra canadensis* (NEWMAN & GRIFFIN, 1994). On only one occasion a non-radio-equipped southern river otter was seen on a little sandy island in the river cleaning itself. According to CHANIN (1985) otters use protected resting sites, such as under trees or rocks, in moderate human disturbed areas. This may lead to the conclusion that studied southern river otters are negatively influenced by human disturbance, as they may not show normal behaviour and only stay in dens, or that the area was anthropogenically modified and did not provide resting sites for *L. provocax*.

Although the activity budget and travel velocity for F 03/36 and F 04/54 are quite similar, they differ in their activity bouts. F 03/36 shows the lowest time bouts of movements and travelled distance. An explanation may be that the area of F 03/36 is more exposed to human constructions (Fig. 3.3.11; p. 71) and time for travelling; including hunting is kept to a minimum to avoid human disturbance. That human disturbance changes activity pattern is recorded for several species, such as Amur tiger *Panthera tigris altaica* (KERLEY *et al.*, 2002), killer whale *Orcinus orca* (WILLIAMS *et al.*, 2006), Dian's tarsiers *Tarsius diana* (MERKER, 2006) as also for the European otter *Lutra lutra* (BEJA, 1992).

3.5 Prospects

In the present study, it was possible to show that two animals established a home range which differed in size. Prey availability is assumed to be responsible for home range size, but is difficult to test, as productive areas are complicated to investigate. Furthermore the results of this study are contrary to this assumption, as the home range area of F 04/54 is located in the ombrophilous swamp forest; which is assumed to be a highly productive area, but shows a higher FK 95 than F 03/36 where productive areas with patches of food density were lower. Therefore, further studies are required to draw a conclusion regarding the relationship of home range size and food availability for southern river otters.

As it was only possible to show the habitat requirements of the southern river otter that established its home range in an anthropogenically modified area, further studies should focus attention on natural environments and preferred habitat requirements.

The southern river otter did not show a strictly nocturnal or diurnal behaviour, but cathemerality was revealed. However, the factors which override the endogenous clocks and may explain the cathemeral activity of *L. provocax* cannot be identified in the present study. Nevertheless, predation is key to several other carnivores (CURTIS & RASMUSSEN, 2006), and therefore future studies should look on prey activity pattern and in fish species activity cycles.

4 Rearing cubs: effect on home range and activity pattern of a female southern river otter (*Lontra provocax* THOMAS 1908)

Abstract

One female southern river otter with cubs was radio tracked in the IX. Region of Chile to show the effect of rearing cubs on females' home range and activity patterns. To avoid loss of cubs due to intra- and interspecific conflicts and to maintain higher energy requirements two predictions were tested: 1) postnatal areas should not be close to home range boundaries and should be free from any kind of disturbance especially human disturbance; 2) activity patterns should change, as female southern river otters with cubs have a higher energy requirement. The home range, using 95 % fixed kernel (FK 95) as well as the core areas (FK 50, FK 25) were estimated antenatally and postnatally. Activity patterns were recorded continuously through both periods. Results show that in the postnatal period home range was reduced and undisturbed tributaries were used. As the cubs aged, all river sections previously used by the mother were visited regularly. The activity pattern of the female with cubs changed significantly, as she spent time outside of the den more frequently. Furthermore a model for the reproductive cycle is presented and discussed.

4.1 Introduction

The southern river otter *Lontra provocax* belongs to the family Lutrinae and is distributed along southern Chile and Argentina. It is likely that it is the otter species with the smallest distribution in the world (CHEHÉBAR *et al.*, 1986; MEDINA-VOGEL, 1996). The southern river otter is listed in CITES Appendix I, and listed in the EU by law 338/97 in Annex A; and in the IUCN Red List of vertebrates as 'endangered' (UNEP-WCMC, 2002).

Although in the last decade there has been an important increase in research on the species, basic ecological studies are still needed as, for example, almost nothing is known about the otters' reproductive cycle and behaviour.

Only recently the territorial behaviour was described for *L. provocax* by SEPULVEDA (2003) as intrasexual territorial, where individuals defend their territory against same sex, but allow the opposite sex to enter their territory. Therefore adult animals live solitarily and are only seen together for copulation during mating seasons. Family groups are then formed only by females and their offspring.

Because of high investment in parturition, female animals should avoid intra- and interspecific conflicts to not lose their offspring (e.g. DAHLE & SWENSON, 2003; PACKER & PUSEY, 1983) and prevent them from external factors, such as flooding (DURBIN, 1996). Furthermore, females with cubs need to feed more frequently as they have a higher energy requirement and as they do not store fat (pers. obs.). More precisely the following predictions were tested:

1. Assuming that the female southern river otter with cubs avoids intra- and interspecific conflicts and human disturbance she should use only limited parts of her home range, which are not close to home range boundaries and also in areas with low human disturbance. Furthermore dens should be secure against flooding.
2. Because the female southern river otter has high energy requirements, the animal should show a different activity cycle compared with the antenatal period (e.g. PHILLIPS & CATLING, 1991) and should demonstrate a higher frequency of activity over the day to meet her needs (e.g. MERTZANIS *et al.*, 2005).

4.1.1 Study site

The river of investigation named Queule lies in the southern limits of the IX. Region, the Araucania region, which has a temperate climate. The river is approximately 87 km long, arises in the coastal mountain range in an altitude of about 550 m (39° 12' 45" S; 73° 00' 24" E) and ends at the village Queule where it enters into the Pacific Ocean (39° 26' 32" S; 73° 12' 59" E). The Queule River is partially covered by a temperate evergreen ombrophilous swamp forest which is mainly composed by *Myrceugenia exsucca*, *Eleocharis macrostachya*, *Scirpus californicus*, *Juncas procerus*, *Temu divaricatum* and *Drimys winteri*

(HAUENSTEIN *et al.*, 2002; RAMÍREZ *et al.*, 1983). The river currents are mainly regulated by the rainfall which reaches an average of 2110 mm per year with the seasonal low level during summer time and high level during winter time.

4.2 Methods

4.2.1 Radio tracking

An adult female southern river otter (F 03/36) was captured, equipped with an intraperitoneal movement-sensitive radio transmitter (Sirtrack Ltd., Havelock North 4201, New Zealand) and radio tracked from April 2003 to November 2003.

Two tracking methods were applied: a) continuous radio tracking; whereby the animals were followed for three consecutive days at least once per month, monitoring time being eight hours, in such a way as to complete a whole-day cycle (00:00 – 08:00; 08:00 – 16:00; 16:00 – 24:00) and b) sequential radio tracking; where separated random radio fixes were taken for up to 14 days per month.

For radio tracking, the southern river otter was first located by 4 Wheel Drive truck using a roof-fixed antenna and then followed by foot with a three-element folding Yagi antenna (Sirtrack Ltd., Havelock North 4201, New Zealand). For triangulations, two teams located the otter from different positions creating an angle between the teams of 60° to 120° for cross bearing as recommended by WHITE & GARROTT (1990). To minimize observer's influence, a minimum distance from the otter of 20 m was maintained in order to remain outside of the visible and audible range of the animal. Both teams used a timer with auto repeat function to take location fixes and behavioural data simultaneously. Location stations were acquired via Global Positioning System (GPS), bearing by compass and the activity status by signal frequency was determined by each team.

As bearing errors are caused by diverse aspects such as terrain, observer and physical factors (SCHOBBER, 1986; WHITE & GARROT, 1990) it was attempted to minimize bearing error by taking three to five location fixes when the animal paused or at least every hour. Calculated deviation was between 0 - 25 m.

In this study we followed the recommendations of BLUNDELL (2001) to estimate the home range with fixed kernel including 95 % of all independent location fixes

(FK 95) with smoothing factor h_{ref} as it is the most accurate linear home range estimate, is robust and has the ability to identify core areas. The innermost 50 % and additional 25 % of all independent location fixes (FK 50, FK 25) is considered as core area estimate. For best results in the linear home range estimate FK 50 and FK 25 were calculated with the smoothing factor selected by least squared cross validation (BLUNDELL *et al.*, 2001).

To avoid autocorrelation of location fixes, range span method was used for calculation of independent data points, as the radio tracked animal F 03/36 was using only linear travel routes which cannot be calculated by software packages, as this would result in untrue independent data points. Average travel speed from all location fixes and the maximum distance of location fixes in the home range was calculated and thereupon the data set was resampled.

Required location fixes for calculating home range size were determined by plotting number of location fixes against home range size until home range size reached an asymptote (HARRIS *et al.*, 1990). Calculation for asymptote of the linear home range size of *Lontra provocax* F 03/36 was done manually in ArcView™, as software packages only analyses the area in hectares which was used by an animal and not linear home range. Furthermore, to not overestimate the “real” home range, home range estimates by fixed kernel were measured to the maximum location fix within the home range contours and not to the contour line of the home range.

4.2.2 Activity pattern

As the southern river otter F 03/36 was equipped with a movement sensitive radio transmitter it was possible to obtain data of activity patterns. By the combination of the configuration of the transmitter and location change ascertained by telemetry, behaviour could be categorized in three different categories: 1) *inactive*; defined as no stationary change within the next data fix - signal of radio transmitter pulsed every 1.5 seconds, 2) *stationary active*; characterized as no change of location within next data fix - transmitter pulse frequency changed to 1.0 second, and 3) *moving*; indicate changes of location within next data fix - transmitter pulsed every 1.0 second. After a preliminary examination it was determined that five minutes intervals for behavioural studies were required, as within 10 minute intervals

L. provocax left the den, hunted and returned to the den before the second data point was taken.

4.2.3 Den sites

All sites where the otter stayed without moving for more than 20 minutes were named “dens”. Consequently for calculation on the time span of movement only bouts longer than 20 minutes and only continuously recorded data were included. If one movement fix was missing, the movement bouts were disregarded.

4.2.4 Data evaluation

Triangulation data were calculated with the software program LOAS (Version 4.0, Ecological Software Solution) – LOAS estimates locations from two or more bearings which can be used for further analysis. Data was otherwise processed and analysed by using the software package ArcView™ (Version 3.2, ESRI, Environmental System Research Institute) and the extension ‘Animal movement’ (HOOGE & EICHENLAUB, 2000a) and ‘HRE’ (RODGERS & CARR, 1998).

The Universal Transverse Mercator (UTM) was used to enable the calculation of distances between locations and simplify estimates in telemetry (WHITE & GARROT, 1990). Digitalized maps for computer analysis provided by the INSTITUTO GEOGRAFICO MILITARY de CHILE were used.

The velocity was calculated using continuous five minute fixes with no missing values only, and by measuring the distance between two locations on the digitized map in ArcView™ 3.2.

All data were tested for normal distribution and equality of variances. Non-parametric tests were applied when the assumptions did not fulfil the criteria. Detailed information on the applied statistical test is specified in the results. For statistical analysis the software package STATISTICA (Version 5.0, Statsoft, Inc.) was used. The significance level of $P < 0.5$ was assumed for all statistical tests. Box-plot diagrams are illustrated with mean (dotted line), median (solid line), 5 and 95 percentile, as well as 25 and 75 quartiles. Values in brackets display median, 25 and 75 percentiles i.e. (25/75).

4.3 Results

4.3.1 Home range

Female F 03/36 showed a 35.3 % larger home range during the time with cubs (FK 95) than during the time without cubs, however the postnatal core area was 39.1 % smaller (FK 50) in relation to the antenatal area. However when analysing the data with FK 25 the values are reverse and the postnatal core area is 45 % larger than the antenatal (Tab. 4.3.1).

In contrast to the home range and core area estimates for the antenatal time, the core areas in postnatal time shifted upstream and show a more round shape than an elongated shape (Fig. 4.3.1). Furthermore three instead of two FK 50 estimates were recognized. The FK 25 estimates in postnatal time in contrast to antenatal estimates moved upstream.

Total fixes are displayed in Fig. 4.3.2 a, b, c. The figures are separated in antenatal time and split in two periods of postnatal time. Only one tributary was used by the female during the antenatal period (Fig. 4.3.2 a). Within the two following months (August – September) the female with their cubs used two different tributaries (Fig. 4.3.2 b). The previous tributaries were left in October – November and the tributary which was used in the antenatal period by F 03/36 was now used by the family group regularly (Fig. 4.3.2 c).

Tab. 4.3.1: Home range and core area (length of river in meters) of the Queule River used by F 03/36 during antenatal period (without cubs; dates) and postnatal period (with cubs)

F 03/36 in time	Number of all fixes	Number of independent fixes	Home range estimate (m)		Core area estimate (m)		Kernel h factor LSCV
			FK 95	FK 50	FK 25		
without cubs	811	44	8490	4260	812	389.12	
with cubs	2134	24	11487	2594	1499	418.31	
Total	2945	68	14358	4749	1606	362.33	

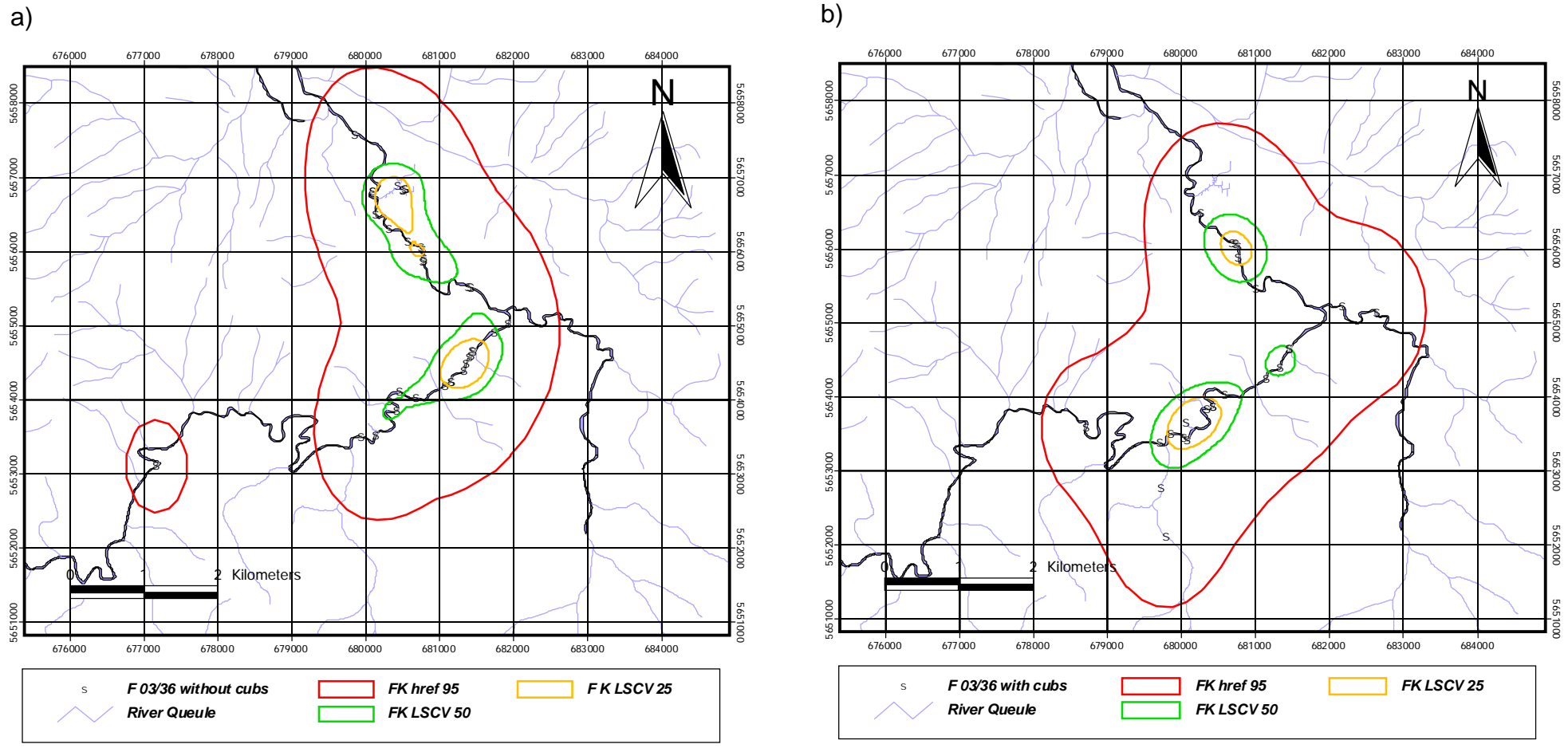


Fig. 4.3.1: Map of Upper Queule River. Displaying fixed kernel home range (FK 95) and core area (FK 50, FK 25) estimates of animal F 03/36 before (a) and after giving birth (b)

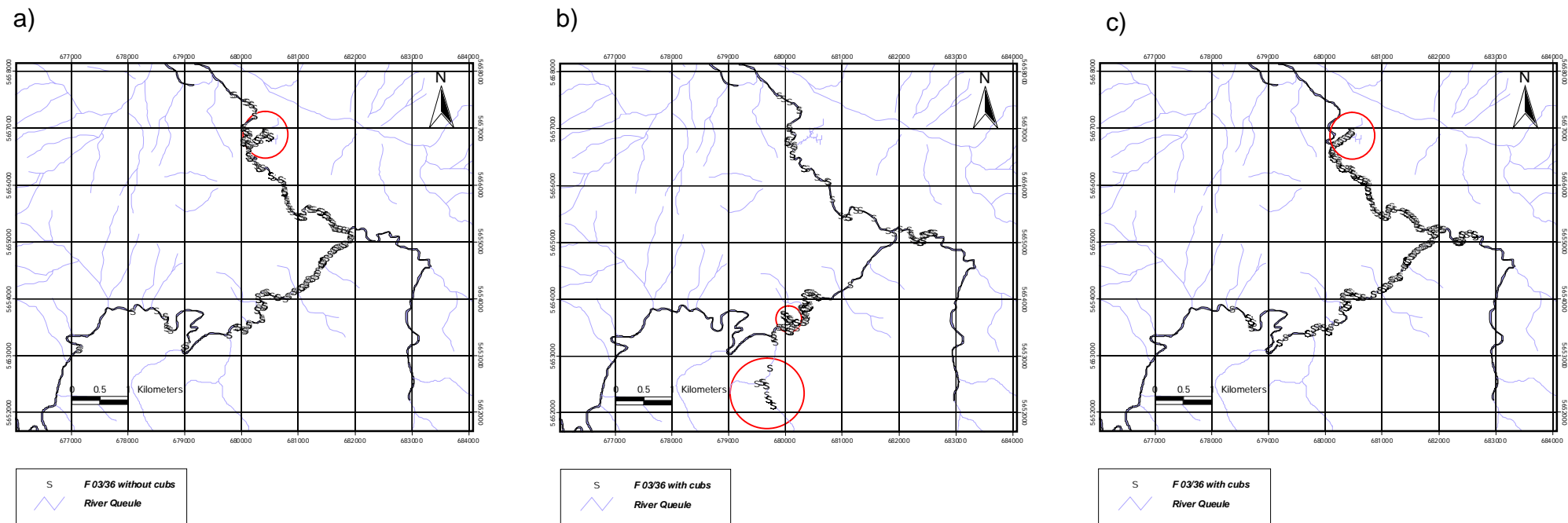


Fig. 4.3.2: Map of Upper Queule River. Displaying all radio-tracking fixes of F 03/36: a) before giving birth, b) after giving birth from August to September, and c) from October to November. Used tributaries are encircled in red

4.3.2 Activity budget

Whilst inactive behaviour before birth has an average value of 67.5 %, it decreases to 55.4 % for the time the female was with cubs (Fig. 4.3.3). On the other hand, the other two behaviours, movement and stationary activity, increased. Whilst the behaviour of stationary activity increased by 2.2 % for the time the female was with cubs, the behaviour movement increased by 9.9 %.

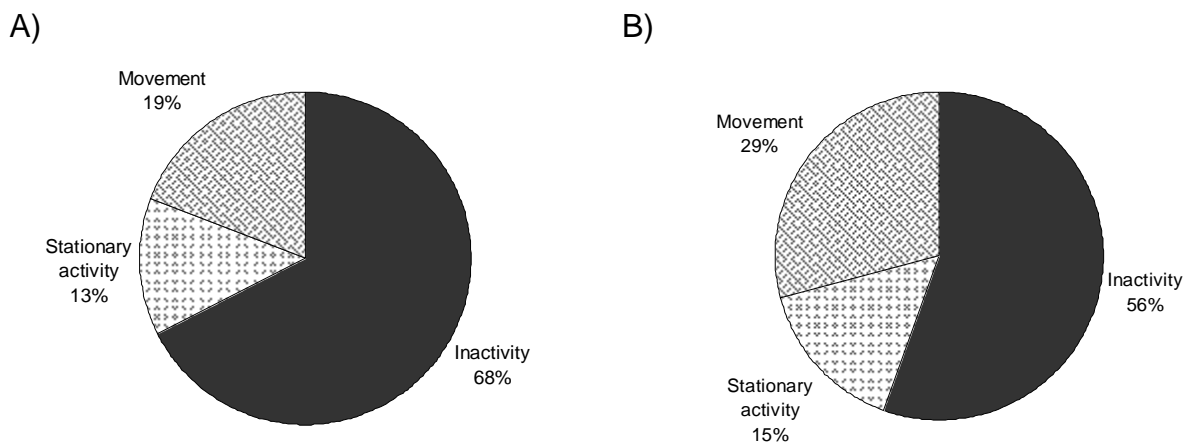


Fig. 4.3.3: Percentage of displayed behaviour of female F03/36 before (A) and after (B) giving birth

Before the southern river otter gave birth, it was not active between 03-06 hours, little activity (4.4 %) occurred between 12-18 hours and highest activity (31.1 %) took place between 18-21 hours (Fig. 4.3.4). Postnatally the movement pattern changed, as movement behaviour was recorded throughout all time intervals. The peak of movement activity was highest between 06-09 hours at 20.0 %. Lowest value was measured between 12-15 hours (1.5 %). The movement pattern of *Lontra provocax* F 03/36 is significantly different between antenatal and postnatal periods ($\text{Chi}^2 = 22.04$; $df=7$; $p<0.01$).

While the female southern river otter F 03/36 stayed in her den antenatally for 75.4 % of the time and was recorded for 24.6 % outside, the postnatal stay outside of the den increased by 12.4 % to 37 % (Fig. 4.3.5).

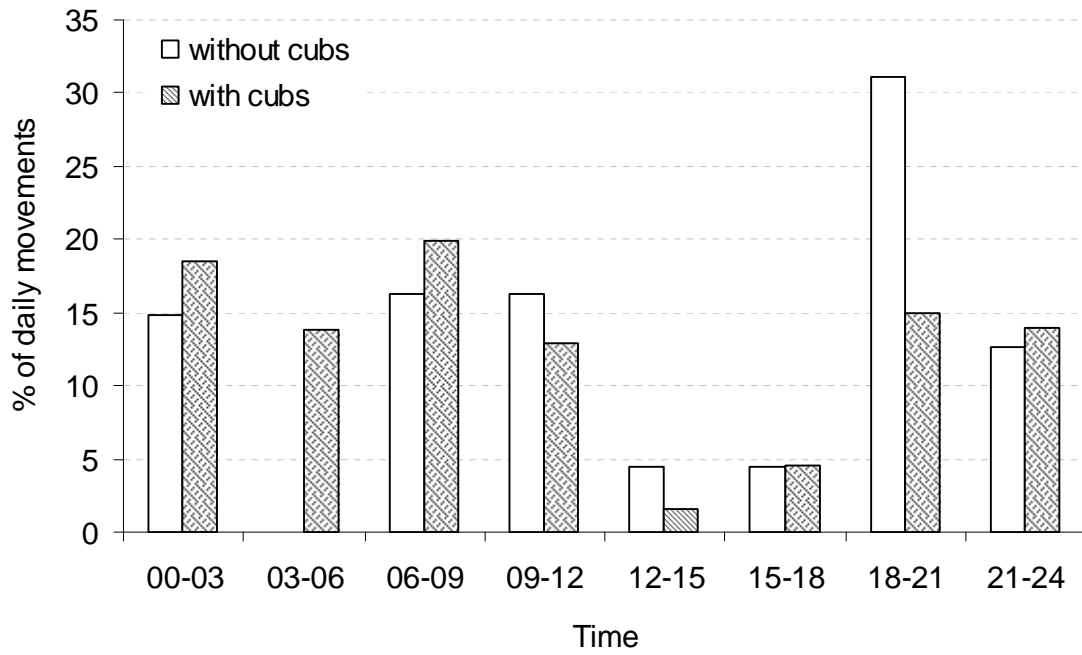


Fig. 4.3.4: Ordinate dates represent averaged values in % of the total amount of movement counts per day before and after F 03/36 gave birth. On the abscissa the 24-hour movement results are displayed in 3h intervals

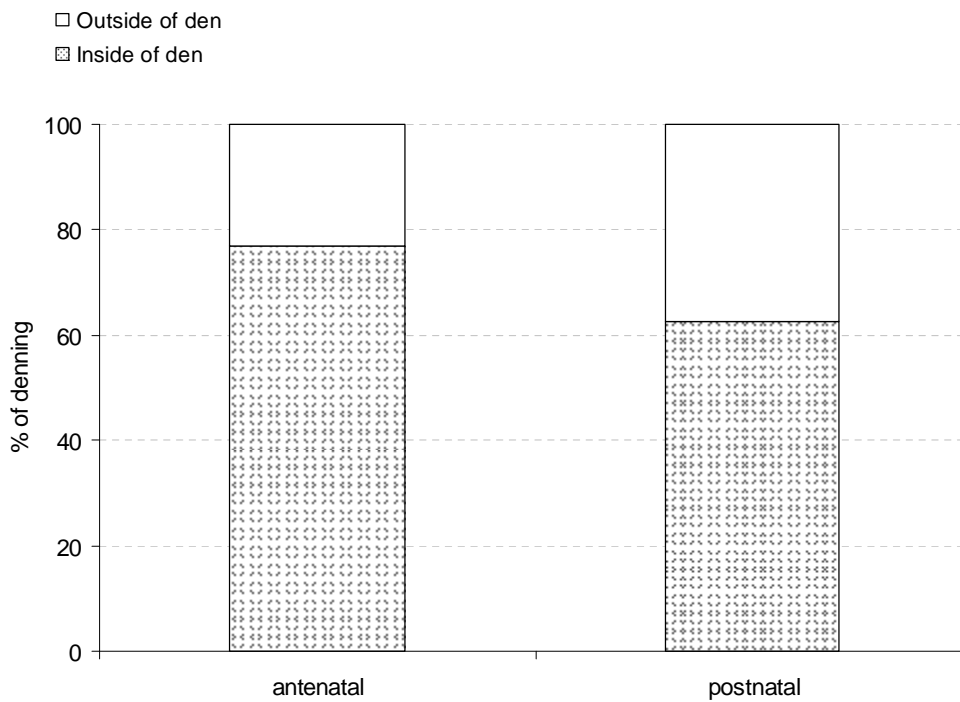


Fig. 4.3.5: Percentage of time female southern river otter F03/36 spent sheltering in den or outside of den before and after giving birth

The distance the female southern river otter travelled antenatally and postnatally differed significantly (Mann - Whitney Rank Sum Test: $T=2292.00$; $p<0.05$). The distance the female southern river otter travelled antenatal was on average 864.8 m (SE=125.56), whereby the range was 8.68 m to 2845.9 m. Postnatally the travelled distance was lower, on average 498.32 m (SE=46.65) with a range of 20.4 m to 372.6 m.

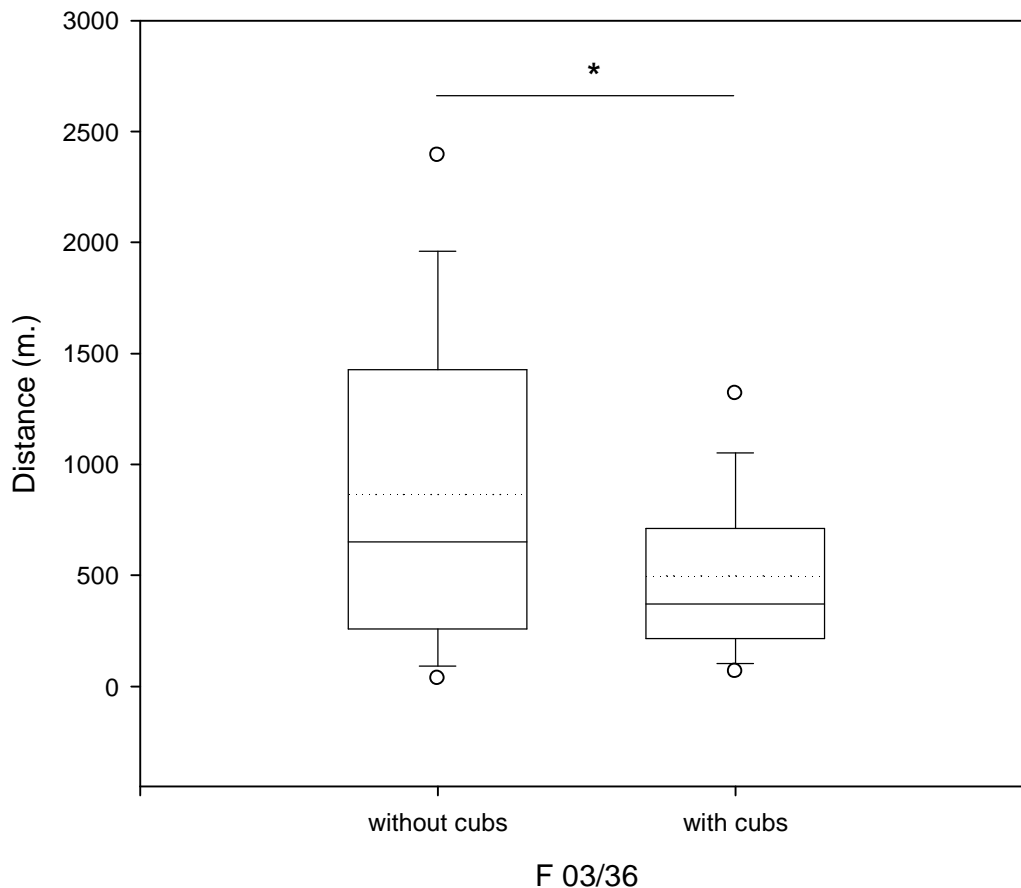


Fig. 4.3.6: Distance travelled by animal F 03/36 between inactive phases before and after giving birth (* $p<0.05$)

Although there was difference in the time span of movements between antenatal and postnatal period (Fig. 4.3.7), no statistical differences was found ($t= -0.154$; $df=21$; $p=0.879$).

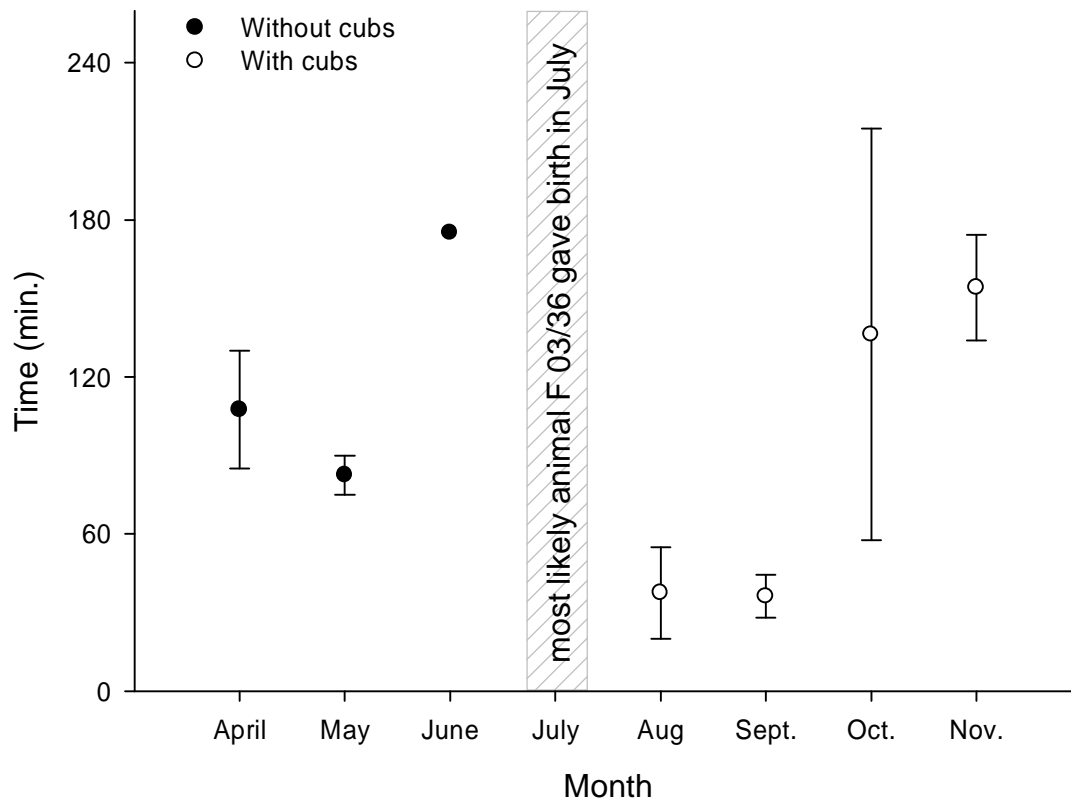


Fig. 4.3.7: Time span of movements per 24h of animal F 03/36 before and after giving birth

The differences of velocity in the antenatal and postnatal periods (Fig. 4.3.8) are highly significant (Mann-Whitney Rank Sum Test: $T=75993.5$; $p<0.001$). The travel velocity of F 03/36 was on average 1.47 km/h (SE=0.09) with a maximum speed of 10.64 km/h during the antenatal period, during the postnatal period the average velocity was reduced (0.90 km/h; SE=0.05). However, the maximum velocity was little higher than found antenatally at 11.21 km/h (Appendix 10.3; Tab. B).

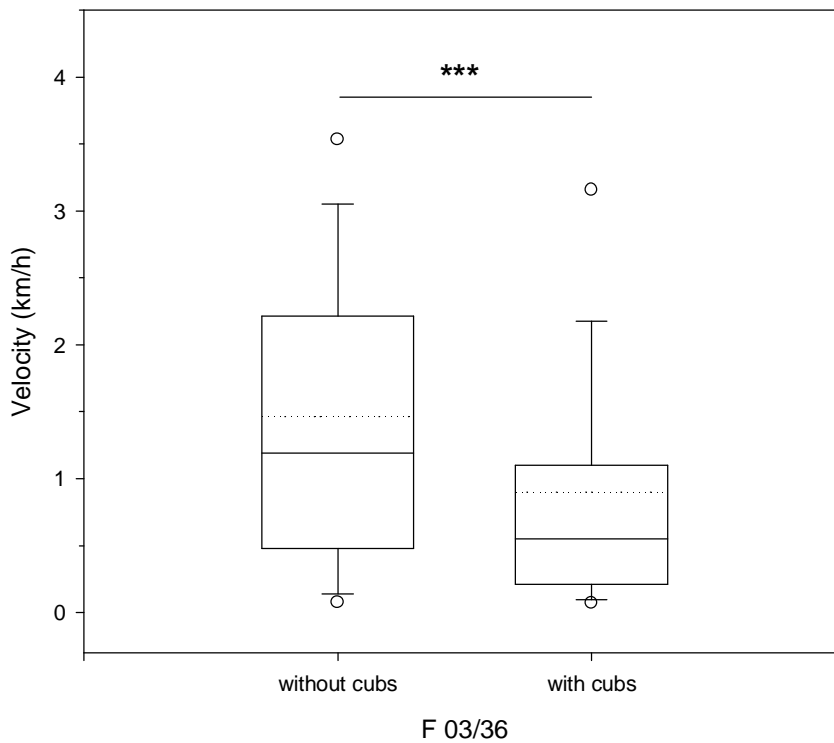


Fig. 4.3.8: Calculated velocity of radio tracked southern river otter F 03/36 without and with cubs

4.3.3 Den sites

During antenatal time the animal F 03/36 was regularly using ten dens, eight located in the lower part (downstream) of the estimated home range (Appendix 10.3; Tab. B). During postnatal time the mother with cubs used only five dens all located close to the tributary (average 702 m) of the natal hole.

The natal hole was located 1380 m from the Queule River in a 30m steep cliff canyon with a bottom wide of approximately three meters. It was only possible to locate the hole from a distance of 20 m, as the natal den itself was not accessible. During this time (August-September) the farthest den measured from the natal den was 3250 m away,

During October and November up to fourteen dens were used. The 14th den was the den furthest located at 7813 m away from the natal den. Also during October and November not all the dens which were used antenatally were visited by mother with cubs, and five dens were used exclusively within these months.

4.3.4 Additional behaviour observations

As reported for *L. lutra* by DURBIN (1996) the same method of “jockey style” transportation was observed for the cubs of *L. provocax*, whereby the cubs bit into the neck of the mother and were transported one by one. The second cub stayed in place and whistled similar to a bird call with a short, clear and bright sound in a high frequency and waited until its mother returned. The first time the cubs were seen outside they always stayed close to the river edge and avoided the middle of the river where the current was strongest. When passing through rapids the mother carried her cubs, holding them by the neck, whereas the cubs show typical carrying position. The mother always stayed close to her cubs, caching crustaceans, and returning to the cubs to feed them. The cubs were observed to whistle when their mother arrived and would take the crustacean out of her mouth. KRUIK & MOORHOUSE (1990), WATT (1991) (cited in: DURBIN, 1996) assume that cubs learn hunting by imitating the foraging behaviour of their mother.

On three occasions cubs followed F03/36 out of the water to mark on the river bank. Cubs never were seen marking. However, in November for the first time two smaller fresh spraints were found at one of F 03/36 marking sites. In November (probably four months after the birth) one cub was observed swimming independently alongside the mother, although on some occasions the cub still used the “jockey style” even when the cub had almost reached the body length of the mother. At the end of this study, only one cub was observed with its mother.

4.4 Discussion

4.4.1 Home range

As predicted, whilst rearing the cubs the female F 03/36 used tributaries, which were not visited antenatal or in previous years and which were less anthropogenic disturbed as no roads, or houses were nearby. Buildings or roads were more than 1300 m away. This is contrary to the findings for the European otter, where even natal holes were close to roads or villages (DURBIN, 1996; RUIZ-OLMO *et al.*, 2005). Consequently, by using tributaries, the postnatal core area shifted upstream for the time F 03/36 was moving with cubs. This behaviour of using different patches when travelling with cubs was also reported for *L. lutra* by several authors (e.g. DURBIN, 1996; KRUIK, 1995; RUIZ-OLMO *et al.*, 2005). It has been suggested that the use of different patches is a strategy to minimize intraspecific disturbance in bordering ranges, which has also been shown for other carnivores such as brown bears *Ursus arctos* (DAHLE & SWENSON, 2003) as they attempt to avoid conflicts. Nevertheless, the studied female might have been also restricted in their movements to her cubs' capabilities, as they were not able to swim with the same velocity as the mother (Appendix 10.3; Tab. A). However, as the cubs aged and body size was almost similar to the mothers body size, river sections and tributaries which were further away and used by the mother before were visited regularly and the former, more 'protective', tributaries were not visited again.

4.4.2 Activity budget

The increase in activity and movements of F 03/36 with cubs, as well as the increase in time outside dens during the postnatal period is assumed to be a logical consequence of the higher demand for nutrition as is known for other species (e.g. GARSHELIS & PELTON, 1980).

However, as a consequence of travelling with cubs the otter's activity decreased, especially movement periods, travelled distances and velocity. Furthermore, when travelling for longer distances, cubs were transported by the mother in jockey style one by one. These findings are consistent with observations on *L. lutra* by SAAVEDRA BENDITO (2002) and DURBIN (1996). Short travel distances and

staying close to den sites may be a strategy to avoid conflicts and increase security (DAHLE & SWENSON, 2003; DURBIN, 1996; ZALEWSKI, 1997).

It is unknown if an internal or external factor influences the low activity period between 12-18 hours of the studied animal. However, human avoidance cannot explain the low activity period as forest workers and farmers were active during the whole day.

4.4.3 Den sites

As mentioned by JENKINS (1980) and DURBIN (1996) the selection of a natal hole in a tributary could be to provide safety against flooding. This was the case in the study area as flooding occurs in autumn, winter and spring (time of parturition). The other dens which were used by the female southern river otter antenatally were located 40 - 300 cm above the water level (measured in summer) and not secure against flooding. Furthermore, the natal hole was undisturbed by any kind of anthropogenic disturbance.

The number of dens used in the first period of postnatal time (August – September) was low compared to antenatal time and reached a maximum in the second period (October – November) as the cubs were getting older and travelled further distances. During the time the mother was travelling with cubs some dens were used exclusively. The findings of dens used exclusively with cubs is consistent with observations by DURBIN (1996) for the European otter in Scotland. These exclusively used dens may be unknown to other individual otters and serve to avoid intraspecific conflicts, or may have been used because they were larger and offered more space for the family group.

4.4.4 Reproductive cycle and parental care – a model

Throughout the five year study and particularly in the present study, where mother and cubs were radio tracked, different observations such as menses, copulation, travelling with cubs and approximate birth time were noted and a model of the reproductive cycle was created (Fig. 4.3.9; Appendix 10.3; Tab. C).

All otter species show a continual polyoestrus, except the northern river otter *Lontra canadensis* (ESTES, 1989).

However, the Eurasian otter shows both continual polyoestrus and seasonal polyoestrus. This has been reported by KRUUK (1996) who demonstrated a seasonal polyoestrus for *L. lutra* in Shetland, but a flexible timing of reproduction in other areas (KRUUK, 1995).

For the southern river otter seasonal breeding is assumed, as cubs were never seen all year round. Observations of female with cubs, also termed family groups, were recorded in October 1999 (two cubs), February 2001 (one cub), November 2001 (two cubs), October 2002 (two cubs), September 2003 (two cubs) and in November 2003 (one cub). Also in the south of Chile cubs were observed in September and October (PARERA, 1996). A polyoestrus is also assumed in the southern river otter, as the female animal showed menses during captivity and gave birth later.

The time of conception was estimated by menses, which occurred in January 2001 and April 2002 and observed copulations in December 2001. These results are similar to the Eurasian otter *L. lutra* (KRUUK, 1995; RUIZ-OLMO *et al.*, 2005; SANDELL, 1989), where mating mainly occurred in the same season but different months as *L. lutra* inhabits the northern hemisphere and the southern river otter the southern hemisphere.

The date for parturition was calculated as July when the female F 03/36 disappeared from her usual home range and was discovered in a tributary, where she stayed for two months. She was then seen in September with cubs. The assumed two month stay in the natal hole is consistent with *L. lutra* (HEGGBERGET & CHRISTENSEN, 1996; KRUUK *et al.*, 1987; KRUUK, 1995; RUIZ-OLMO *et al.*, 2002), and with observations by PARERA (1996).

An average gestation period of 63 days, as is known for other otter species (for review see CHANIN, 1985) is not assumed for *L. provocax* as copulation also

takes place in spring but cubs were never reported at the end of summer or in autumn. Instead a variable delayed implantation, such as for northern river otter *L. canadensis* or the sea otter *Enhydra lutris* (for review see CHANIN, 1985), is supposed for *L. provocax*.

Independence of the cubs seems to be reached in summer after 7 - 8 months, which is also reported in other areas (per. comm. by VALENZUELA, J.). This time may be chosen due to high abundance of the main prey population (Crayfish, *Samastacus spinifrons*) and/or the female is again in gestation and therefore may abandon her cubs. Period of lactation is unknown and was not observed.

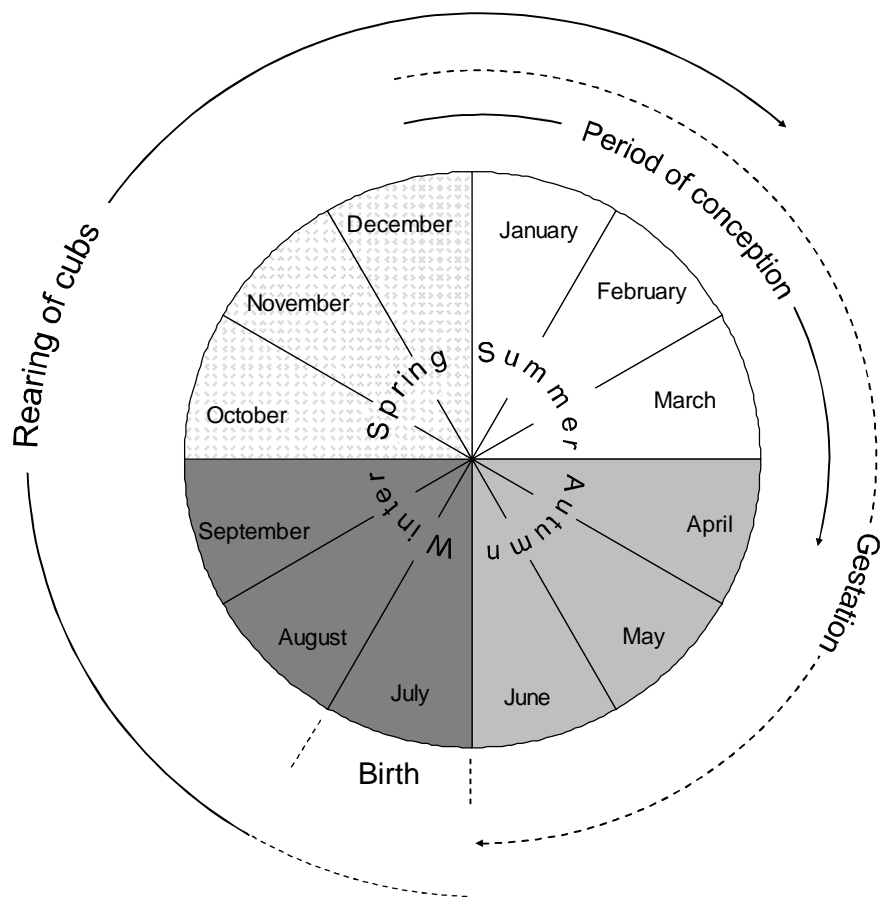


Fig. 4.3.9: Model of the reproduction cycle of *L. provocax*; based on observations from 2000 - 2004. (Continuous line based on observations; dotted line based on assumptions).

5 Prey availability, diet composition and food competition

5.1 Introduction

5.1.1 Prey availability

To understand what determines the distribution and abundance of organisms is an essential goal in ecology. One of these factors is food or prey availability as it has a powerful influence on animal populations in both the determination of habitable areas and the number of individuals which these areas can support (KREBS, 1994). Food availability is a concept which was first introduced by NEIL (1938) who was analysing the food of brown trout *Salmon salar*, in relation to its accessibility. If enough food is available the number of individuals an area can support increases. On the other hand, if prey availability is limited, animals which depend on prey will face higher intraspecific competition and have to expand their home range or disperse. Thus show SOMERS & NEL (2004) that the home-range length of the Cape clawless otters *Aonyx capensis*, was correlated with high food density patches. Also, differences in prey diversity between habitats influence the dietary breadth of a species (PIELOU, 1975). Factors such as these can have far-reaching effects on the demographic stability of populations (RICKLEFFS, 1973).

In the time of reproduction adults must adjust their own energy requirements with those of their offspring (STEARNS, 1992), thus has prey availability a strong effect on reproductive success like pup mortality and timing of birth is described by several authors for sea lions *Otavia flavescens*, (SOTO *et al.*, 2004); wolverine *Gulo gulo* (PERSSON, 2005), kit foxes *Vulpes velox* (WHITE & RALLS, 1993) and European otter *Lutra lutra* (HEGGBERGET & CHRISTENSEN, 1996; RUIZ-OLMO *et al.*, 2002).

Prey availability is influenced by numerous factors, such as habitat structures, temperature, activity, and competition; and, prey availability is also sensitive to environmental changes (e.g. KEDZIERSKI & SMOCK, 2001). The most important determinants of the composition and structure of prey communities, however, are abiotic environmental factors (SMITH & SMITH, 2000). Therefore, the physical and chemical factors of water are very important for aquatic species. Though generally less visible than biotic factors, these factors also significantly affect the abundance, distribution and diversity of species (REASH & PIGG, 1990) and in

this case of the prey species. Therefore, physico-chemical factors of water can have an indirect and far-ranging effect on the distribution of the southern river otter.

5.1.2 Food competition

Competition between two species exists when they use the same limited resource or harm one another while exploiting a resource (KREBS, 1994). To avoid competition coexisting species should possess niche differentiation or resource partitioning (BEGON *et al.*, 1996). If a strong competition exists, and the species are not able to differentiate into niches, one species may be displaced; or in other words, one species may become extinct as it reaches a suboptimal state (KREBS, 1994).

The most important niche dimensions for coexisting vertebrates are food, habitat use and activity patterns (SCHOENER, 1986). Several authors show that this is also the case for coexisting mustelides (BONESI *et al.*, 2004; MEDINA, 1997; PERRIN & CARUGATI, 2000; SOMERS & PURVES, 1996; WU, 1999).

One of the main factors which may negatively influence an individual from maximising its energy intake, and thereby forcing it to shift its diet, is interspecific food competition (BONESI *et al.*, 2004). For carnivore predators, food is an especially essential resource, and its partitioning among sympatric species is crucial for coexisting (JEDREZEJEWSKI *et al.*, 1989).

One theory, based on the evolutionary history of communities, proposes that competition resulted in adaptations that serve to minimize competitive effects (KREBS, 1994). As long as the community and environmental parameters are stable, or change slowly, strong competition may not exist. However, if alien species are introduced, the competition may increase and lead to extinction of native species (e.g. LOCKWOOD *et al.*, 2007; MAGIN *et al.*, 1994).

As in Eurasia (JEDRZEJEWSKA *et al.*, 2001), the non-native American mink *Mustela vison* established free-living populations from farm escapees in Chile (MEDINA, 1997) and competitive interferences between American mink and otter are suggested by several authors (e.g. CHANIN, 1981; CLODE & MACDONALD, 1995; ERLINGE, 1972). MEDINA (1997) found little competition for space and food between American mink and southern river. However, interactions between both species depend on each respective situation.

5.1.3 Diet composition

The diet composition for each specific animal is a consequence of external factors such as predation risk, prey availability and social interactions, as well as internal factors such as the animal's condition, age, sex and reproductive state. In addition, morphological aspects such as its skull and mouth shape, as well as dentition, play an important role in prey selection (CARSS, 1995; LITVAITIS, 2000).

Mustelides are primarily carnivorous; they will, however, consume vegetation. The consumption of vegetation depends on the species and on the season of the year. In this case they are known as opportunistic feeders, rather than specialists. Mustelides tend to hunt in terrestrial, arboreal and aquatic habitats; and, some species prey on animals larger than themselves (VAUGHAN *et al.*, 2000).

Otters are well-adapted to hunt aquatic prey and are commonly known as opportunistic food generalist (CHANIN, 1985). However, the diet composition of otter depends also on species, habitat and prey type availability (CARSS, 1995; CHANIN, 1985). Thus, according to JEDRZEJEWSKA (2001), the diet of *L. lutra* changes with relation to specific habitats. Fish are seen as the dominant food when otters are close to the seashore; but crustaceans and amphibians become more important food sources in areas closer to inland waters.

The otter species *Lutra lutra*, *Lutra maculicollis*, *Lontra canadensis*, *Lontra longicaudis* as well as *Pteronura brasiliensis* are commonly classified as piscivorous, because fish consumption generally dominates their diet (BONESI *et al.*, 2004; DOLLOF, 1993; PERRIN & CARUGATI, 2000; REID *et al.*, 1994; ROSAS *et al.*, 1999). *Enhydra lutris* feeds mainly on invertebrates (CHANIN, 1985), whereas the diet of *Aonyx capensis* is dominated by crabs (SOMERS & PURVES, 1996). Food such as crayfish, frogs, mammals and birds are usually seasonal components of their diet, and are generally regarded as a secondary food source. In order to establish protocol for the conservation of otters, observations on diet are useful to determine how the species deals with changes in aquatic systems in terms of both prey population and habitat availability (ANOOP & HUSSAIN, 2005).

Most research on diet composition has been conducted and published on common otter species, such as *L. lutra*, *L. canadensis* and *E. lutris*, but is scarce for secretive and difficult-to-observe species like the southern river otter.

Previous statements for the diet composition of *Lontra provocax* were made as a result of faeces analysis which showed that crustacean species (*Samastacus spec.*, *Aegla spec.*) comprise the vast majority of collected faecal sample remains in freshwater habitats (CHEHÉBAR & PORRO, 1998; MEDINA, 1997; MEDINA, 1998; MEDINA-VOGEL *et al.*, 2004). However food availability was not considered.

5.1.4 Aims

The principle aim of this chapter is to determine whether the southern river otter is a food specialist or is compelled to nourish on the only available prey items.

More specific objectives are to: 1) determine the seasonal variation of prey species in faecal samples collected over a 12 month period; 2) determine the factors which are crucial for prey availability; 3) calculate required quantity of main prey for basic metabolic requirements; 4) compare the diet composition and the degree of food similarity between American mink and southern river otter.

5.2 Methods

Estimation and comparison of prey availability and diversity was conducted in the Upper Queule River (UQR). To estimate prey availability, amphibian sampling and electrofishing was carried out. Nine patches were examined for occurrence of amphibians. Electrofishing was employed at ten stations in the UQR and on one additional station in the nearby Mahuidanche River during two consecutive dry seasons (adapted from RUIZ-OLMO, 1998, CARSS *et al.*, 1998). Spraints, for diet analysis were collected along the UQR. Water samples for detailed physico-chemical analysis were collected monthly on five stations in UQR and two stations in Mahuidanche River. Figure 5.2.1 is displaying the stations for electrofishing, amphibian inventory and water sample stations.

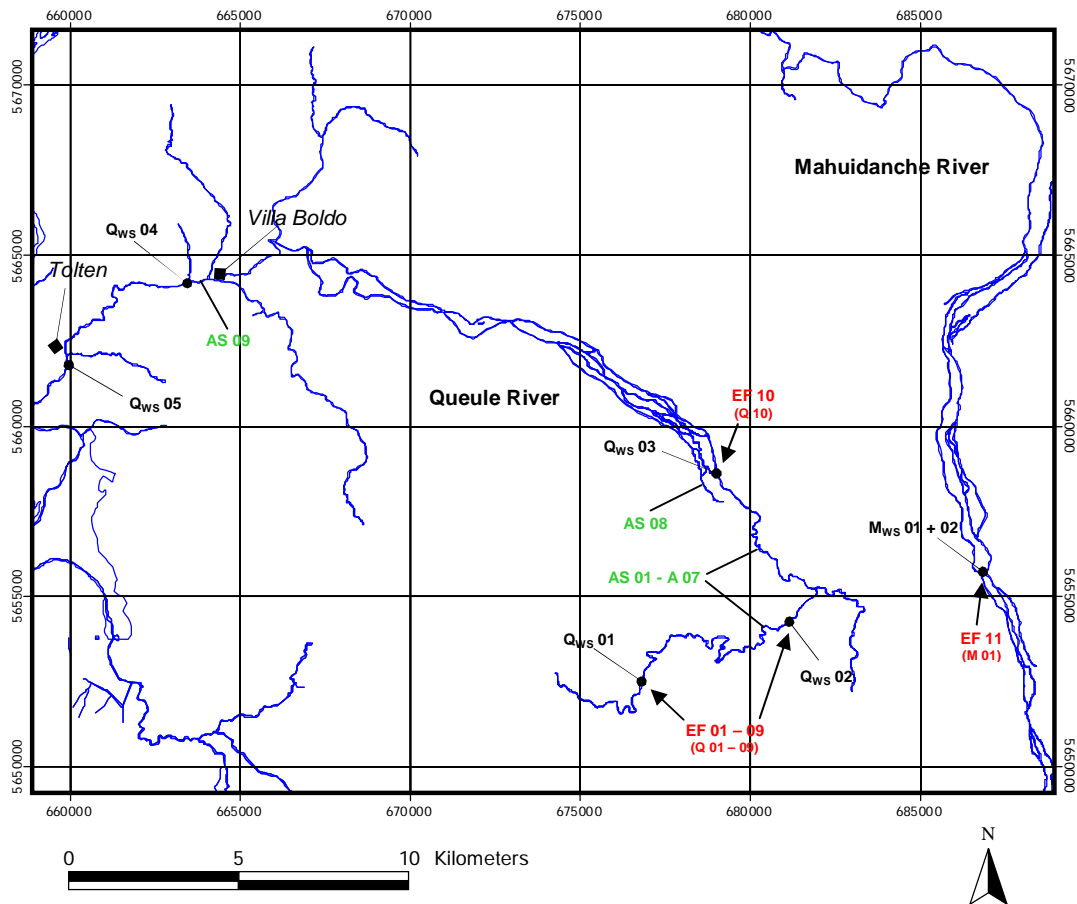


Fig. 5.2.1: Stations where water samples were taken, electrofishing and amphibian sampling took place; Q_{WS} = water sampling stations at Queule River, M_{WS} = water sampling station at Mahuidanche River, EF = electrofishing stations; A = amphibian sampling patches; only main streams are displayed; map is displayed in UTM coordinates

Contents of the stomach of dead southern river otter finds were defined, since they provide insight into the nutritional components (preyed species) which are normally absorbed in the digestive tract and can not be detected in faeces samples.

5.2.1 Sampling methods

5.2.1.1 Amphibians

Inventories of amphibians were carried out using two methods: patch sampling and strait-line drift fences with pitfall traps.

Patch sampling is a method which can be used to examine the densities of amphibians in an environment which are often associated with specific microhabitats or patches, e.g. logs, trees buttresses, bromeliads (JAEGER *et al.*, 1982). Patch sampling can be used to determine the number, relative abundances, and densities of species present in discrete subunits of an area of interest. Given that patches are sampled at random in an area and that each patch constitutes an independent sample, it is possible to make statistical inferences of data with sufficiently large sample size. These inferences can be used either for monitoring or inventory. The number of patches required for statistical treatments depend on the variance in the data, which is not known a priori.

Drift fences with pitfall traps are used to inventory and monitor populations of amphibians and reptiles (SZARO *et al.*, 1988). Drift fences intercept amphibians moving on the surface of the ground within a several meter area and redirect them into a pitfall. Pitfall traps without fences act in a similar manner, but individual traps intercept only a few square centimetres of ground (CORN & BURY, 1990).

All captured amphibians were sexed; weighed in grams on a digital scale (DIPSE XL500; 500 g/0.1 g) and measured for length with a calliper from snout to vent in mm. Nine sites for investigation were chosen at random. The microhabitat was characterised by following variables: sand/stones, silt, leaf litter, marsh grass *Juncetum procerii*, grass (< 10 cm), herbs (> 10 cm), logs, roots, bushes, trees (< 10 m) and big trees (> 10 m).

5.2.1.2 Fish and crustaceans

Two primary methods exist for catching crustaceans: crustacean traps and “red de palito”. Crustacean traps generally only help to determine the occurrence species, not total counts. “Red de palito” is a simple method in which a researcher holds a setup of two sticks connected by a 5 mm wide, conically shaped net, such that the sticks are perpendicular to the ground. The opening of the net has a height of 1 m with its lower portion lined with a metal chain to maintain contact with the riverbed. The researcher collects samples by walking backwards in the river against the current while flipping up objects on the riverbed with his feet. The river current sends the animals hidden under the substrate into the net (5.2.2).

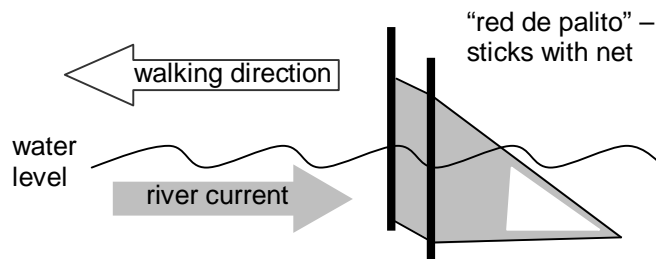


Fig. 5.2.2: Function of “red de palito”

Total length of crustaceans was measured in mm with a calliper (rostrum to final pleon) and weighed in grams on a digital scale (DIPSE XL500; 500 g/0.1 g). The rostrum of each crustacean was measured separately. This was done to determine if a correlation of rostrum length to crustacean weight exists, which provides a basis for discover prey weight or rather prey size preferences in crustacean selection out of faeces samples.

For electrofishing stop-nets were used to reduce emigration and leeway of stunned fish during fishing operations. By following a standard procedure, the river section was fished at least three times upstream in an s-shape manner, with a 30 minutes interval between removals (BOHLIN *et al.*, 1989; CAMPOS & MORENO, 1985; PERRIN & CARUGATI, 2000) until no new samples were collected. Stunned fish were transferred into buckets, measured with a calliper (fork-length in mm) and identified as species. Each fish was weighed in grams (DIPSE XL500; 500 g/0.1 g) and scales were removed with forceps and stored as reference material.

In both cases, “red de palito” and electrofishing, a river section of 100 m² was investigated and all riverbed structures were noted. The riverbed structure was classified into sand (≤ 2 mm), gravel ($> 2 - \leq 63$ mm), stones (> 63 mm - ≤ 500 mm), rocks (> 500 mm), woody debris (dead wood like logs and branches in river), trees/roots and aquatic plants. The classification of grain size was abutted on DIN 4022, except rocks. Additionally, the type of riverbed structure where each single species was captured was listed. After the collection and determination procedure all animals were released in the river section from which they were taken out.

5.2.2 Spraint analysis

Otter spraints were collected during each survey; each day for 14 days of a month for diet analysis. Additionally, mink scats which were placed on the same sites of otter spraints were collected and determined. After storing and labelling the faeces samples in plastic bags, they were washed and rinsed with washing agent in the laboratory. The spraints then were placed in a drying cupboard at a temperature of 75 °C for 72 hours and stored in labelled paper bags for later analyses.

With the help of a stereoscopic microscope (3x – 12x) and a magnifying glass (8x), prey remains found in dried spraints were identified and compared with reference materials obtained in the same or nearby river sections. According to KLOSKOWSKI (1999; 2000) maxillae, articularies and dentaries of fish remains from collected faeces samples were used to identify fish species. Intact rostrums of crustacean were measured with a calliper in mm for later correlation analysis of crustacean body length and weight. The diet composition of *Lontra provocax* was specified according the definition by CARSS & PARKINSON (1996) as frequency of occurrence, whereby the results are presented as *percentage frequency* – the total number of spraints in which a certain prey artefact was found, and as *relative frequency* – the frequency an artefact was found, presented as percentage of all items registered. It was attempted to verify all prey artefacts to species level. However, some fish remains were unidentifiable and therefore combined into one class. The same was done with rodent and bird in mink samples.

5.2.3 Water analysis

Water samples were taken monthly from April 2003 to March 2004, excluding May 2003 due to otter trapping activity. Samples were taken at five stations on the Queule River (Q_{WS} 01 - Q_{WS} 05) and at two stations at the Mahuidanche River (M_{WS} 01 - M_{WS} 02). Water samples were obtained with a Friedinger-water-sampler from 0.50 m depth, but dependent on the season e.g. summer, the sample depth averaged 0.30 m. Two samples were taken from each station, one with a membrane filter (SCHLEICHER & SCHWELL, GERMANY; pore size 0.2 μ m) and one left unfiltered. Samples were stored in 1litre plastic bottles (PE). Additionally, river current was measured with the drift body (surface float) method (SCHWOERBEL, 1994), and river width and depth were noted.

Water sample station 1 (Q_{WS} 01) was influenced by forest management and situated between pine plantations close to a gravel road. Clear-cutting occurred several times during sampling years. The riverbed structure consisted of gravels. River station 2 (Q_{WS} 02) is located close to a school and pasture land which was seldom used. The riverbed structure consists of sand. The third station (Q_{WS} 03) was situated in the ombrophilous swamp forest with sand, roots and woody debris as riverbed structure. Station 4 (Q_{WS} 04) was directly behind the village Villa Boldo, with sand and algae on the riverbed. Station 5 (Q_{WS} 05) lay behind the village Tolten with identical riverbed structure as in Q_{WS} 04. While the waste water from Villa Boldo drained into the River Queule, the village Tolten lead its waste water into the nearby river Tolten. Two additional stations M_{WS} 01 and M_{WS} 02 located in the river Mahuidanche were sampled too. Station M_{WS} 01 was on a normal river section whereas station M_{WS} 02 lay on a tributary stream with no current in summer and adjoined heavily used grazing land. Water sample stations Q_{WS} 01, Q_{WS} 02, Q_{WS} 03 and M_{WS} 02 also were sections where electrofishing was carried out.

Physical measurements

Water temperatures were obtained using the mounted standard thermometer in the Friedinger-water-sampler, with an accuracy of temperature readings of 0.2 °C. Water turbidity was measured by spectrophotometry (Model 2260, DELTA SCIENTIFIC, Inc.), at 440 nm. Conductivity and pH - values were acquired with a pH meter and conductivity meter (HANNA Instruments, U.S.A.).

Chemical measurements

For the measurement of water quality, the chemical parameters, listed in Table 5.2.1 were analysed. This study followed the standard methods (APHA, 1980; ZAHRADNIK, 1981) for analyses of relevant parameters. Titration was used to measure alkalinity, chloride, dissolved oxygen, and German hardness. The parameter ammonia, chemical oxygen demand (COD), nitrate, nitrite, nitrogen, phosphorus, silicate and sulphate were measured using a double-beam spectrophotometer (UV-150-02, SHIMADZU Corporation, Japan) (for specific wave length see Tab. 5.2.1).

Conductivity, pH, and alkalinity, were measured immediately on the premises. Water samples for dissolved oxygen were preserved by acidification. The analysis of additional parameters were carried out (phosphorus, ammonia, nitrate, nitrite, silicate, sulphate, chloride, total hardness) after a brief freezing of water samples in the limnology laboratory of the zoology department at the University Austral, Chile (Laboratorio Limnológico del Instituto de Zoología, Universidad Austral de Chile). Filtered water samples were used for analyses of silicate and nitrite content.

Tab. 5.2.1: Chemical analysis methods for water samples taken in 2003 -2004

Analyse	Method	Specification
Alkalinity	APHA, section 2320 B	By titration with 0.02 mol hydrochloric acid
Ammonia (NH ₃ – N)	APHA, section 4500-NH3 F	Phenate method; colorimetric measure (685 nm)
Chloride (Cl)	APHA, section 4500-Cl C	By titration with mercury nitrate solution
Chemical oxygen demand (COD)	APHA, section 5220 D	Closed reflux colorimetric method; colorimetric measure (585 nm)
Dissolved oxygen (DO)	APHA, section 4500-O C	By iodometric Winkler method
Total hardness	APHA, section 2340 C	By titration with titriplex B (hardness – EDTA)
Nitrate (NO ₃ ⁻ – N)	(ZAHRADNIK, 1981)	By sodium-salicylate solution, sulphuric acid and sodium-hydroxide Seignette salt method; colorimetric measure (420 nm)
Nitrite (NO ₂ ⁻ – N)	(ZAHRADNIK, 1981)	By sulfanil acid and naphthyl-1-amin solution; colorimetric measure (550 nm)
Nitrogen (N _{org})	(ZAHRADNIK, 1981)	By sulphuric acid and hydrogen peroxide; colorimetric measure (685 nm)
Total Phosphorus (TP)	(ZAHRADNIK, 1981)	By ammonium molybdat; colorimetric measure (720 nm)
Silicon (Si)	APHA, section 4500-Si D	By molybdosilicate method; colorimetric measure (660 nm)
Sulphate (SO ₄ ²⁻)	APHA, section 4500-SO ₄ ²⁻ E	Turbidimetric method; colorimetric measure (415 nm)

5.2.4 Ecological parameters and statistics

Resource preference

To measure preference in resources like food or habitat, usually the *forage ratio* or generally called *selection index* is used:

$$w_i = \frac{o_i}{p_i}, \quad (\text{Equation 5.2.1})$$

where w_i = selection index for species i ;
 o_i = Proportion of species i in resources (diet or habitat);
 p_i = Proportion of species i available in environment.

Manly *et al.* (2002) recommend selection indices as *standardized selection index* whereby all resources types are summed up to 1.0:

$$B_i = \frac{\hat{w}_i}{\sum_{i=1}^n \hat{w}_i}, \quad (\text{Equation 5.2.2})$$

where B_i = standardized selection index for species i ;
 \hat{w}_i = selection index for species i .

No preference is indicated by the standardized ratios of 1/number of resources. Relative preference is indicated by values higher as standardized ratios; values lower than this specifies relative avoidance.

Niche overlap

By measuring the resources which are used among species in a guild, the community structure can be better understood. Several equations for niche overlap exist. SMITH & ZARET (1982; cited in KREBS, 1998) discussed that *Morisita's index of similarity* is best as it is nearly zero biased. However, in this study resources are expressed as percentage and therefore the recommended

measure of niche overlap is *Horn's Index* (RICKLEFS & LAU, 1980; SMITH & ZARET, 1982; cited in KREBS, 1998).

$$R_o = \frac{\sum (p_{ij} + p_{ik}) \log(p_{ij} + p_{ik}) - \sum p_{ij} \log p_{ij} - \sum p_{ik} \log p_{ik}}{2 \log 2}, \quad (\text{Equation 5.2.3})$$

where R_o = Horn's index of overlap for species j and k ;

p_{ij} = Proportion resource i is of the total resources utilized by species j ;

p_{ik} = Proportion resource i is of the total resources utilized by species k .

Niche breadth

The niche breadth (niche size, niche width) indicates the specialisation of a species. It can be quantitatively measured by observing the distribution of individuals within resources (KREBS, 1998). In this study the Levins's standardized niche breadth was used, which can be expressed on a scale from 0 to 1.0.

$$B = \frac{Y^2}{\sum N_j^2}, \quad (\text{Equation 5.2.4})$$

$$B_A = \frac{B-1}{n-1}, \quad (\text{Equation 5.2.5})$$

where B = Levins's measure of niche breadth;

N_j = Number of individuals found in or using resource state j ;

$Y = \sum N_j$ = Total number of individuals sampled;

B_A = Levins's standardized niche breadth;

n = Number of possible resource states.

As is often found in the literature, the *number of frequently used resources* is mentioned. This information will be used as well as Levins's standardized niche breadth in the current study.

Species diversity

Diversity is an independent parameter of the species community. It is calculated via species number and dominance structure. In general, two categories of diversity index exist, *Type I* indices and *Type II* indices. Whereby the *Type I* indices are sensitive to rare species, *Type II* indices are most sensitive to changes in common species. The most popular diversity index is the Shannon – Wiener index (sometimes wrongly cited as *Shannon – Weaver* index (WASHINGTON, 1984)). However, the Shannon – Wiener index describes more the rare species in the community analysis (*Type I*), whereby the Simpson's index weight the common species more (*Type II*) (KREBS, 1998). Shannon – Wiener and Simpson's index are measuring exclusively the proportion of individual species to each other, consequently reference values like sample volume or sample area remain without influence. The higher the number of species and/or balanced the occurrence of species, the higher the diversity is in the community.

In this study the Simpson's index is used for measuring species diversity, but to allow for comparison with data presented in the literature, the Shannon – Wiener index calculated with \ln (natural logarithm) is also listed in the results. The Simpson's index can be calculated by the equation:

$$1 - D = 1 - \sum (p_i)^2, \quad (\text{Equation 5.2.6})$$

where $(1 - D)$ = Simpson's index of diversity;

p_i = Proportion of individuals of species i in the community.

The used equation for the Shannon – Wiener index is:

$$H_s = - \sum_{i=1}^s p_i * \ln p_i, \quad (\text{Equation 5.2.7})$$

where H_s = Shannon – Wiener index of species diversity;

s = Number of species;

\ln = natural logarithm;

p_i = Proportion of total sample belonging to i -th species.

Evenness

Evenness or equitability is a measure that quantifies how equally species are represented in a community, whereby the unequally represented community is quantified against a hypothetical equal distribution. When the abundances of all species in a community are equal, evenness is maximal. KREBS (1998) discuss that the Smith and Wilson index is the best available evenness index as it is independent of species richness and is sensitive to both rare and common species in the community. The index is defined as:

$$E_{\text{var}} = \left[\frac{2}{p \arctan \left\{ \frac{\sum_{i=1}^s \left(\log_e(n_i) - \sum_{j=1}^s \log_e(n_j) / s \right)^2}{s} \right\}} \right], \quad (\text{Equation 5.2.8})$$

where E_{var} = Smith and Wilson's index of evenness;

n_i = Number of individuals in species i in sample;

n_j = Number of individuals in species j in sample;

s = Number of species in entire sample.

Species similarity index

To discern how separate areas vary in their fauna composition, a similarity coefficient can be used to measure this difference. Of the many measures of similarity found in the literature, this study uses two, the Soerensen's similarity coefficient and the Renkonen index.

The Soerensen's similarity coefficient allows for a simple comparison of species communities. It takes into consideration both the number and type of species common to two comparable habitats.

The Soerensen's similarity coefficient is:

$$S_s = \frac{2}{2a + b + c}, \quad (\text{Equation 5.2.9})$$

where S_s = Soerensen's similarity coefficient;

a = Number of species in sample A and sample B;

b = Number of species in sample B but not in sample A;

c = Number of species in sample A but not in sample B.

The Sorensen's similarity coefficient produces values between 0 % to 100 %; the higher the value the higher the similarity of species composition (MÜHLENBERG, 1993).

The compliances of dominance proportion between two species communities can be calculated with the Renkonen index. To measure the similarity with the Renkonen index, all community samples have to be standardized to percentages (KREBS, 1998). The equation is:

$$R_e = \sum_i \text{minimum} (p_{1i}, p_{2i}), \quad (\text{Equation 5.2.10})$$

where R_e = Renkonen index, similarity between sample 1 and sample 2;

p_{1i} = Percentage of species i in community sample 1;

p_{2i} = Percentage of species i in community sample 2.

WOLDA (1981; cited in KREBS, 1998) describes this similarity measure as the best quantitative similarity coefficients available. The index ranges from 0 % (no similarity) to 100 % (complete similarity).

Dominance structure

Dominance classes for electrofished species were assigned according to ENGELMANN (1971; cited in MÜHLENBERG, 1993).

32.00	-	100.00 %	eudominant	}	main species
10.00	-	< 32.00 %	dominant		
3.20	-	< 10.00 %	subdominant		
1.00	-	< 3.20 %	recedent	}	companion species
0.32	-	< 1.00 %	subrecedent		
		< 0.32 %	sporadic		

Presence / consistency

The quantity of one species or structure type which is found in a habitat is calculated in relation to the total sum of species/habitats. This is a measure of the distribution for a species within a special investigation area.

$$\text{Presence} = \frac{n_i * 100}{n}, \quad (\text{Equation 5.2.11})$$

where n_i = Number of habitat of species or structure type i ;

n = Number of all habitats.

To calculate the ecological parameters, Excel 2003 and the computer program Ecological Methodology 6.1.1 (Ecological Methodology, 2003) were used.

Calculation of correlation

A rang correlation after Spearman, which is insensitive for outliers, was used to determine a correlation of data. The correlation coefficient provides a degree for linear correlation between two value series. A value of 0 describes that the value series is uncorrelated; values of 1 or -1 are indicating a positive or negative correlation.

Cluster analysis

The cluster analysis was used to classify the electrofished sections by species abundance and amphibian microhabitats. Cluster analysis is used to build classifications of a series of samples. In this study average linkage clustering is used because it is capable of determining the dissimilarity between cluster average values. The most recommended and most frequently used clustering strategy is the unweighted pair-group method using arithmetic averages (UPGMA)(KREBS, 1998). In the UPGMA the distance between two clusters is computed as the average distance between all pairs of objects in the two different clusters. The Euclidean distance setting was used for amphibian microhabitats and the dissimilarity coefficient for river species communities.

Statistical tests

Verification of normal distribution was carried out using the Kolmogorov-Smirnov test. Because samples were not drawn from a normal distribution, differences in weight and length between two amphibian species were analysed for significance using the Mann-Whitney rank sum test. Using χ^2 - Test, the following frequencies were tested: between investigation sites of amphibian samplings; riverbed structure composition of electrofished areas; abundance and biomass of two consecutive years; mink and southern river otter spraints; and between crustacean and fish biomass. ANOVA was applied for the analysis of variances by the examination of species occurrences in riverbed structure by electrofishing and by average weight of captured species by electrofishing. If samples were not normally distributed or had unequal variances, Kruskal-Wallis ANOVA on ranks was conducted. The level of significance was defined as $\alpha = 0.05$ for all tests.

Statistical analyses were conducted by using the computer programs STATISTICA 6.0 (StatSoft, 1984-2001), SigmaStat 3.1 (Systat Software, Inc., 2004), Excel 2003, and Excel Add-in PopTools.

5.3 Results

5.3.1 Diversity and abundance

5.3.1.1 Amphibians

Patch sampling resulted in only two detected species of amphibians during the amphibian survey (Tab. 5.3.1). In total 37 individuals of *Batrachyla leptopus* and 30 individuals of *Batrachyla taeniata* were found. The difference in weight and length (snout – vent) of the two species is highly significant (Mann-Whitney Rank Sum Test for weight: T=1432; p<0.001; and for length: T=1424; p<0.001). The sex ratio for *B. leptopus* is 9:1 (27 males to 3 females) and for *B. taeniata* 8:1 (33 males to 4 females).

Tab. 5.3.1: Amphibian length, weight and proportion of sex of discovered species in the Upper River Queule area

Species	Length in mm (\bar{x})	Weight in g (\bar{x})
<i>Batrachyla leptopus</i>	33.71 (SE=0.167)	2.51 (SE=0.058)
<i>Batrachyla taeniata</i>	38.04 (SE=0.749)	3.78 (SE=0.186)

Figure 5.3.1 displays the vegetation structure for nine examined site in the UQR area. Most of the surveyed area had little diversity in respect to vegetation structure. The pooled data on substrate, named total in the figure, show that the most represented was marsh grass *Juncetum procerii* (31.9 %) and silt (25.9 %), followed by leaf litter (12.8 %) and grass (11.1 %). All other vegetation structure types constitute less than 10 %. The investigated sites reveal highly significant differences ($c^2 = 2417.36; df = 80; p < 0.001$).

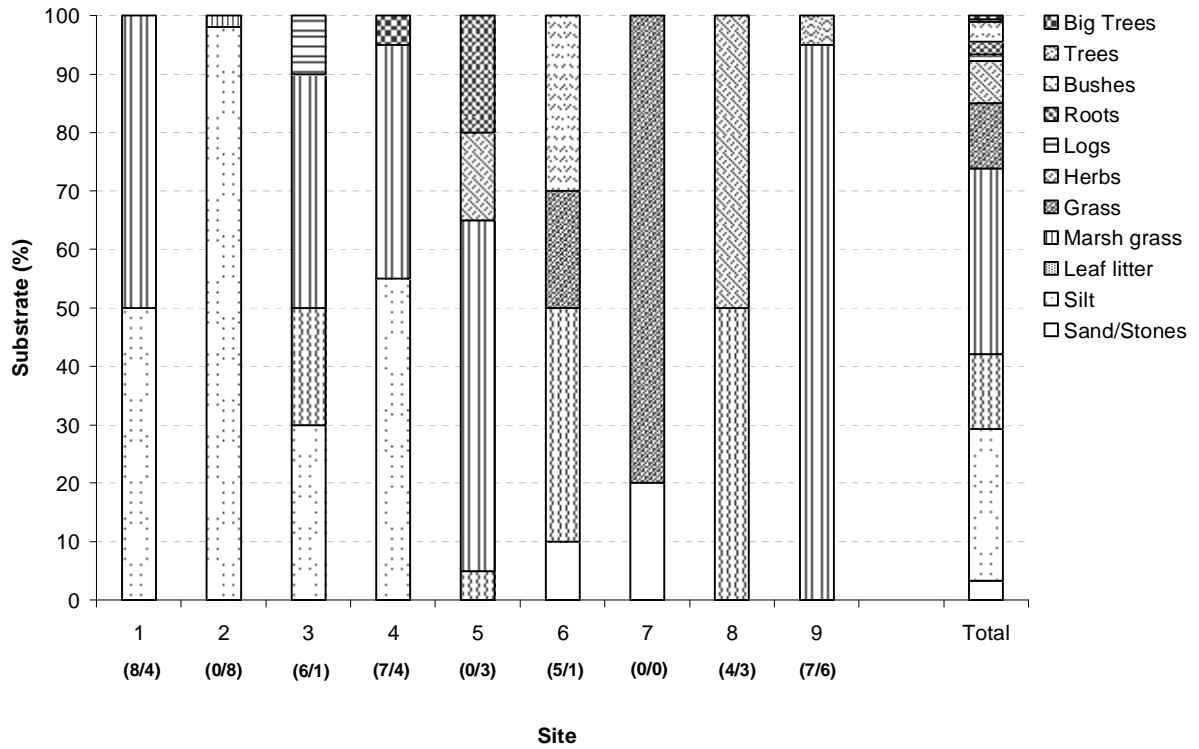


Fig. 5.3.1: Substrate composition of nine explored sites; (x/y) = abundance of *Batrachyla leptopus* and *Batrachyla taeniata*

The dendrogram (Fig. 5.3.2) shows that the Euclidean distance from the main used substrate swamp grass to the other clusters, leaf litter, grass and silt, is highest. The substrates grass and silt build a cluster because they were used less frequently.

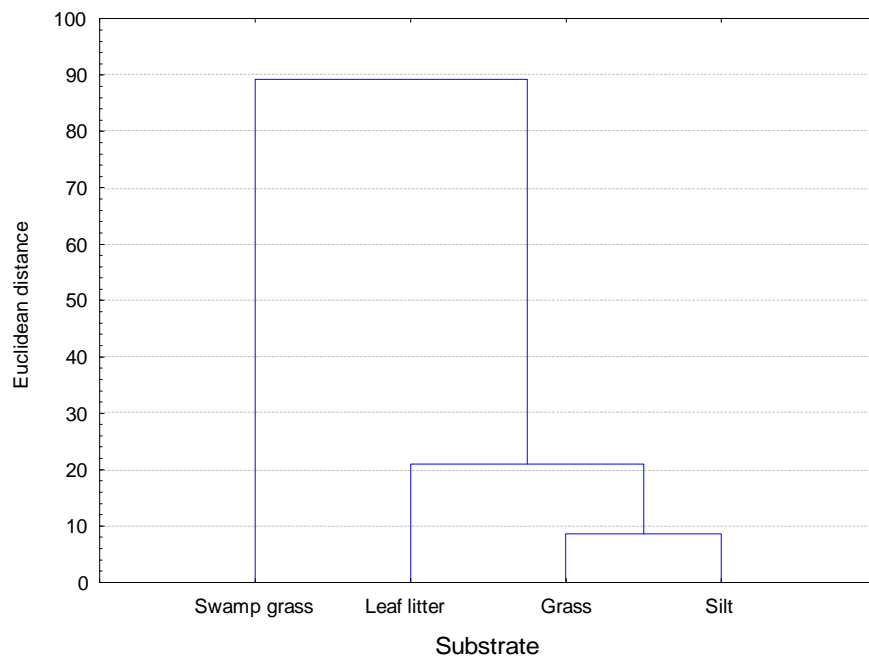


Fig. 5.3.2: Dendrogram of used substrate by two species of the genus *Batrachyla*

B. leptopus is using four out of 11 available vegetation structures as displayed in Figure 5.3.3. The structure forms most commonly inhabited by *B. leptopus* are the variable marsh grass with a standardized selection index (B_i) of 0.486 and leaf litter with 0.387. The other two variables, silt (0.072) and grass (0.056) do not present a common selected vegetation substrate. The second identified species *B. taeniata* inhabited only three substrate types of vegetation consisting of marsh grass (0.606), by leaf litter (0.329), and silt (0.065). A high niche overlap exists between *B. leptopus* and *B. taeniata* ($R_0 = 0.982$; Horn's index of similarity). The Levins's standardized niche breadth for *B. leptopus* and *B. taeniata* is 0.319 and 0.307 respectively. Both species frequently use three resources (substrates).

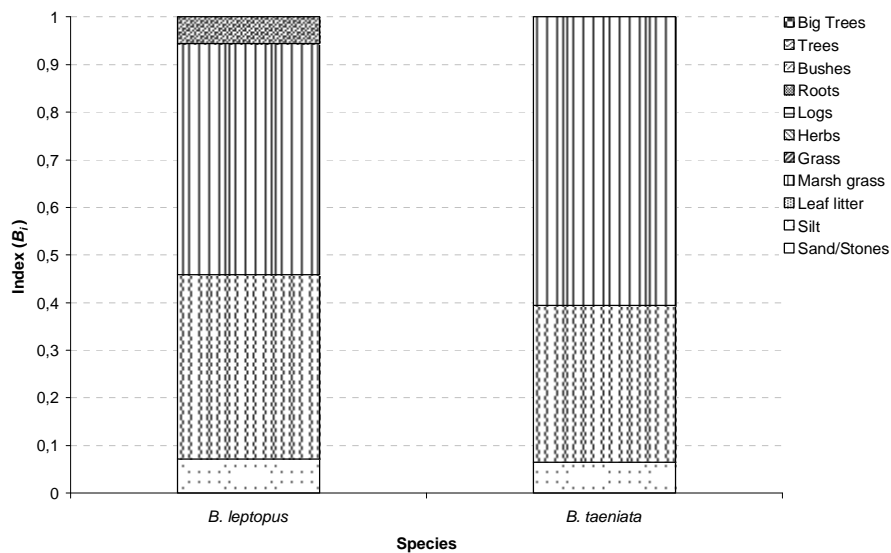


Fig. 5.3.3: Standardized selection index (B_i); vegetation structure where amphibian species were discovered

Strait-line drift fences with pitfall traps were set over 14 days on different locations and in different vegetation structure types. No amphibians were captured during this time span using this method.

Two further species, *Caudiverbera caudiverbera* and *Pleurodema thaul* were discovered occasionally crossing gravel roads and during telemetry studies on *Lontra provocax*.

5.3.1.2 Fish and Crustaceans

By using the “red de palito” gear, two species of crustaceans were discovered (Fig. 5.3.4 a). The majority of the crustaceans were found in the riverbed structures woody debris (75.5 %) by gravel (16.0 %) and stones (5.5 %). In the substrate sand only *Samastacus spinifrons* (3.1 %) was collected, whereas the substrate rock was without any findings.

Stop-net was used while electrofishing to prevent fish from escaping and crustacean for being flushed away with the current. However, the stop-net was insufficient for crustacean and fish smaller than 10 mm . While electro stunned fish was collected easily and swam into the spoon net, crustacean moved their pleon pulsative and “swam” to the water surface area, where it had to be caught immediately for not be carried away by the current. Using electrofishing gear, not only were four species of fish discovered, additionally the total abundance in crustaceans increased (Fig. 5.3.4 b). The total number of discovered crustaceans is three times higher (75.7 %) than it was when collected with the first described method (24.3 %). In general the “red de palito”- method discovered 22.3 % out of 740 individuals and 33.3 % out of six species. Interestingly the most undetected crustaceans were found in the riverbed substrate woody debris. Fish were present in sand, gravel, stones and woody debris but absent in the substrate rocks. The species similarity index was relatively high between the two investigated methods (Soerensen’s similarity coefficient $S_s = 0.750$).

Eleven sections were examined with electrofishing gear in 2003 and five sections in 2004. Ten of these sections were located in the UQR (four in 2004) and one section in the near by Mahuidanche (one in 2004) river for comparison. In total eleven species were discovered using electrofishing. In Table 5.3.2 the scientific names, common names and the status of each located species are described. The riverbed structure was classified into seven categories: sand, gravel, stones, rocks, woody debris, trees/roots and aquatic plants (Appendix 10.4; Tab. C). The presence for the most common substrate types was 90.1 % for woody debris and 81.8 % for sand. The substrate aquatic plant was only found in section eleven and therefore displays the lowest presence with 9.1 %. Within the species,

S. spinifrons shows the highest presence, as it was discovered in all examined sections. The species *Brachygalaxias bullocki*, *Caudiverbera caudiverbera*, *Galaxias maculatus* and *Oncorhynchus mykiss* were also minimally represented (9.1 %), occurring in only one in out of the eleven sections.

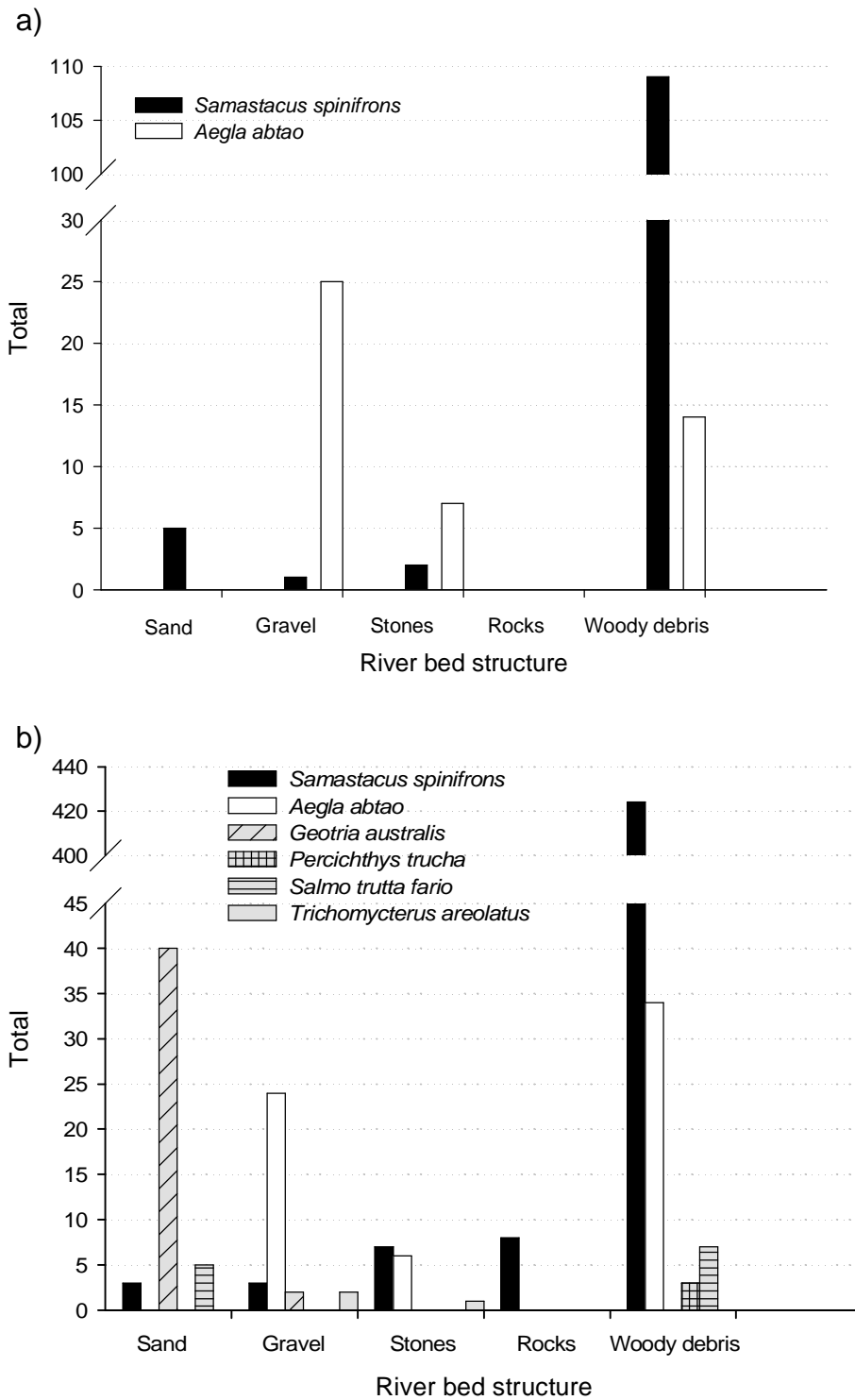


Fig. 5.3.4: Total number of crustaceans and fishes by “red de palito” fishing (a) and electrofishing (b) on five sites in Upper Queule River

Tab.5.3.2: Discovered species in Upper Queule River and Mahuidanche by electrofishing (n.n.= not named)

Family	Scientific name	Common name	Local name	Status
Crustacean				
Aeglidae	<i>Aegla abtao</i>	Squat Lobster	Pancora	native
Parastacidae	<i>Samastacus spinifrons</i>	Crayfish	Camarón de río	native
Fish				
Characidae	<i>Cheirodon galusdai</i>	n.n.	Pocha	endemic
Galaxiidae	<i>Brachygalaxias bullocki</i>	n.n.	Puye	endemic
Galaxiidae	<i>Galaxias maculatus</i>	Jollytail	Puye	native
Geotriidae	<i>Geotria australis</i>	Pouched lamprey	Lamprea de bolsa	native
Percichthyidae	<i>Percichthys trucha</i>	Creole perch	Perca	native
Salmonidae	<i>Salmo trutta fario</i>	Brown trout	Salmon trucha café	introduced
Salmonidae	<i>Oncorhynchus mykiss</i>	Rainbow trout	Trucha arcoiris	introduced
Trichomycteridae	<i>Trichomycterus areolatus</i>	Pencil catfish	n.n.	native
Amphibian (tadpole)				
Leptodactylidae	<i>Caudiverbera caudiverbera</i>	Helmeted water toad	Rana chilena	endemic

The riverbed structure composition of each surveyed site is displayed in Fig. 5.3.5. Other than site Q 03, which only consists of sand, all examined sites include more than one riverbed structure variable. It should be noted that the riverbed structure in the UQR does not contain aquatic plants, whereas site M 01 in Mahuidanche River consists 95 % of aquatic plants and 5 % of woody debris. The main riverbed structure component (Q total) is more diverse in the UQR, whereby sand (37 %), gravel (29 %), and woody debris (22 %) dominated the structure variables. All other structure variables were present under 10 %.

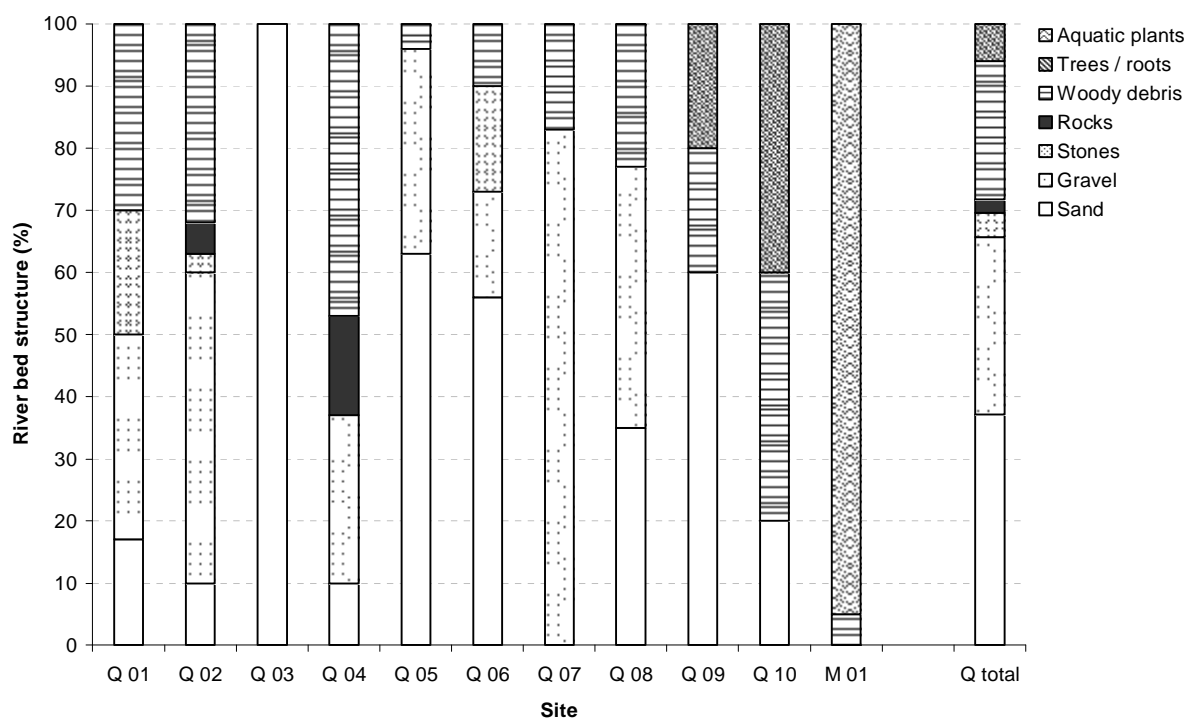


Fig. 5.3.5: River bed substrate composition of the electrofished area (Q = Queule River; M = Mahuidanche River)

The dissimilarity of species community of the examined sites is shown as a dendrogram in Fig. 5.3.6. All investigated river sections branch further into several clusters but the separated site M 01, which displays the only analysed section in the Mahuidanche River. In this river section most aquatic species (9) were discovered.

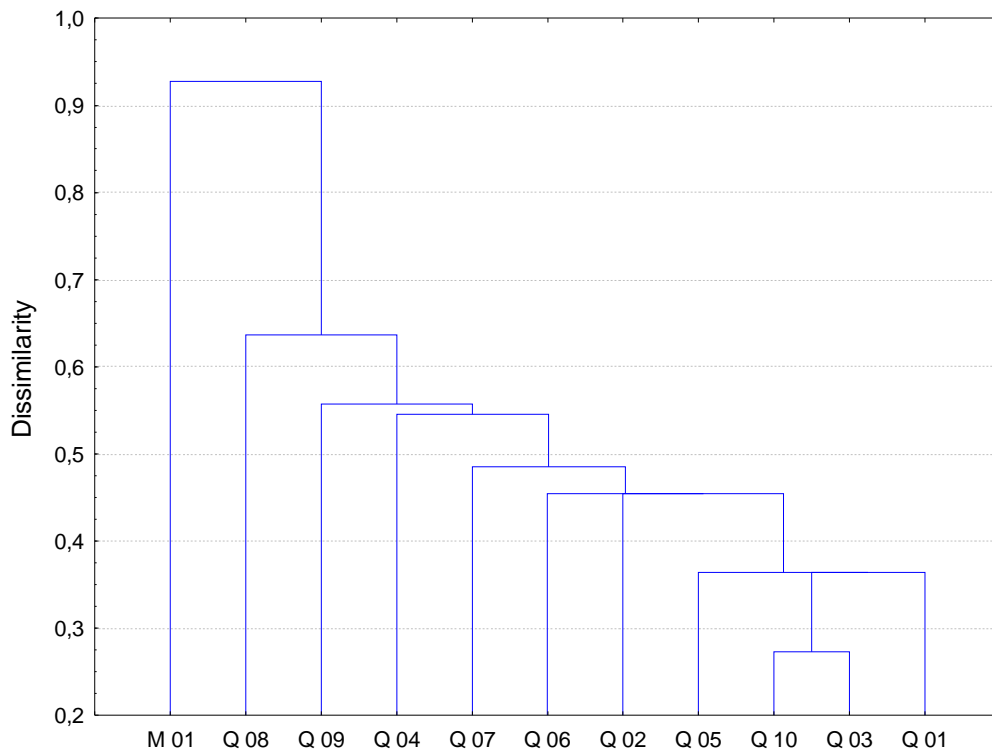


Fig. 5.3.6: Tree diagram resulting from an unweighted pair-group average cluster analysis of river species community (Appendix 10.4; Tab. C); (Q = Queule River; M = Mahuidanche River)

It should be noted that of the eleven electrofished sites only sites Q 02 and Q 07 have a Simpson's diversity index ($1-D$) higher than 0.4 (Fig. 5.3.7). The lowest diversity index was found in site Q 10 with $1-D = 0.04$. Likewise the evenness has a high variance between the examined sites. The highest Smith and Wilson's index of evenness (E_{var}) was found in site Q 01 with $E_{var} = 0.39$. The lowest E_{var} was found in site Q 10 with 0.16. On average the Simpson's diversity index for the UQR is 0.26 and the E_{var} averages 0.25. Whereas $1-D$ is 0.20 and E_{var} is 0.17 for the Mahuidanche River site (M 01). No correlation was found between species diversity and substrate diversity ($r_s = 0.0727$; $p = 0.818$).

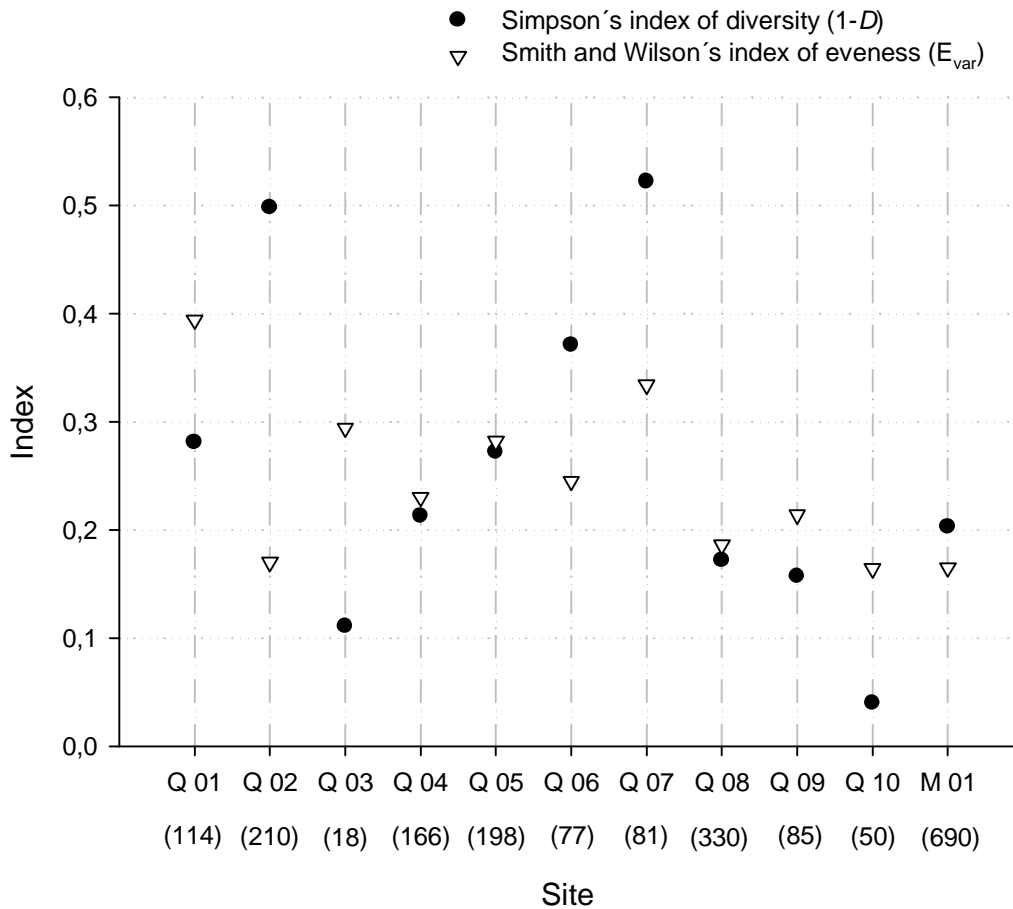


Fig. 5.3.7: Diversity and evenness indices are listed for all electrofished areas. Total number of caught individuals is displayed in parentheses (Q = Queule River; M = Mahuidanche River)

The average weight of electrofished species within the 11 examined sites is displayed in Fig. 5.3.8. The weight of species differed significantly in the median values among the groups (ANOVA on Ranks; $H=369.066$; $df=10$; $p<0.001$). However, the adjacent all pairwise multiple comparison procedures (Dunn's Method) did not detect any significant difference. The highest median in weight is shown by *Oncorhynchus mykiss* ($\tilde{x} = 40.45$; $SE = 9.55$) and the tadpole *Caudiverbera caudiverbera* ($\tilde{x} = 11.90$; $SE = 3.60$). For all other species the median is lower than 2.5 g. The highest range was found in *S. spinifrons* (51.32 g) and *Salmo trutta fario* (179.90 g); however these values are not displayed, as only the first outliers that lie outside the 10th and 90th percentile are shown.

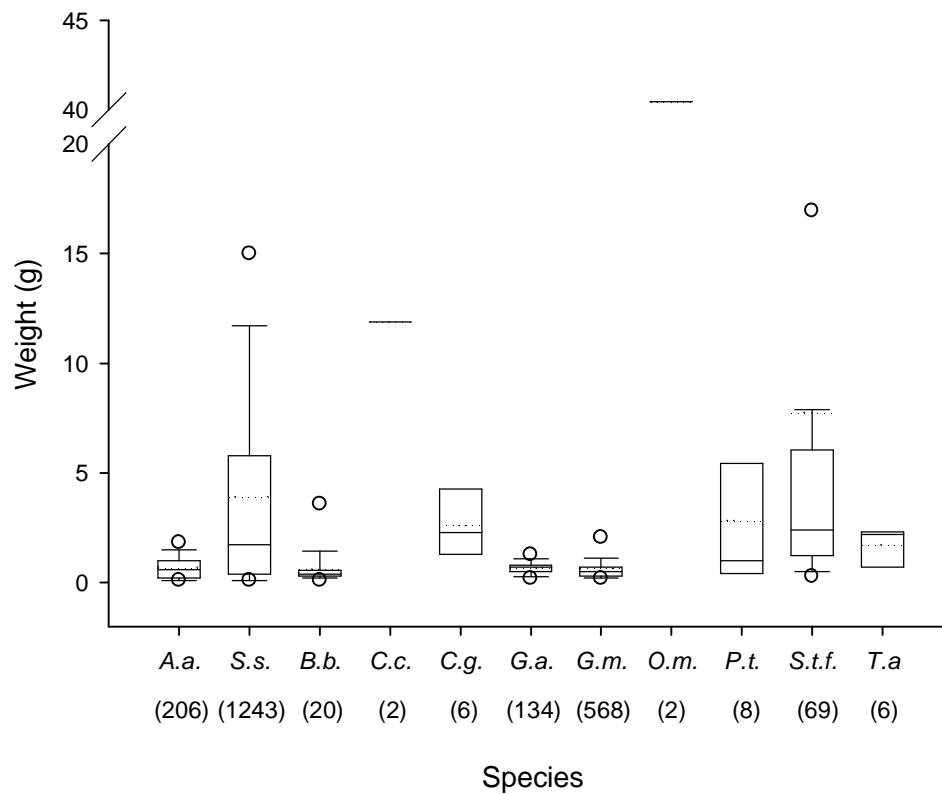


Fig. 5.3.8: Average weight of captured species by electrofishing. (x) = number of individuals; A.a. = *Aegla abtao*; S.s. = *Samastacus spinifrons*; B.b. = *Brachygalaxias bullocki*; *Caudiverbera caudiverbera*; C.g. = *Cheirodon galusdai*; G.a. = *Geotria australis*; G.m. = *Galaxias maculates*; O.m. = *Oncorhynchus mykiss*; P.t. = *Percichthys trucha*; S.t.f. = *Salmo trutta fario*; T.a. = *Trichomycterus areolatus*

The dominance structures of discovered species using electrofishing are displayed separately in Fig. 5.3.9 a, b for the UQR and the Mahuidanche River. *Samastacus spinifrons* present with 81.7 % the eudominant species in the Upper River Queule and is presented with *A. abtao* and *Geotria australis*, the stock forming species. The other fish species are by definition companions which are not markedly associated with this community and are represented by less than 3.2 %. In the Mahuidanche River *Galaxias maculates* forms the eudominant species with 89 %. Here, the crustacean species *S. spinifrons* and *A. abtao* are only subdominant, but still represent the stock forming species. Two more species are listed in the Mahuidanche than in the UQR section, but these are only companion species.

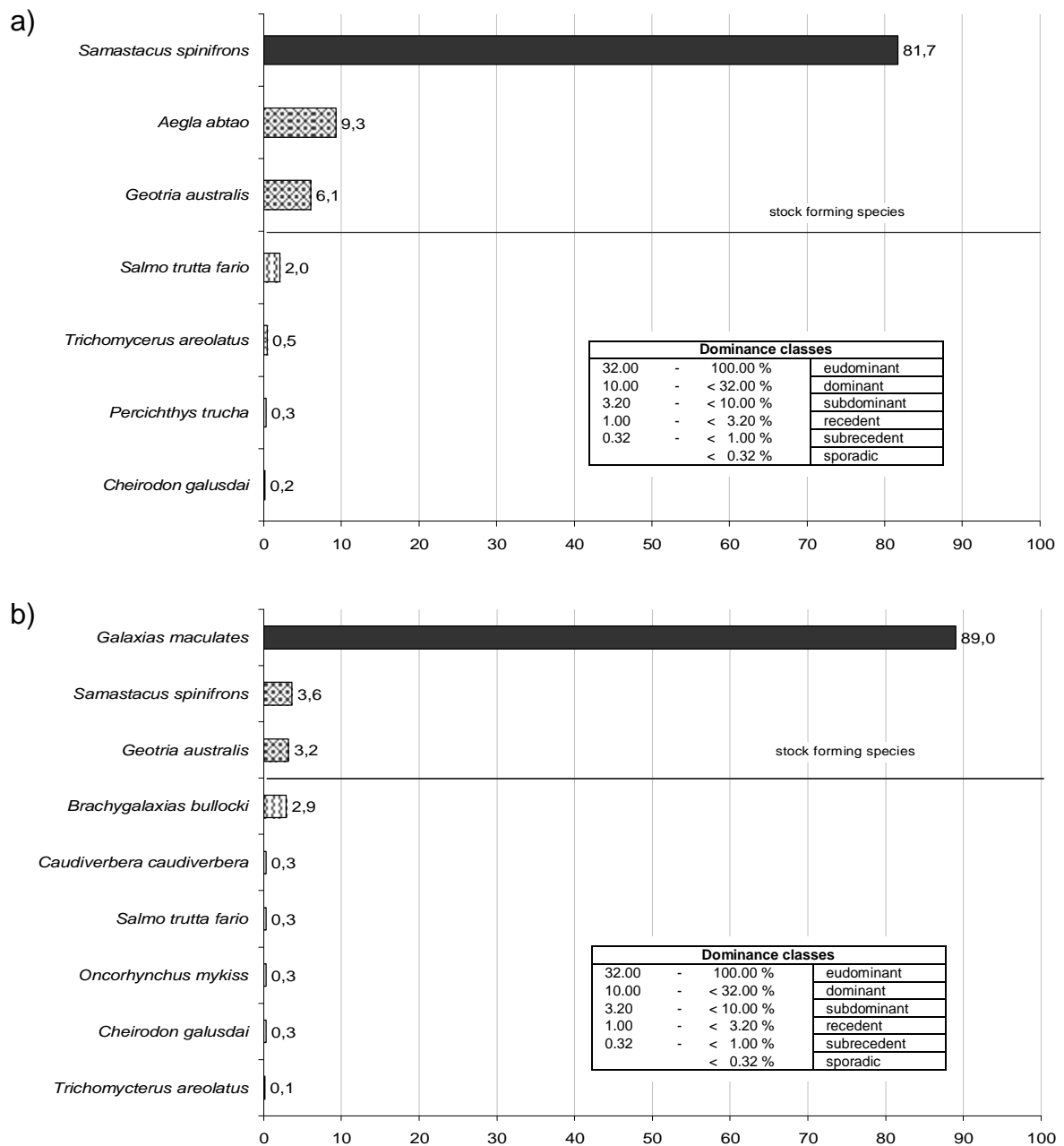


Fig. 5.3.9: Dominance structure for UQR (a) and for Mahuidanche River (b) (Queule River describes 10 sections, Mahuidanche River describes one section)

Within the electrofished samples, two introduced fish species, *Salmo trutta fario* and *Oncorhynchus mykiss*, were identified. As Fig. 5.3.10 displays, these species have different influence in the community composition. In the Upper Queule River 27 of 119 captured fish were *Salmon trutta fario*, whereas in the Mahuidanche electrofished site two *Salmon trutta fario* and additional two *Oncorhynchus mykiss*

(of 664) were collected. The impact on biomass in these areas is very high. In the UQR endemic fish species contribute only 36 % to the biomass. In the Mahuidanche River the impact is much stronger as only 1 % of introduced species form 48 % of the biomass.

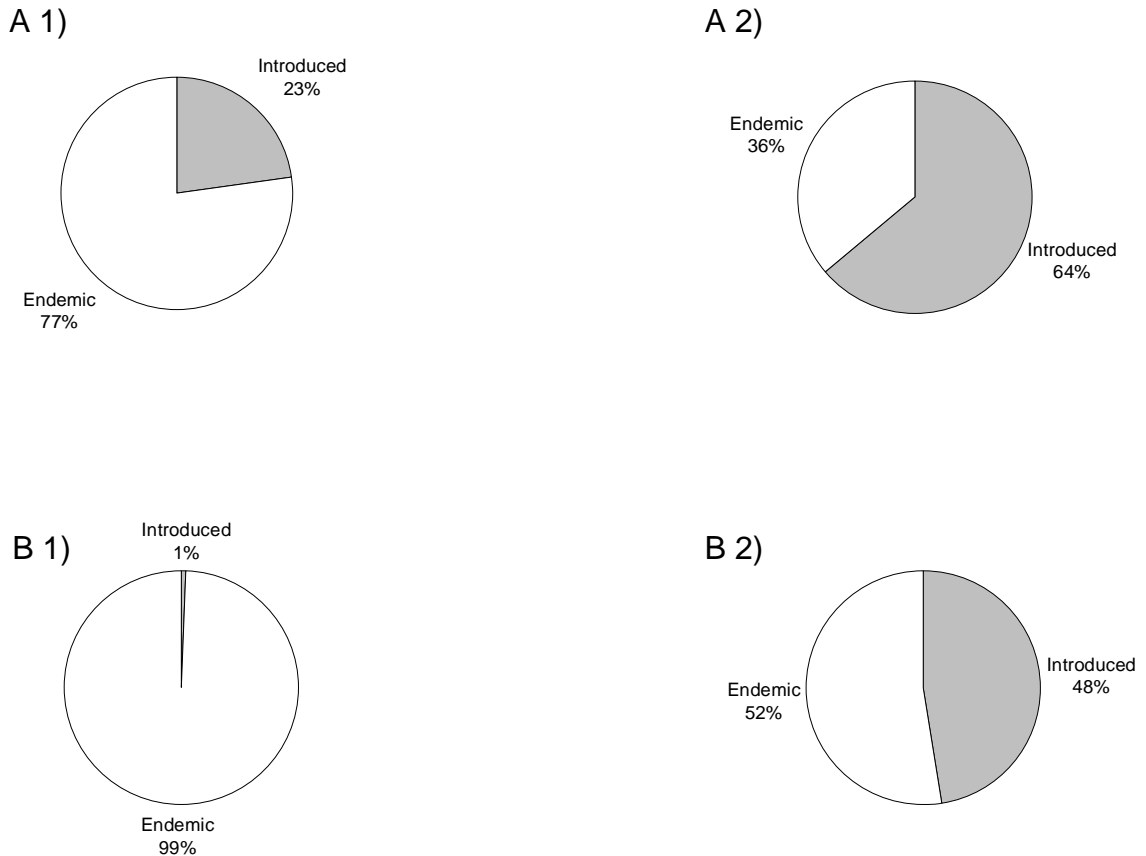


Fig. 5.3.10: Endemic versus introduced fish species in Queule (A) and in Mahuidanche river (B); 1= individuals, 2= biomass.

In the ten sites examined in the UQR, crustaceans accounted for 95.8 % of all biomass, whereby *S. spinifrons* alone accounted for 93.9 % (Fig. 5.3.11). Among the fish species *Salmo trutta fario* was present in the greatest proportion with 60.3 %, followed by *Geotria australis* with 28.2 %. The biomass in crustaceans is 23-fold higher than fish biomass, which is highly significant ($c^2 = 26.237$; $df = 1$; $p < 0.001$). The results of the site 11 of Mahuidanche River contrast starkly from these findings. The single species of crustacean present, *S. spinifrons*, accounts for merely 25.3 % of the total biomass. Fish, primarily,

Galaxias maculatus and *Salmo trutta fario*, produce the principal part with 74.6 %. The biomass in fish on this site is 3-fold higher than crustacean biomass. The difference between crustacean and fish was not tested due to low number of cases within the crustaceans.

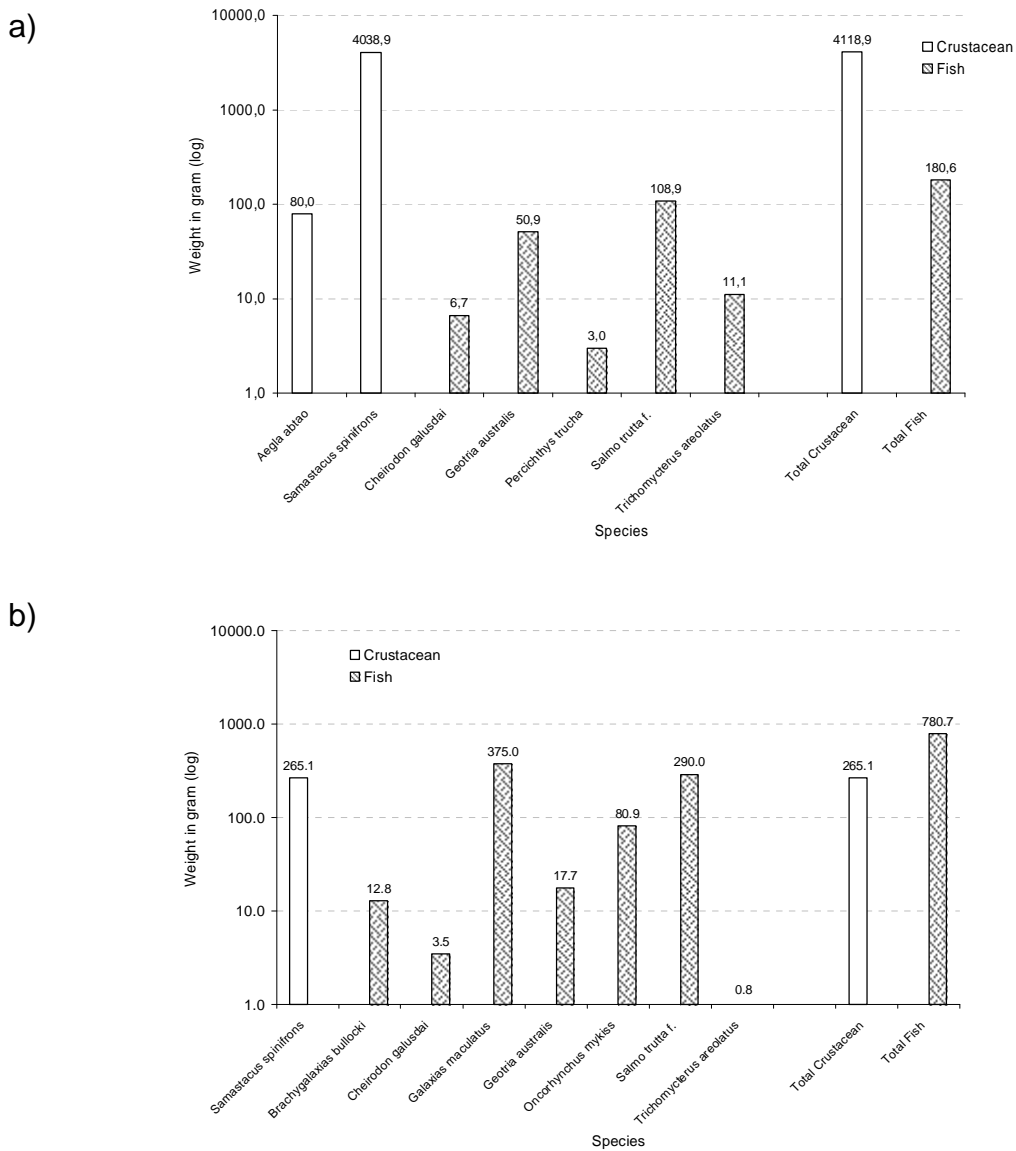


Fig. 5.3.11: Biomass of (a) Upper Queule River (10 sections) and (b) Mahuidanche River 2003 (1 section)

Partitioning species based on the riverbed substrate in which they are found reveals that species richness is highest in aquatic plants (8) where all species but *A. abtao* and *Percichthys trucha* are present (Fig. 5.3.12). On this substrate *Galaxias maculatus* forms the eudominant species with 89.4 %. Woody debris

follows with six species; *S. spinifrons* (92.2 %) and *A. abtao* (5.3 %) being dominant. Five species are present in the gravel substrate; the dominant being *A. abtao* with 74.6 % followed by *S. spinifrons* with 16.9 %. Four species are present in the substrate trees/roots, where *S. spinifrons* is the dominant species with 94.6 % followed by *Salmo trutta f.* with 3.6 %. The same species richness (3) is found in the substrates stones and sand. In the riverbed structure stones crustaceans form the dominant species, *A. abtao* with 53.6 % and *S. spinifrons* with 42.9 % respectively. In contrast *Geotria australis*, with 81.3 %, was the dominant species in sand. Only *S. spinifrons* was found in the substrate rocks (100 %). The Kruskal – Wallis ANOVA on Ranks did not show any significant statistical differences between the riverbed structure and number of individuals found ($H=11.424$, $df=6$; $p=0.076$).

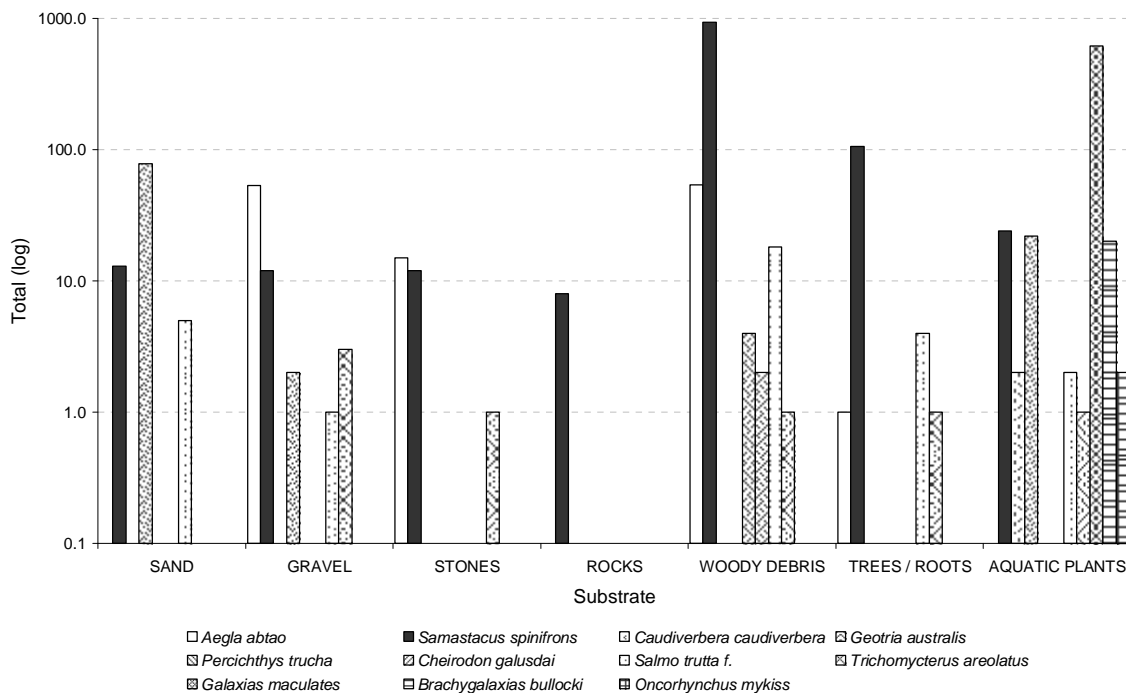


Fig. 5.3.12: Occurrence of species in river bed structure by electrofishing in Upper Queule River and Mahuidanche River 2003 (electrofished areas $n=11$, species $n=11$; total $n=2013$)

The standardized selection index (B_i) shows that *A. abtao* preferred the river bed substrate stones ($B_i = 0.438$), followed by woody debris ($B_i = 0.300$) and gravel ($B_i = 0.238$) (Fig. 5.3.13.). Levins's measure of standardized niche breadth (B_A) is

0.515 and the number of frequently used resource constitutes 3 (Appendix 10.4; Tab. A). For *S. spinifrons* substrates woody debris ($B_i = 0.597$), and trees/roots ($B_i = 0.255$) are most important, whereas rocks ($B_i = 0.056$), stones ($B_i = 0.044$) and aquatic plants ($B_i = 0.037$) are from minor significance. *S. spinifrons* uses two resources/substrates frequently. The B_A value is 0.065.

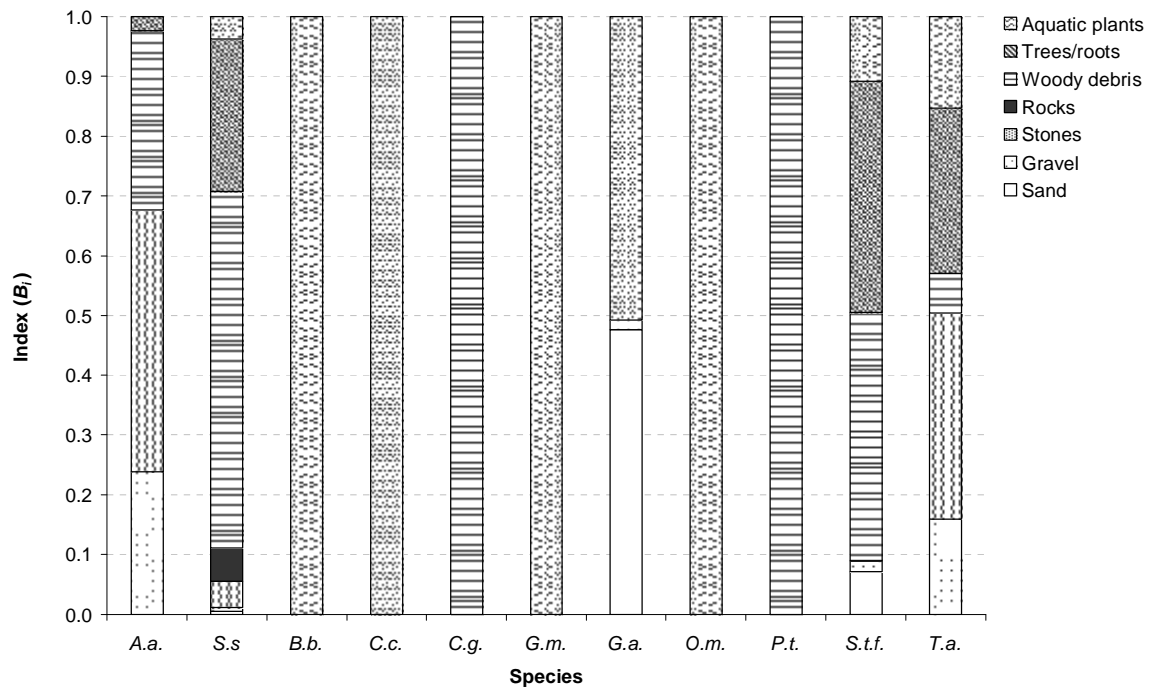


Fig. 5.3.13: Standardized selection index (B_i); river bed structure where species were electro stunned; A.a. = *A. abtao*; S.s. = *Samastacus spinifrons*; B.b. = *Brachygalaxias bullocki*; C.c. = *Caudiverbera caudiverbera*; C.g. = *Cheirodon galusdai*; G.a. = *Geotria australis*; G.m. = *Galaxias maculatus*; O.m. = *Oncorhynchus mykiss*; P.t. = *Percichthys trucha*; S.t.f. = *Salmo trutta fario*; T.a. = *Trichomycterus areolatus*

The species *Brachygalaxias bullocki*, *Galaxias maculatus*, *Oncorhynchus mykiss* and *Caudiverbera caudiverbera* were only found on site 11 in Mahuidanche River in the substrate aquatic plants. Two other species *Cheirodon galusdai* and *Percichthys trucha* were also found in only one substrate, in woody debris. Due to this fact, B_i is 1.00 and B_A was not calculated. *Geotria australis* favourite aquatic plants ($B_i = 0.508$) a little bit more compared to sand ($B_i = 0.477$). The B_A results in 0.298 and the number of frequency used resources composes two. However, it has to be considered, that the bottom substrate of aquatic plants consists of sand.

Woody debris ($B_i = 0.415$) and trees/roots ($B_i = 0.387$) are preferred by *Salmo trutta fario*, followed by aquatic plants ($B_i = 0.108$) and sand ($B_i = 0.071$). Four substrates are frequently used by *Salmo trutta fario* which B_A is 0.357. The B_i values for *Trichomycterus areolatus* were highest for stones ($B_i = 0.345$) and much lower for gravel ($B_i = 0.159$) followed by trees/roots ($B_i = 0.276$) and aquatic plants ($B_i = 0.153$), whereas the substrate woody debris has the lowest value ($B_i = 0.066$). Levins's measure of standardized niche breadth for *Trichomycterus areolatus* is 0.669 and it frequently used 5 substrates. The difference in the river bed structure composition for each species is highly significant ($\chi^2 = 2225.18$; $df = 60$; $p < 0.001$).

For the purpose of comparison electrofishing was carried out in 2003 and 2004 on five similar sites. The difference of abundance and weighted biomass is shown in Tab. 5.3.3. Ten days before the five sites were examined in 2004 heavy rain produced flooding. The differences between total catches and biomass in 2003 and 2004 are highly significant ($c^2 = 359.792$; $df = 10$; $p < 0.001$) ($c^2 = 184.439$; $df = 10$; $p < 0.001$). The proportion of the abundance of the crustaceans *A. abtao* to *S. spinifrons* in 2003 was 11 % to 89 % which changed to 31 % to 69 % in 2004 following the flooding. This difference is highly significant ($c^2 = 56.342$; $df = 1$; $p < 0.001$). Furthermore the difference for fish between 2003 and 2004 was also highly significant ($c^2 = 447.291$; $df = 14$; $p < 0.001$) which was mainly attributed to the absence of *Galaxias maculatus*, which had a strong influence on the samples of 2003 versus 2004 (85.77 %, entirety of column; 99.84 %, entirety of row). Riverbed structures in the some section changed in 2004 due to flooding and strong current.

Tab. 5.3.3: Total abundance and biomass of five electrofished sections in 2003 and 2004 after flood

Species	Total		Biomass (g)	
	2003	2004	2003	2004
Crustaceans (Σ)	(710)	(262)	(3537.9)	(801.8)
<i>Aegla abtao</i>	79	82	116.6	64.4
<i>Samastacus spinifrons</i>	631	180	3421.3	737.4
Fish (Σ)	(717)	(65)	(1036.7)	(150.1)
<i>Brachygalaxias bullocki</i>	20	0	12.8	0.0
<i>Cheirodon galusdai</i>	4	1	10.3	0.1
<i>Galaxias maculatus</i>	615	0	375.0	0.0
<i>Geotria australis</i>	50	26	60.0	20.2
<i>Oncorhynchus mykiss</i>	2	0	80.9	0.0
<i>Percichthys trucha</i>	1	4	19.9	19.7
<i>Salmo trutta fario</i>	20	34	469.7	110.1
<i>Trichomycterus areolatus</i>	5	0	8.1	0.0
Amphibians (tadpole) (Σ)	(2)	(0)	(23.8)	(0.0)
<i>Caudiverbera caudiverbera</i>	2	0	23.8	0.0
Total	1429	327	4574.6	951.9

5.3.2 Spraint analysis

5.3.2.1 *Lontra provocax*

Over a time span of 17 months an average of 13 ($SE=1.49$) spraint sites used by southern river otters in the UQR were discovered, whereby the minimum of six sites were detected in April 2003 and the maximum of 29 sites were found in August 2003 (Fig. 5.3.14). The averaged number of faeces samples collected per month was 37.2 ($SE=7.3$). The minimum number of faeces samples occurred in December 2006 with nine samples and the maximum in August 2003 with 132 samples. There is a strong correlation between sprainting sites and number of faeces sampled ($r_s=0.746$; $p<0.001$).

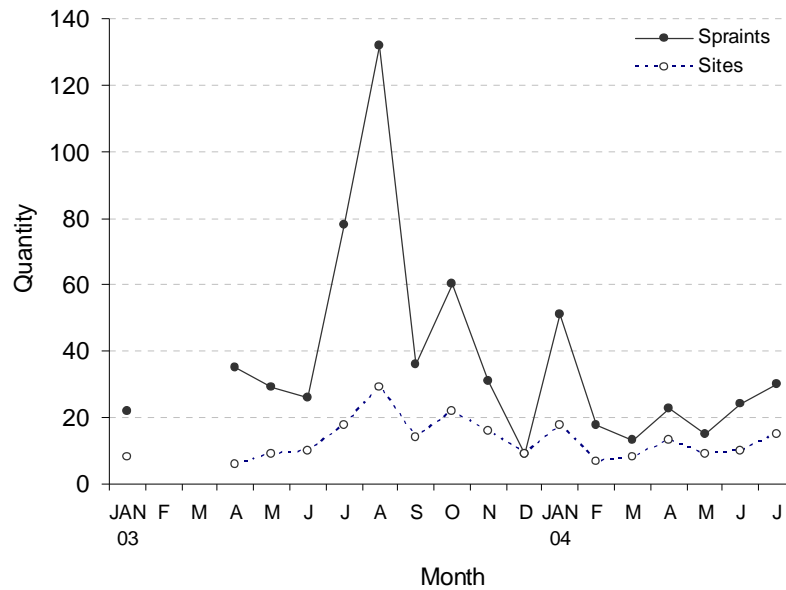


Fig. 5.3.14: Quantity of spraint sites and spraints on the Queule Upper River (n=630 spraints)

Little precipitation was noted in the Queule River area between January and May, where precipitation events never exceed 100 mm (Tab. 5.3.4). From August through September moderate precipitation (100 – 250 mm) was recorded, though the months of June and July received the most precipitation. The lowest number of faeces samples was collected in months with low precipitation, whereas months of high precipitation provided more faeces samples in 2003. The numbers of low precipitation in 2004 are similar to 2003; however there is a difference in faeces samples between 2003 and 2004 when highest precipitation occurred. The difference between collected faecal samples in lowest and highest precipitation seasons is insignificant (One-Way ANOVA: $F = 1.399$; $df = 16$; $p = 0.279$).

Tab. 5.3.4: Precipitation and average numbers of otter faeces

Precipitation	Low	Medium	High
	(< 100 mm)	(100 – 250 mm)	(> 250 mm)
2003	26.6	53.6	52
2004	24	---	27

Of the examination of 606 otter spraints, relative frequency was found to be highest for *Samastacus spec.* with 77.4 % (Tab. 5.3.5). The presence of the second crustacean *Aegla spec.* is very low with 3.4 %. Only some parts of fish in spraint samples were available for observation. Most fish items (71.1 %) were not identifiable to any specific species. Only remains of *Percichthys trucha*, *Oncorhynchus mykiss* and *Salmo trutta fario* were identifiable in the faeces. The mollusc *Diplodon chilensis* was also observed, however, the relative frequency was very low (0.5). In sum, six quantifiable species were detected. The calculated Levins's standardized niche breadth results in 0.05 for *Lontra provocax*. The number of frequently used resources resulted in 1.

Tab. 5.3.5: Prey species occurrence, relative frequency (RF) and percentage frequency (PF) in otter spraint collected for 17 month in 2003 and 2004 (n=606)

Species	Occurrence	RF (%)	PF (%)
Total crustaceans	615	80.8	
<i>Samastacus spec.</i>	589	77.4	97.19
<i>Aegla spec.</i>	26	3.4	4.3
Total fish	142	18.7	
<i>Percichthys trucha</i>	8	1.1	1.3
<i>Oncorhynchus mykiss</i>	12	1.6	2.0
<i>Salmo trutta fario</i>	21	2.8	3.5
Undetermined	101	13.3	16.7
Total bivalves	4	0.5	
<i>Diplodon chilensis</i>	4	0.5	0.7
Σ of occurrence / frequencies	761	100	

While *Samastacus spec.* was found in more than 87 % ($SE = 0.77$) of all monthly collected faeces (Fig. 5.3.15), *Aegla spec.* occurred sporadically and was found only in July 2004 at a relatively high frequency (54.2 %) ($\bar{x} = 10.6$ %; $SE = 5.55$). The bivalve *Diplodon chilensis* occurred only four times in low quantity. However, fish items were found frequently ($\bar{x} = 23.9$ %; $SE = 3.35$) in southern river otter

sprints. In both years frequency of fish items were highest in July with 51.3 % and 40.7 % respectively. No data are available for February 2003 and March 2003 as no field stay took place in this time. The difference of food composition between wet (June - September) and dry season (October - May) is highly significant ($c^2 = 70.11$; $df = 7$, $p < 0.001$).

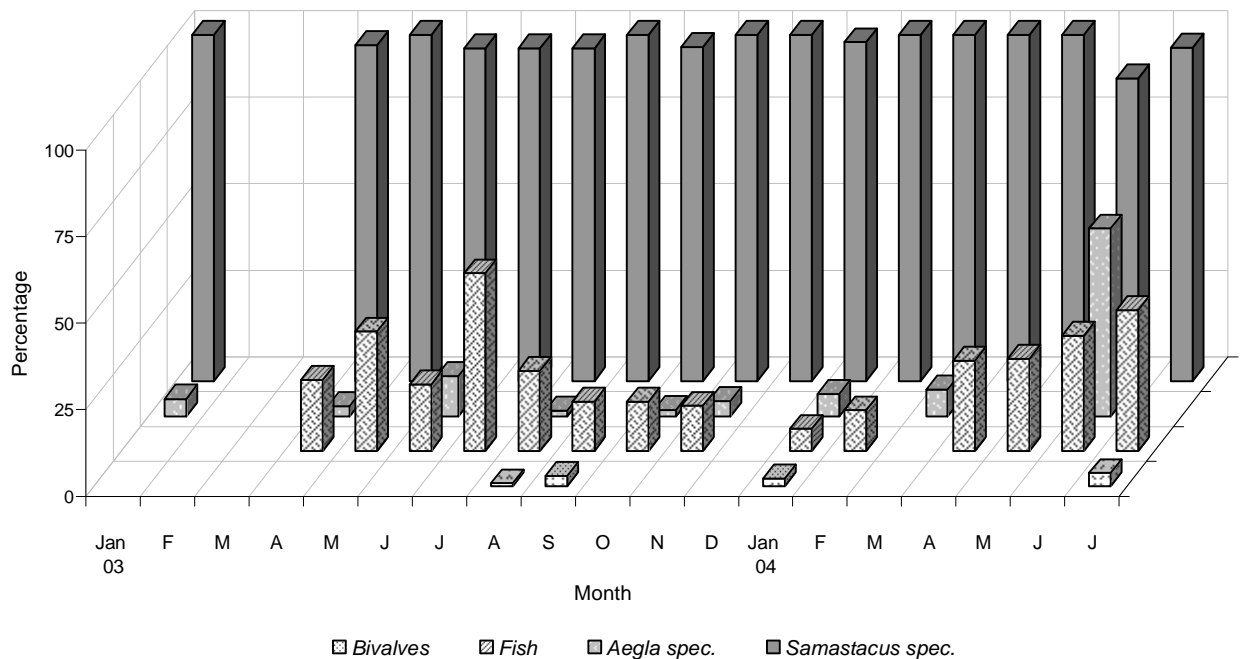


Fig. 5.3.15: Monthly occurrence of prey remains in southern river otter spraints

By summarizing the collected spraint samples of all four seasons, a trend of prey occurrence is visible (Fig. 5.3.16). While crustaceans are found in almost 100 % (96.7 % - 99.0 %) of otter spraints in all seasons, fish remains increase in frequency from summer with 5.2 % to 26.5 % in autumn and 31.9 % in winter. From the winter season to spring the finding of fish items increases to 12.5 %.

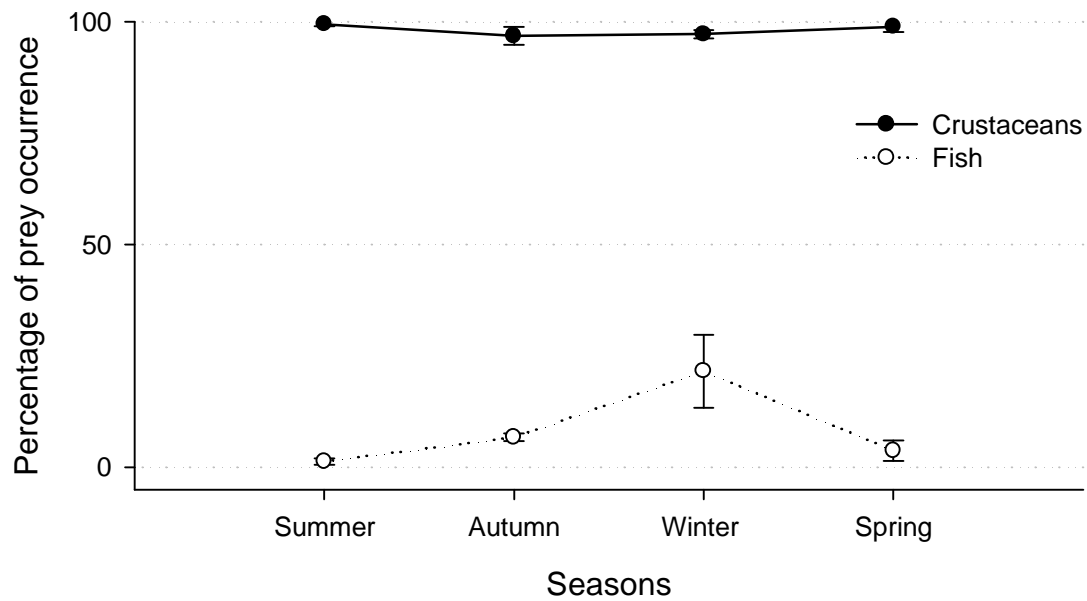


Fig. 5.3.16: Seasonal frequency of prey remains in otter spraint

Stomach content

The stomach content of two southern river otter was examined. The other otter which died in captivity was not used for further analysis as it was only fed fish.

The male subadult – adult southern river otter was from the UQR, whereas the female adult southern river otter was found in the River Cruces (close to Valdivia). Stomach and intestine were rinsed thoroughly and prey items were identified. In both sexes only the crustacean species *S. spinifrons* was detected and no fish remains.

5.3.2.2 *Mustela vison*

The prey occurrence and relative frequency of 24 mink sprains is shown in Tab. 5.3.6. The main prey items are rodents with a relative frequency of 60.5 %, followed by the crustacean *Samastacus spec.* with 36.8 %. One bird was found with a relative frequency of 2.6 %.

Tab. 5.3.6: Prey species occurrence, relative frequency (RF) and percentage frequency (PF) in mink spraint (n=24)

Species	Occurrence	RF (%)	PF (%)
Total crustaceans	14	36.8	
<i>Samastacus spec.</i>	14	36.8	58.3
Total rodent	23	60.5	
Undetermined	23	60.5	95.8
Total Bird	1	2.6	
Undetermined	1	2.6	4.2
Σ of occurrence / frequencies	38	99.9	

The spraints of *Mustela vison* comprise only 3.8 % of the total faecal samples collected (Fig. 5.3.17; Tab. 5.3.7). A highly significant difference of sample frequency exists between mink and southern river otter ($c^2 = 59$; $df = 16$; $p < 0.000$). Most samples of mink (8) were found in November, in contrast to *Lontra provocax* for which the maximum numbers of samples (130) were found in August 2003.

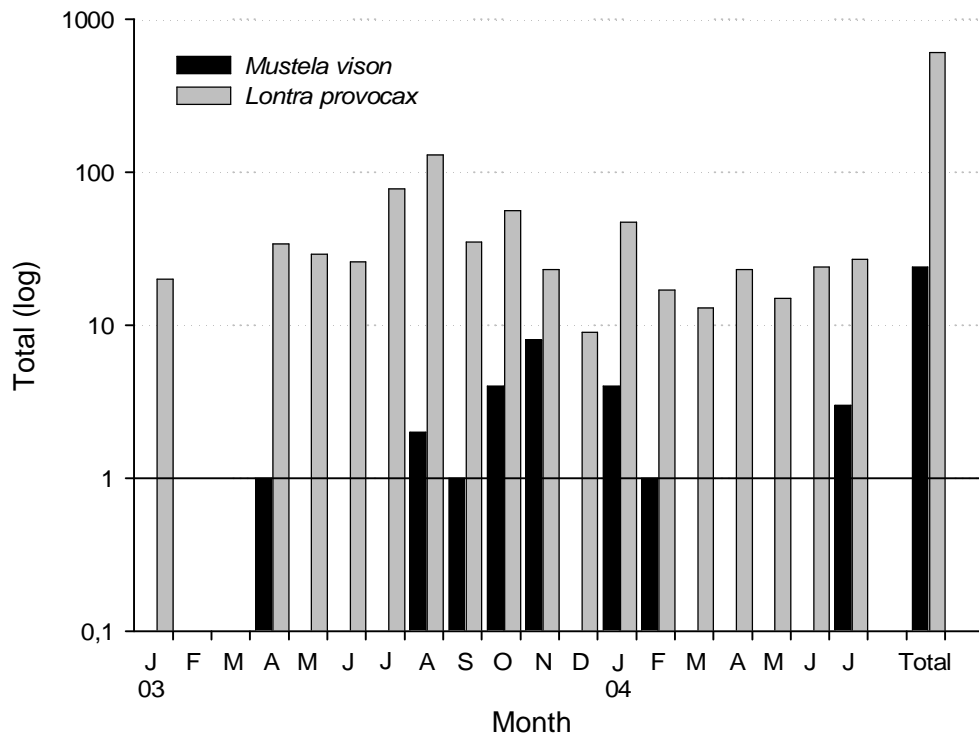


Fig. 5.3.17: Monthly occurrence of mink and southern river otter spraints

The species richness found in spraint samples of *Mustela vison* was 50 % as great as those of southern river otters (Tab. 5.3.7). In contrast to this, the diversity indices Shannon-Wiener and Simpson as well as the Smith and Wilson index for evenness were higher for mink. The Renkonen-Index for similarity of food resources between determined food items in faeces samples of mink and southern river otter is $R_e = 36.84\%$.

Tab. 5.3.7: Diet diversity from spraints collected on the Queule river 2003 – 2004 (H' - Shannon – Wiener Diversity Index; (1-D) = Simpson's diversity index)

Index	<i>Lontra provocax</i>		<i>Mustela vison</i>
Total Abundance	606	>	24
Species Richness	6	>	3
Shannon's H'	0.496	<	0.768
Simpson (1-D)	0.201	<	0.511
Smith and Wilson's E_{var}	0.240	<	0.309

5.3.3 Prey availability versus diet composition

Relative frequencies of available prey species found in the UQR and detected in faecal samples are compared in Tab. 5.3.8. Prey abundances were calculated using data from electrofishing only in 2003, whereas the abundance of prey in faecal samples includes all collected samples during 2003 to 2004. No correlation was detected between prey availability and diet composition ($r_s = 0.537$; $p > 0.05$). This is due to the absence of the fish species *Ch. galusdai*, *G. australis* and *T. areolatus* in faecal samples. In contrast to the ranked fish species, which show no similarity in ranking order (except *Ch. galusdai*), the rank order of crustaceans is identical. Unidentified fish were not considered in ranking. The Renkonen-Index, which measures similarity between the aquatic species composition and the dietary composition of *L. provocax* is calculated as $R_e = 83.7\%$.

Tab. 5.3.8: Relative frequency (RF) of collected aquatic animals in river versus detected in faeces of the southern river otter. Rank order in brackets

Species	in river (RF)	in faeces (RF)
Total crustaceans	91.0	81.2
<i>Samastacus spec.</i>	81.7 (1)	77.8 (1)
<i>Aegla spec.</i>	9.3 (2)	3.4 (2)
Total fish	9.1	18.7
<i>Percichthys trucha</i>	0.3 (6)	1.1 (5)
<i>Oncorhynchus mykiss</i>	0.0 (8)	1.6 (4)
<i>Salmo trutta fario</i>	2.0 (4)	2.8 (3)
<i>Cheirodon galusdai</i>	0.2 (7)	0.0 (7)
<i>Geotria australis</i>	6.1 (3)	0.0 (7)
<i>Trichomycterus areolatus</i>	0.5 (5)	0.0 (7)
Undetermined*	0.0	13.0
Total	100.1	99.9

* not considered in rank order

5.3.4 Required quantity of staple prey

The weight, rostrum length, and total length of crustaceans caught by electrofishing were measured. Fig. 5.3.18 presents the linear regression of rostrum length to total length, rostrum length to weight (log transformed), and total length to weight (log transformed) for the crustacean species *S. spinifrons* and *A. abtao*.

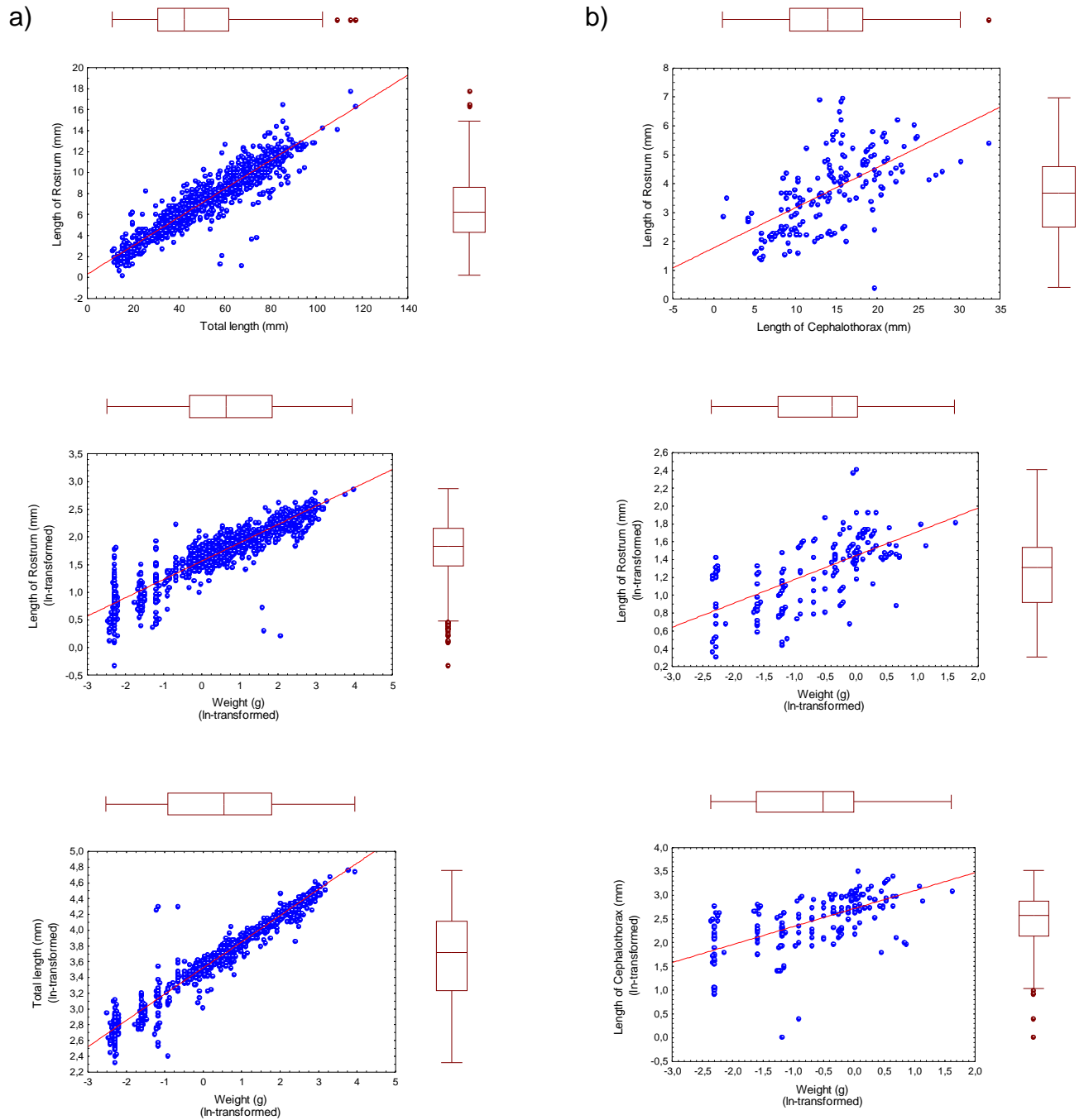


Fig. 5.3.18: Correlation of rostrum and total length of (a) *Samastacus spinifrons* (n=1242) and (b) *Aegla abtao* (n=190)

The cephalothoraxes length of *A. abtao* was considered instead of total length due to this species' morphology. The correlation coefficient for linear regression between the rostrum length and total length of *S. spinifrons* is $r=0.943$ ($n=1242$; $SE=7.121$). A high correlation coefficient was also found for the variables weight / total length ($r=0.887$; $SE=2.409$) as well as for weight / length of rostrum ($r=0.883$; $SE=2.882$), indicating that the dependent variables can be predicted from a linear combination of the independent variables ($p<0.001$) (Tab. 5.3.9). For the crustacean *A. abtao*, a lower correlation coefficient between the length of cephalothoraxes and rostrum length was found, namely $r=0.535$ ($SE=4.877$). The correlation coefficients for weight / length of rostrum ($r=0.459$; $SE=0.553$) and weight / length of cephalothoraxes do not differ significantly ($r=0.579$; $SE=0.522$). However, the dependent variables also can be predicted from a linear combination of the independent variables ($p<0.001$).

Tab. 5.3.9: Regression equation for measured values on *S. spinifrons* and *A. abtao*

Variables	Regression equation	ANOVA
<i>Samastacus spinifrons</i>		
Total length / length of rostrum	Total length = $3.173 + (6.541 * \text{length of rostrum})$	($F=9868.499$; $df=1$; $p<0.001$)
Weight / length of rostrum	Weight = $-4.979 + (1.413 * \text{length of rostrum})$	($F=2810.297$; $df=1$; $p<0.001$)
Weight / total length	Weight = $-5.311 + (0.211 * \text{total length})$	($F=4562.064$; $df=1$; $p<0.001$)
<i>Aegla abtao</i>		
Length of cephalothoraxes / length of rostrum	Length of cephalothoraxes = $6.681 + (2.031 * \text{length of rostrum})$	($F=74.562$; $df=1$; $p<0.001$)
Weight / length of rostrum	Weight = $0.132 + (0.169 * \text{length of rostrum})$	($F=50.705$; $df=1$; $p<0.001$)
Weight / length of cephalothoraxes	Weight = $-0.0792 + (0.0604 * \text{length of cephalothoraxes})$	($F=102.799$; $df=1$; $p<0.001$)

Faeces samples were inspected for the presence of intact rostrums of crustaceans. Figure 5.3.19 shows the results for rostrums of *S. spinifrons* and *A. abtao*. A total of 107 measurable rostrums of *S. spinifrons* and eight of *A. abtao* were detected. The average length of the rostrum for *S. spinifrons* is 7.328 mm ($SE=0.259$; Min.-Max.: 0.100 mm – 16.600 mm) while for *A. abtao* it is 4.002 mm ($SE=0.339$; Min.-Max.: 2.600 mm – 5.190 mm). Both samples were tested for normal distribution with Kolmogorov-Smirnov test. Both data sets of the samples match the expected pattern of normal distribution (*S. spinifrons*: K-S Dist. = 0.053; $p>0.200$; *A. abtao*: K-S Dist. = 0.190; $p>0.200$).

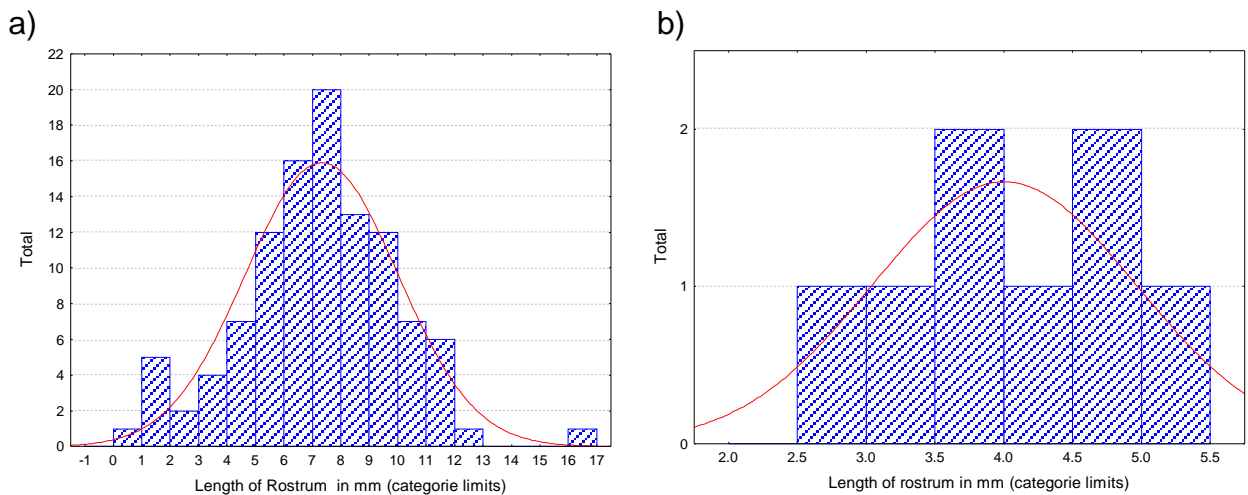


Fig. 5.3.19: Total number and length of rostrums found in spraints of *Lontra provocax*; a = rostrum length of *Samastacus spinifrons*, b = rostrum length of *Aegla abtao* (red line displays the predicted normal distribution)

The average daily crustacean consumption of *Lontra provocax* was calculated using the caloric intake of an otter in captivity (see Chapter 2) as a reference. The median caloric intake of the southern river otter in captivity was 1707.50 kcal. Its diet consisted of fish. The caloric content in kcal/g of *S. spinifrons*, collected in the Upper River Queule, was measured at the Institute of Animal Production at the University Austral of Chile, Valdivia (Instituto Producción Animal, Universidad Austral de Chile). It amounted to 99 kcal/100 g.

The average rostrum length of *S. spinifrons* is 7.328 mm. Using the equation:

$$\text{Weight (g)} = -4.979 + (1.413 * \text{length of rostrum})$$

and inserting the value for the rostrum gives:

$$\text{Weight (g)} = -4.979 + (1.413 * 7.328) = 5.375$$

To convert to kcal, the outcome is multiplied by 0.99 kcal (0.99 kcal/g *S. spinifrons*), which results in 5.322 kcal for an averaged consumed *S. spinifrons* by *Lontra provocax*. To reach the quantity of 1707.5 kcal, the southern river otter has to ingest 317.7 crustaceans of *S. spinifrons*. The resulting 5 % and 95 % percentile in reference to the measured rostrum in southern river otter spraints constitutes 149.8 and 1922.8.

By inserting the rostrum length of 4.002 mm of *A. abtao* in following equation, it results in:

$$\text{Weight (g)} = 0.132 + (0.169 * 4.002) = 0.808.$$

In contrast to previous calculations, the kcal/g of *A. abtao* is 0.88 kcal/g. This value was converted as it was presented as J/g wet weight in CIANCIO & PASCAL (2006), whereby 1 Joule = 0.238 calorie. From this follows, that an averaged eaten *A. abtao* had a kcal content of 0.701 kcal. To attain 1707.5 kcal, an adult southern river otter would have to eat 2435.8 individuals (5 % / 95 % percentile = 1922.8 / 3395.8).

5.3.5 Water analysis

River current

The annual mean river current was strongest at the first water sample site $Q_{WS} 01$ in the Queule River (0.9 m s^{-1}) with a peak in spring 2003 (November) of 2.0 m s^{-1} (Appendix 10.4; Tab. D). Lowest average river current was measured at water sample station $Q_{WS} 03$ (0.4 m s^{-1}). At the two water sample sites in Mahuidanche River the annual average was 0.3 m s^{-1} .

Water temperature; Turbidity; Electrical conductivity; pH

The annual average water temperature for the five stations in UQR ranged between $11.2 \text{ }^{\circ}\text{C}$ and $12.3 \text{ }^{\circ}\text{C}$ (Fig. 5.3.20). Lowest water temperature was measured on the first water sample station ($Q_{WS} 01$) with $6.8 \text{ }^{\circ}\text{C}$ (Fig. 5.3.20) in winter (August 2003). Highest water temperature was found in station $Q_{WS} 03$ with $18.6 \text{ }^{\circ}\text{C}$ in summer (January 2004).

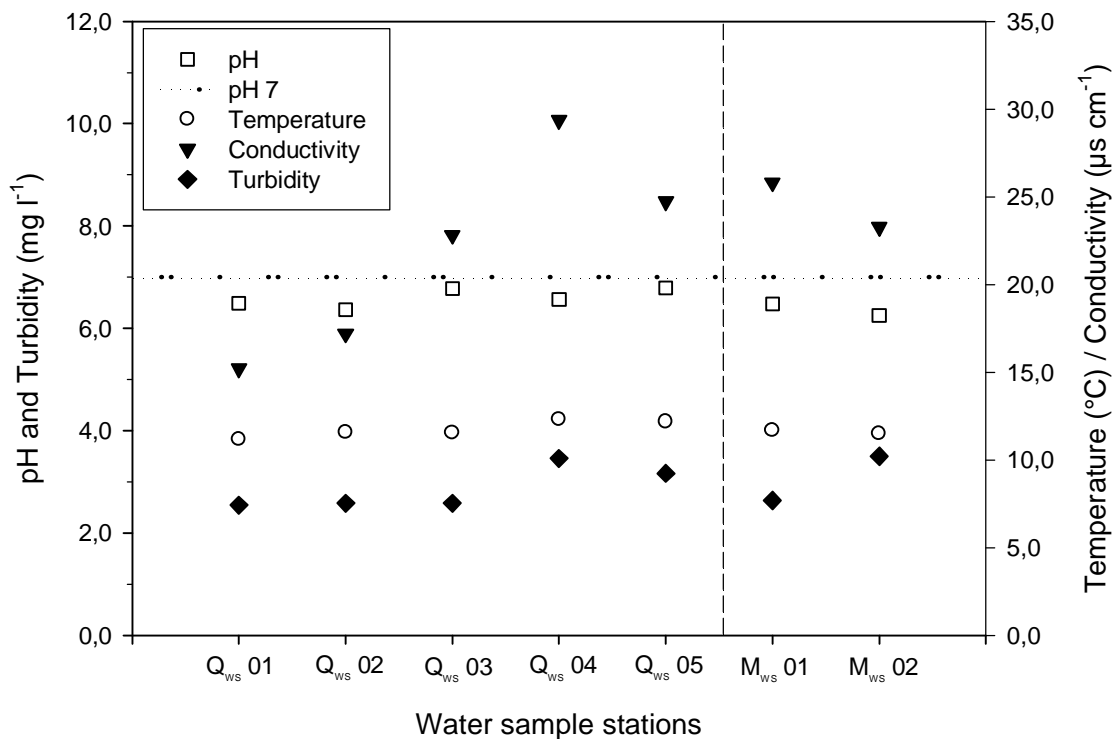


Fig. 5.3.20: Mean annual pH, temperature and electrical conductivity at five Upper River Queule ($Q_{WS} 01 - Q_{WS} 05$) and two Mahuidanche River ($M_{WS}01 - M_{WS} 02$) water sample stations

The annual average water temperatures for the stations M_{WS} 01 and M_{WS} 02 in Mahuidanche River averaged 11.5 °C to 11.7 °C with a range from 7.0 °C in July 2003 to 17.1 °C in January 2004 (Appendix 10.4; Tab. D).

The annual mean turbidity showed little variation between sample stations and ranged from 2.5 – 3.5 mg l⁻¹ (Fig. 5.3.20). Highest concentrations were found at water sample station Q_{WS} 04 and M_{WS} 02 with 7.0 mg l⁻¹ in autumn (March 2003) and in winter (August 2003), respectively (Appendix 10.4; Tab. D).

The pH value in the UQR and Mahuidanche River was always below pH 7.0, which stands for a temperate basic watercourse (Fig. 5.3.20; Appendix 10.4; Tab. D).

Electrical conductivity in the UQR was low on average (Fig. 5.3.20). The lowest annual mean value was measured at the sample station Q_{WS} 01 with 15.2 $\mu\text{S cm}^{-1}$ and the highest value at the fourth station (Q_{WS} 04) with 29.4 $\mu\text{S cm}^{-1}$. However, the lowest conductivity was measured at station Q_{WS} 01 in winter (September) with 6.0 $\mu\text{S cm}^{-1}$ and highest conductivity was observed at the water sample station Q_{WS} 03 in winter 2003 (August) with 59.0 $\mu\text{S cm}^{-1}$ (Appendix 10.4; Tab. D). At the water sample stations M_{WS} 01 and M_{WS} 02 in Mahuidanche River the annual mean values ranged between 23.3 – 25.8 $\mu\text{S cm}^{-1}$. The highest value was measured at station Q_{WS} 05 in winter 2003 (July) with 128 $\mu\text{S cm}^{-1}$. The conductivity in the UQR steadily increased from the first water sampling station to the fourth (Q_{WS} 01 - Q_{WS} 04) and decreased at the fifth station (Q_{WS} 05).

Chemical oxygen demand; dissolved oxygen demand

In the Queule River station Q_{WS} 01 the lowest annual mean value of chemical oxygen demand (COD) was measured (6.3 mg l⁻¹) with an increasing trend towards the fifth water sample station (11.0 mg l⁻¹) (Fig. 5.3.21; Appendix 10.4; Tab. D). The lowest COD was measured at Q_{WS} 02 with 0.5 mg l⁻¹. The first water sampling station in Mahuidanche River had the lowest annual mean COD value at 5.2 mg l⁻¹, and at the second station the value was 8.8 mg l⁻¹.

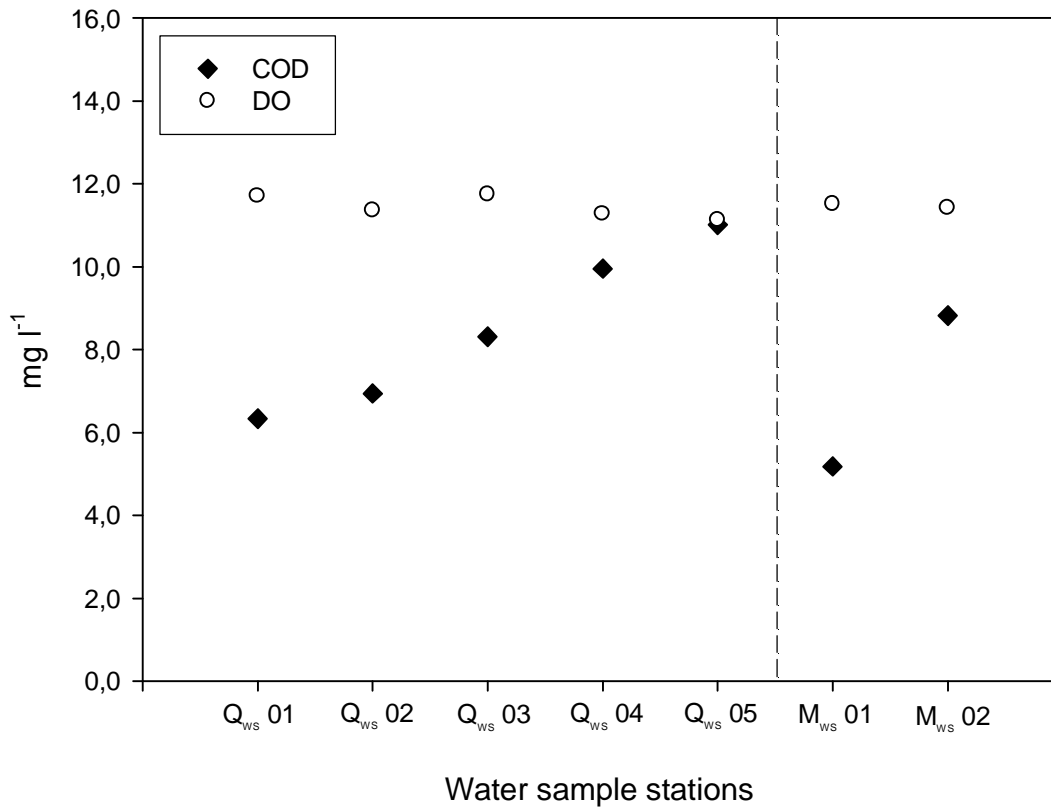


Fig. 5.3.21: Mean annual Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) at five Upper River Queule (Q_{WS} 01 – Q_{WS} 05) and two Mahuidanche River (M_{WS} 01 – M_{WS} 02) water sample stations

Both rivers were consistently well oxygenated. The saturation was usually almost 100 % or higher. The annual mean dissolved oxygen (DO) concentration varied between 11.13 – 11.74 mg l⁻¹. The lowest DO was measured in the summer (March 2004) at M_{WS} 02 with 7.87 mg l⁻¹ and the highest in the spring (September 2003) 17.73 mg l⁻¹ at station M_{WS} 01 (Fig. 5.3.21; Appendix 10.4; Tab. D).

Nitrate, Nitrite, Ammonia, N_{org}

The concentration of nitrates, nitrites, ammonia, and organic nitrogen were very low in general (Fig. 5.3.22; Appendix 10.4; Tab. D). Nitrates levels were higher in the UQR (53.7 – 85.2 µg l⁻¹) than in the Mahuidanche River (33.8 – 48.6 µg l⁻¹). An increase of nitrates was monitored downstream of Queule River. The highest

values were found at Q_{WS} 02 (March 2003) and Q_{WS} 04 (August 2003) with $182.5 \mu\text{g l}^{-1}$.

Annual mean values of nitrites ranged from $0.44 - 1.14 \mu\text{g l}^{-1}$. The concentrations of nitrites at Q_{WS} 04 and Q_{WS} 05 were up to two times greater than at the first three stations. Some difference exists between M_{WS} 01 and M_{WS} 02 whereby the range was between $0.45 - 0.95 \mu\text{g l}^{-1}$.

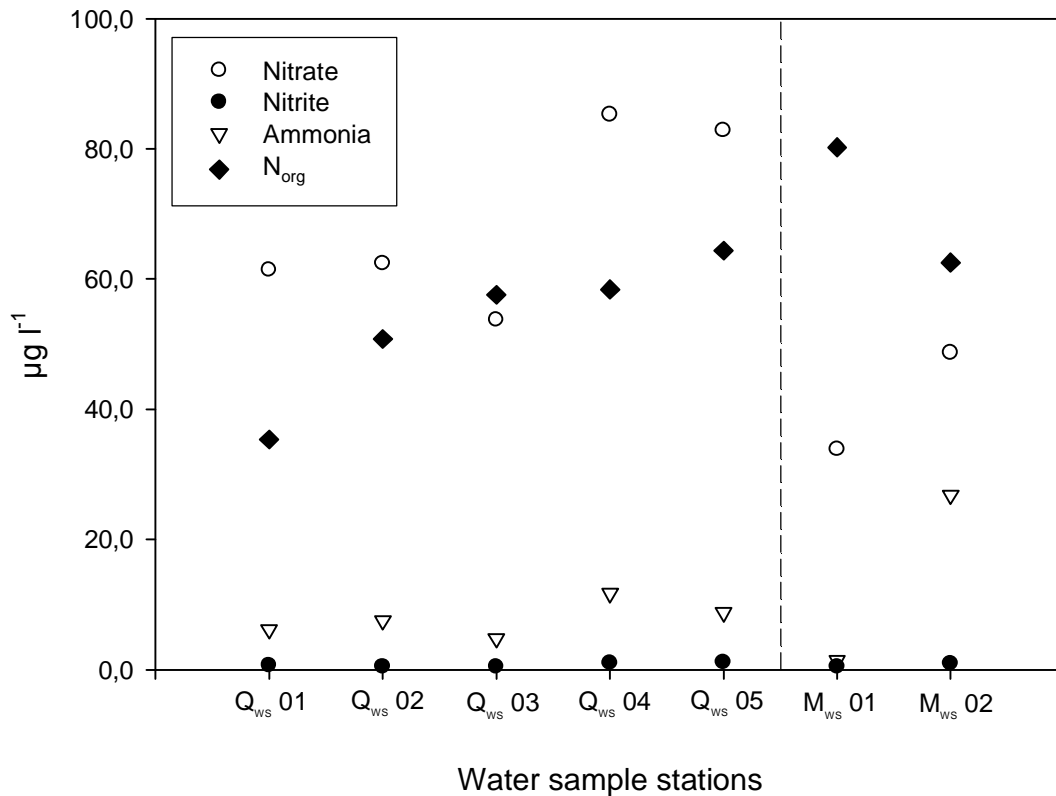


Fig. 5.3.22: Mean annual nitrates, nitrites, ammonia and nitrogen at five Upper River Queule (Q_{WS} 01 – Q_{WS} 05) and two Mahuidanche River (M_{WS} 01 – M_{WS} 02) water sample stations

In the UQR the annual mean ammonia concentration varied between $4.8 - 11.7 \mu\text{g l}^{-1}$, the highest concentration detected at Q_{WS} 02 (in March 2003) and Q_{WS} 04 (in August) with $52.5 \mu\text{g l}^{-1}$. The lowest annual mean value for ammonia was measured in Mahuidanche River in the station M_{WS} 01 with $1.4 \mu\text{g l}^{-1}$, however likewise the highest value in M_{WS} 02 with $26.8 \mu\text{g l}^{-1}$.

Organic nitrogen concentration also increased progressively from the first water sample station (Q_{WS} 01 = $35.4 \mu\text{g l}^{-1}$) in Queule River towards the fifth station

($Q_{WS\ 05} = 64.4\ \mu\text{g l}^{-1}$). However, the highest annual mean organic nitrogen value was measured in Mahuidanche River ($M_{WS} = 80.2\ \mu\text{g l}^{-1}$).

Sulphate; Phosphate; Silicate

The range of annual mean sulphate concentration found in the Queule River was $1.2 - 3.0\ \text{mg l}^{-1}$. The highest values were measured in $Q_{WS\ 02}$ and $Q_{WS\ 04}$ with $11.8\ \text{mg}$ in March and August 2003 respectively. The water sample stations in Mahuidanche River also revealed different values as $M_{WS\ 01}$ was lower ($1.3\ \text{mg l}^{-1}$) as $M_{WS\ 02}$ ($2.5\ \text{mg l}^{-1}$) (Fig. 5.3.23; Appendix 10.4; Tab. D).

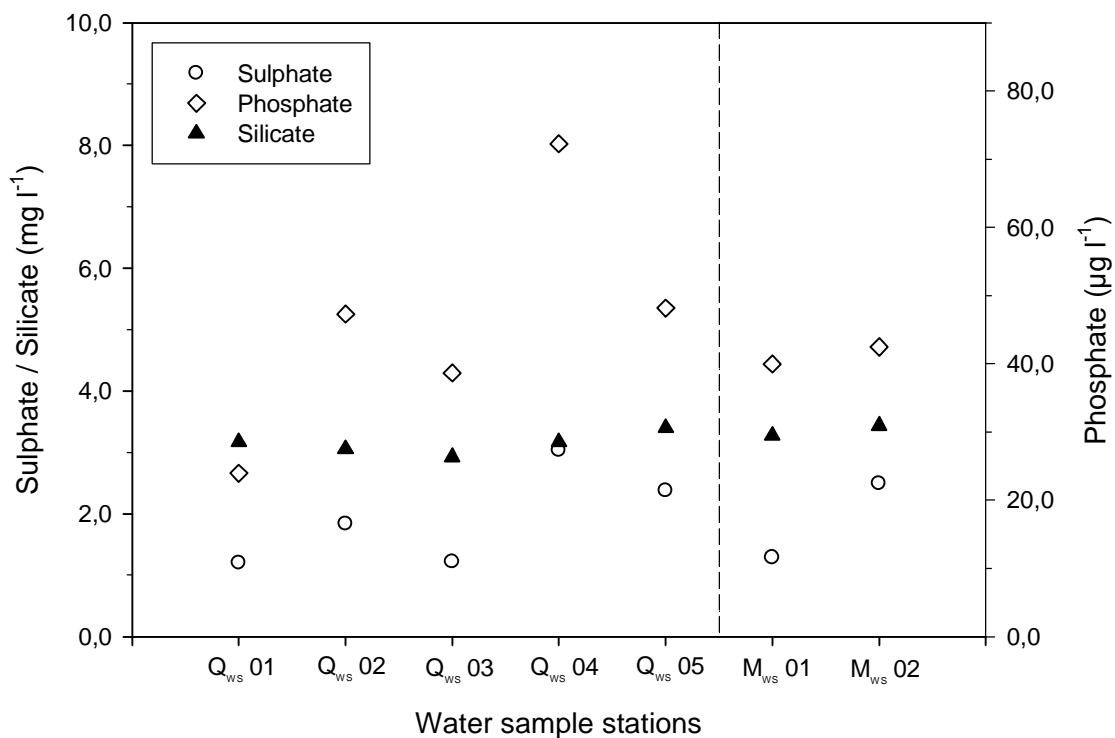


Fig. 5.3.23: Mean annual sulphates, total phosphorous and turbidity at five Upper River Queule ($Q_{WS\ 01} - Q_{WS\ 05}$) and two Mahuidanche River ($M_{WS\ 01} - M_{WS\ 02}$) water sample stations

Total phosphates varied strongly in between water sampling stations in Queule River (Fig. 5.3.23; Appendix IV, Tab. D). The lowest annual mean was measured in $Q_{WS\ 01}$ ($23.9\ \mu\text{g l}^{-1}$) and the highest in $Q_{WS\ 04}$ ($72.2\ \mu\text{g l}^{-1}$). Water sampling station $Q_{WS\ 04}$ also showed high variation within the year with a peak of $180.1\ \mu\text{l l}^{-1}$ in autumn (June 2003). Average phosphate values for the

Mahuidanche River ranged between 39.9 – 42.5 $\mu\text{g l}^{-1}$. However, the highest phosphate value of all water samples was found in $M_{WS} 01$ (209.5 $\mu\text{g l}^{-1}$).

Annual mean values of silicates showed low differences among the water sample stations. The measurements ranged between 2.93 – 3.44 mg l^{-1} (Fig. 5.3.23; Appendix 10.4; Tab. D).

Alkalinity; Bicarbonate; Total Hardness

The annual mean of total hardness taken at all water sampling stations indicates soft conditions. Values ranged between 0.05 – 0.06 mmol l^{-1} (Fig. 5.3.24).

Bicarbonates among all water sample stations did not show significant differences. The range of annual means was 15.25 – 18.41 mg l^{-1} . Highest value measured was 39.04 mg l^{-1} at $Q_{WS} 03$ in autumn (March 04) (Fig. 5.3.24; Appendix 10.4; Tab. D).

The annual mean alkalinity was moderate and ranged between 0.25 - 0.30 mmol l^{-1} . The lowest and highest values were 0.20 mmol l^{-1} and 0.64 mmol l^{-1} , respectively (Fig. 5.3.24; Appendix 10.4; Tab. D).

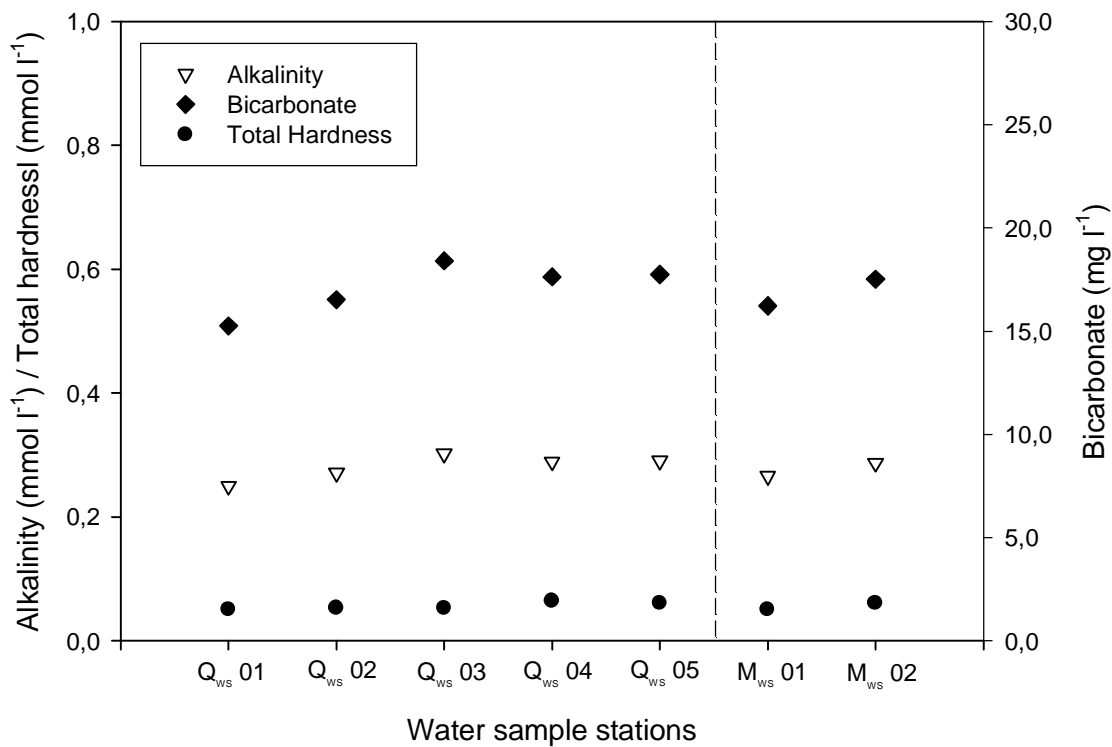


Fig. 5.3.24: Mean annual alkalinity, bicarbonates and total hardness at five Upper River Queule ($Q_{WS} 01 - Q_{WS} 05$) and two Mahuidanche River ($M_{WS} 01 - M_{WS} 02$) water sample stations

Chloride; Salinity

In Queule River the annual mean concentrations of chlorides were highest at water sample station Q_{WS} 05 (3.90 mg l⁻¹) (Fig. 5.3.25; Appendix 10.4; Tab. D), whereas the lowest annual mean concentration was found at Q_{WS} 02 (3.05 mg l⁻¹). In contrast to these findings, chlorides in both water sample stations at Mahuidanche River had lower values (2.49 – 2.92 mg l⁻¹). Salinity concentrations varied little among all water sample stations. The range averaged 0.10 – 0.11 (Fig. 5.3.25; Appendix 10.4; Tab. D).

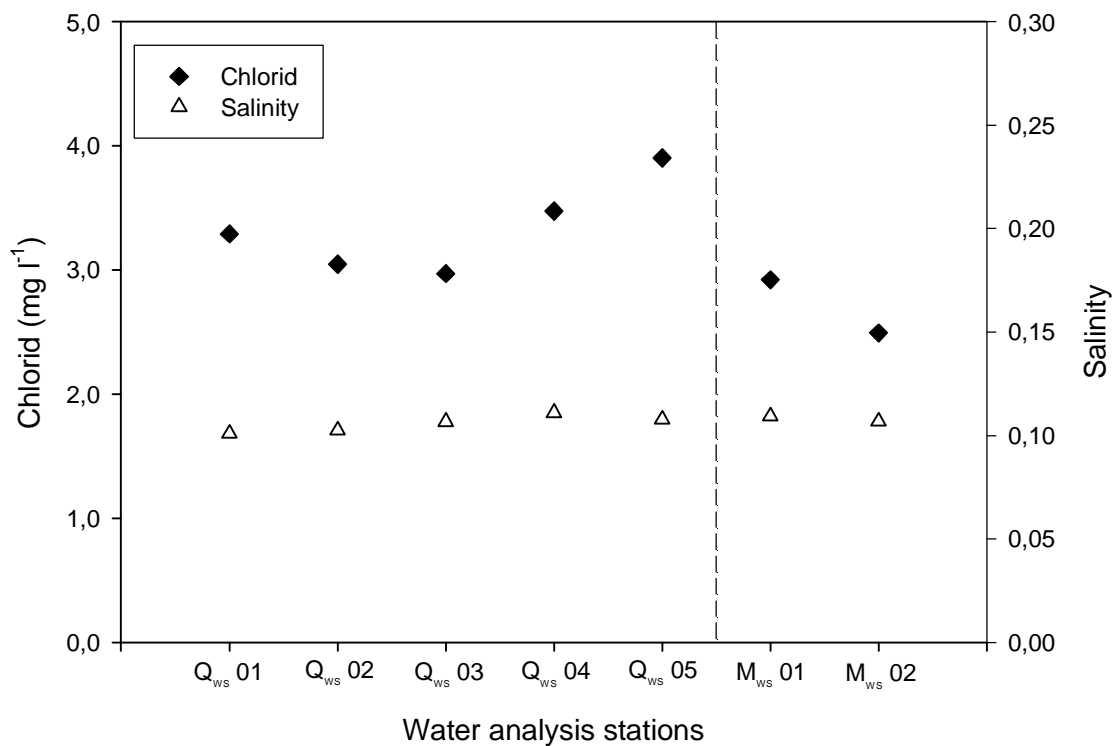


Fig. 5.3.25: Mean annual chlorides and salinity at five Upper River Queule (Q_{WS} 01 – Q_{WS} 05) and two Mahuidanche River (M_{WS} 01 – M_{WS} 02) water sample stations

5.4 Discussion

5.4.1 Methodology

Prey availability

Usually long periods of investigation are needed to obtain information about amphibian richness or density (in scale of years). Short sampling efforts often do not give total number of species present (SCOTT, 1994), therefore more quantitative short-term sampling should be performed. In the present study only nine stations were investigated once, therefore results should be interpreted with caution.

Two inventory methods were used: 1) patch sampling and 2) straight-line drift fences with pitfall traps. No amphibians were captured by straight-line drift fences even near boggy areas. This may be due to non-migratory behaviour of the amphibians at this time and/or to a very restricted spatial defence of their territory. In contrast the patch sampling technique was more useful. However, by using this method, personal abilities may have, to a certain degree, influenced the results of species richness and abundance. Additionally, some areas of research interest were not accessible due to dense vegetation and high water level.

For investigation on the river biocoenosis, two techniques were performed; “red de palito” and electrofishing. By using the “red de palito” – method bias can result due to failing to capture biotic material which passed at the side of the net while flipping up river bed material with feet (pers. obs.). Furthermore problems exist by investigating bigger objects (e.g. woody debris) as these provide a hiding-place for crustaceans in higher positions and collecting with “red de palito” was almost impossible. Therefore the “red de palito” – method is only helpful for crustaceans in substrate at the river bed level.

Electrofishing was restricted to summer where river sections depth did not exceed 1.20 m and current was low. Consequently samples do not represent the true species diversity and composition as fish species prefer different habitat compositions like water depth, current, river bed structure and elevation (e.g. JOWETT & RICHARDSON, 1996).

A further bias was the loss of some crustacean legs when electro stunned which is not considered in biomass calculations and could lead to an underestimate of biomass.

As the electrofishing technique showed a higher sampling success, in aquatic species as well as in number of crustacean, in contrast to the “red de palito” – method, electrofishing forms the main method in the present study for the investigation of prey availability in the UQR.

Spraint analysis

To investigate the diet of an animal several methods, such as direct observations, examination of stomach content or faeces analysis, exist (for review see: JORDAN, 2005). However, the feasibility is dependant upon the species. Observations in foraging otter species which show diurnal activity and the examination of stomach content have been successfully used, e.g. *Enhydra lutris* (ESTES *et al.*, 1981; ESTES *et al.*, 2003; OSTFELD, 1982), *Lutra lutra* (HEGGBERGET, 1995; HEGGBERGET & MOSEID, 1994; KRUIK & MOORHOUSE, 1990; WATT, 1991), *Lontra canadensis* (MELQUIST & HORNOCKER, 1983; TOWEILL, 1974), *Lutra maculicollis* (STUART, 1981, cited in LARIVIÈRE 2002) and *Lontra felina* (MEDINA, 1995). However, the southern river otter is an elusive living animal and observations on feeding or findings of dead animals for stomach analysis are rare. Therefore the method of faeces analysis has to be used, which is common and widely used as an indirect method for otter diet analysis (e.g. CARSS & PARKINSON, 1996; JEDRZEJEWSKA *et al.*, 2001; KRUIK & MOORHOUSE, 1990; MEDINA-VOGEL *et al.*, 2004; SOMERS & NEL, 2003).

A confounding component in faeces analysis is that soft parts are digested and hard parts remain in a distinct condition for examination. This fact makes it difficult to verify species or to calculate the weight and size of prey eaten by the otter and may result in an underestimation of soft parts. A further bias is the availability of faeces, as the animals may defecate into the water too, as it is described for *Lutra lutra* (KRUIK, 1995).

CARSS & PARKINSON recommend collecting faecal samples within a few weeks as they are ephemeral, which is mainly the case in winter, when heavy

precipitation occurs. In this study it was attempted to collect faeces samples every month for 14 consecutive days daily to minimize the influence of weather conditions which may lead to a misinterpretation in the results of seasonal variations.

Bias resulting from sample size is the main factor affecting the accuracy of faeces analysis (CARSS & PARKINSON, 1996). For the otter species *Lutra lutra*, which is the species with the widest distribution of all otter species, occurring in Europe, Africa, and Asia (REUTHER & HILTON-TAYLOR, 2004), faecal sample size can reach up to 1000 within a few months (TAASTRØM & JACOBSON, 1999). However, for other otter species, like *Aonyx capensis* (PARKER *et al.*, 2005), *Lontra longicaudis* (GORI *et al.*, 2003; WATSON & LANG, 2003), and *Lontra provocax* (GONZALEZ LAGOS, 2006; MEDINA, 1998; MEDINA, 1997) a sample quantity between 60 and 242 were used. In this study marking sites were resampled to survey seasonal variations for a period of 17 months and 606 faeces samples were obtained.

Water analysis

Due to laboratory limitations, metal concentrations were not measured in this study. However, it is important to consider that metals can have a high influence on organisms as, for example, iron oxides can lower pH (WHITNEY & WRIGHT, 1975) and furthermore iron is known to be responsible for gill-damage and death of fish (DALZELL & MACFARLANE, 1999; PEURANEN *et al.*, 2002).

There are also indirect influences of metal on fish, which can accumulate metal through preying on metal burdened aquatic insects and this is also assumed to have lethal effects on fish (SAIKI *et al.*, 2004).

5.4.2 Prey availability

The purpose of my investigation is to reach a conclusion about whether the southern river otter is a high food specialist, or whether it is nourished primarily by feeding on remaining prey. In order to reach a conclusion, knowledge of the diversity and abundance of prey species is essential.

5.4.2.1 Diversity and abundance

Amphibians

The proportion of the two prominent amphibian species that were collected, *Batrachyla leptopus* (55.2 %) and *Batrachyla taeniata* (44.8 %), was quite similar. However, the two *Batrachyla* species differ significantly in length and weight. Interestingly, more male representatives were found in both *Batrachyla* species. BARTELT *et al.* (2004) attributes the prevalence of males as a sexual difference in habitat selection. TEIXEIRA *et al.* (2002) found that gender differences varied with the seasonal changes that occur throughout the year.

Amphibian abundance was strongly influenced by the presence of marsh grass *Juncetum procerii* and by the abundance of leaf litter (Fig. 5.3.3; p. 140) found near areas where there are small runlets of water. MÉNDEZ-TORRES *et al.* (2005), while conducting an inventory in the X. Region of Chile, found amphibian abundance in a variety of microhabitats. Such microhabitats include those where moss is present, and areas under tree trunks, under stones and in runlets. The geographical location for my study on prey availability of amphibian, however, did not include the same microhabitats found in X. Region of Chile. In the present study, habitats such as those described by MÉNDEZ-TORRES *et al.* (2005) were absent, or were only found in small numbers in this predominantly anthropogenic influenced study area. As this area is widely used for livestock farming and forestry, suitable and attractive habitat structures for amphibians are rare. Furthermore, several studies have shown that amphibian abundance declines when the natural habitat is negatively impacted, or when anthropogenic influences modify pasture land and roads, and cause deforestation of the woodlands (e.g. KOLOZSVARY & SWIHART, 1999; TEIXEIRA *et al.*, 2002; TODD & ROTHERMEL, 2006). Stream amphibians, in particular, may be negatively influenced by clear cutting in the study area as a result of fine sediments from

erosion that can stay in the headwaters for several decades creating a transformed habitat that is unsuitable.

Two species, *Caudiverbera caudiverbera* and *Pleurodema thaul* were unexpectedly detected in study areas that were close to marsh grass. These species were not known to live in these study areas. It appears that during previous inventory studies, conducted by other scientists, *C. caudiverbera* and *P. thaul* had not been collected; therefore, it is evident that sampling methods may play an important role in obtaining accurate data. Sampling methods may result in the collection of only some of the species living in the habitat being studied.

A contributing factor that may influence the appearance and abundance of amphibians is the use of pesticides by the forestry industry in their attempts to control pest invasion. Insecticides and herbicides can reach surface water through runoff from treated plants or soil, or by aerial overspray (THOMPSON *et al.*, 2004). Practices such as these have an indirect and/or direct effect on the biodiversity and productivity of aquatic communities (RELYEA *et al.*, 2005; RELYEA, 2005a). Roundup®, an herbicide, was used in pine and eucalyptus plantations along the UQR. Detailed studies on Roundup® and its impact on the aquatic and terrestrial amphibians by RELYEA (2005b) show that 96-100 % of larval amphibians were killed after three weeks; and, it caused high lethal impact rates on juvenile amphibians. Therefore, the lack of abundance of amphibians in this area may not only be a result of fragmentation and habitat destruction, but also a consequence due to the utilization of the herbicide Roundup® commonly used over the past several years in forest plantations in the study area.

Fish and crustaceans

Twelve crustacean species are described by JARA *et al.* (2006) for the IX. Region. The same region where this study was conducted. However, in this study, a total of only two malacostracan species were detected in different sections of Queule and Mahuidanche River. The method used for crustacean trapping may not be effective enough to collect all species that are actually present in the water. If the method was not sufficiently effective, low diversity would have resulted. *S. spinifrons*, for example, is a species which hides itself under or in river bed

structures. As a contrast, *Parastacus spec.* also occurs in the IX. Region (JARA *et al.*, 2006); however, it is a burrowing species that can be encountered in horizontal tubes in riparian walls (pers. comm., JARA). Therefore, it may be true that *Parastacus spec.* do not exist in the shallow waters where electro fishing was performed as part of this study. There was no evidence, however, of other crustacean species that might serve as important food sources for the otter. In addition, no other crustacean remains were detected in otter faeces.

While the ichthyofauna of Chile is characterized as being of low diversity, it is known to be of high endemism (HABIT & VICTORIANO, 2005). This study supports their findings. Six out of the thirty-nine known native freshwater species of Chile (DYER, 2000) and two introduced species were found in the investigated area (Tab.5.3.2, page 143). The study area was not found to have richly diverse populations. On average, three species were found per investigation site; therefore, the density of species found in the study area was very low compared to numbers found in other studies conducted on continental rivers. TAYLOR (1969, cited in: JOWETT & RICHARDSON 1996) examined more than 82 species in a tributary of the Mississippi. However, the average species richness is similar to findings of JOWETT & RICHARDSON (1996) in New Zealand where, on average three to five species were collected per investigation site and may be transferable to Chile freshwater systems.

Influencing factors

Fish and crustacean diversity, abundance, as well as biomass are influenced by a multitude of factors. One of the more influential factors is that of the riverbed structure because it must provide a suitable habitat where aquatic organisms can spawn, grow, acquire food, and protect themselves from predators.

The most common substrate type encountered by aquatic animals in the UQR is sand (Appendix 10.4; Tab. C). Additionally, aquatic organisms encounter a lower abundance of gravel and woody debris. According to local inhabitants, these substrates were absent in this area 10 – 20 years ago. Sediment input rose as a result of clear cutting by the forestry industry, resulting in serious land (soil) erosion (e.g. GOMI *et al.*, 2004). According to GRANT & WOLFF (1991) sediment

in the river can increase up to twelve times, and may stay for more than 10 years, as a result of timber harvesting. Siltation negatively impacts fish species (CASATTI *et al.*, 2006) and may be responsible for low diversity in the UQR. On the other hand, some species may benefit from the change. For example, in this study, juvenile *Geotria australis* were the predominant species collected. *Geotria australis* burrow into fine sediment where they undergo metamorphoses from the larval stages to the adult phase (BEAMISH & JEBBINK, 1994; HARDISTY & POTTER, 1971; KELLY & KING, 2001).

The most common substrate typically found in a rithral zone is gravel (SCHWOERBEL, 1994), however, in this study, it was only second most commonly found substrate. The crustacean species, *A. abtao*, was identified in this study to have a preference for rocky habitats. This is supported by the research done by SCHMITT (1942). Furthermore the fish species *Trichomycterus areolatus*, was found in the study area as well, is a species also adapted to rithral habitats (HABIT *et al.*, 2005).

The highest species diversity in the UQR was found to exist in substrates where there was an abundance of woody debris. This is similar to the research done by WRIGHT & FLECKER (2004) where a higher diversity of fish species were found in pools that contained woody debris. ANGERMEIER & KARR (1984) assumed that association between fish diversity and woody debris is more related to protecting fish from predation than an association based on increased food availability. This assumption was supported by EVERETT & RUIZ (1993) in their experimental conclusions for epibenthic fish and for invertebrates. In addition to the fact that woody debris provides shelter for aquatic animals, thereby decreasing predation risk, it also offers visual isolation and water velocity refuge (CROOK & ROBERTSON, 1999). These findings may also be transferable to *S. spinifrons* and *A. abtao* the most abundant species found in this type of substrate. Since woody debris is also colonized by other invertebrates (BENKE, 1998), it may, however, also serve as a food source for crustaceans.

In contrast to the findings of ANGERMEIER & KARR (1984), in this study only smaller-sized fish, namely, *Cheirodon galusdai*, *Percichthys trucha*, *Salmo trutta fario*, inhabited the waters where woody debris was found. It is assumed that these three species used the woody debris for protection from predators, since other structures such as roots and aquatic plants were limited in

number or were non-existent. In general, it seems that woody debris is an important structural element for aquatic animals. Another important fact is that small to medium-sized woody debris, as well as large-sized woody debris seems to be important. The variety of sizes of woody debris causes a high geomorphic impact on the river structure (e.g. KAIL, 2005) by building dam pools, plunges and backwater scours (DOLLOFF, 1994), where smaller woody debris accumulates, thus creating a preferable habitat for fish and macroinvertebrates (HILDERBRAND *et al.*, 1997; LEMLY & HILDERBRAND, 2000; NAKAMOTO, 1998).

The comparative section of the Mahuidanche River contains aquatic plants that are not present in UQR and has a species community that is different (see Fig. 5.3.5, p. 144; Fig. 5.3.6, p. 145). These findings are similar to the results of several authors (e.g. CHARÁ *et al.*, 2006; LAMOUREUX *et al.*, 1999; VLACH *et al.*, 2005) where each fish species prefers specific habitat structures. In contrast to the UQR, where both crustacean species, *S. spinifrons* and *A. abtao*, are the most abundant stock-forming species, the fish species *Galaxias maculatus* is eudominant (see Fig. 5.3.9; p. 148) suggesting it may have chosen the aquatic plants as a breeding habitat since only small fishes were caught.

JOWETT & RICHARDSON (1995) suggested that water depth is more important than riverbed structure in determining species composition; species composition varies considerably with water depth. It is important to note that, in this study, examination of river depth was not applicable because electrofishing was conducted in rivers only at depths that were < 1.4 m. Furthermore, there remains the question of whether elevation is an influencing factor for species composition, as was shown by JOWETT & RICHARDSON (1996) in New Zealand. Nevertheless, the aim of the study was not to detect differences in krenal, rhithral and potamal zones, but to find differences within a river length of 20 km where faecal samples of southern river otters were able to be collected.

MERRINER *et al.* (1976) described that seasonal migration of fishes has an effect on the abundance and species diversity of fishes in lotic habitats. This was not considered in this study since electrofishing was done only in the summer when river water levels were low. Furthermore, the low diversity and abundance of fishes may be explained as being the result of high crustacean abundance, as both feed on the same macroinvertebrates (HANSON *et al.*, 1990). On the other

hand, *Samastacus spec.* and *Aegla spec.* are also known to be prey for *Salmo trutta fario* and *Oncorhynchus mykiss* (SOTO *et al.*, 2006), and both species were found to occur in the UQR.

The resulting biomass of the examined river is not only a factor of abundance, but is influenced by the age and size of the aquatic animals. Therefore, fish biomass is low in the UQR (see Fig. 5.3.11 a; p. 150) as a result of the fact that only juveniles of *Salmo trutta fario* were collected in investigated sites. In contrast to the Mahuidanche River, the resulting fish biomass depended not only on the high abundance of *Galaxias maculatus*, but on weight of adult *Oncorhynchus mykiss* and *Salmo trutta fario* as well.

Both species, *Oncorhynchus mykiss* and *Salmo trutta fario* are introduced fish species which show a widespread occurrence and are often a result of management for sport fishery and aquaculture in Chile (CAMPOS & MORENO, 1985; PÉREZ-LOSADA *et al.*, 2002; SOTO *et al.*, 2006). It is presumed by several authors (e.g. ADAMS *et al.*, 2001; SOTO *et al.*, 2006) that they have an indirect impact on native species since they place a predatory pressure on them. MCDOWELL (2003) points out that in New Zealand, which is considered the closest comparison for introduced fish species, *Oncorhynchus* and *Salmo trutta* seem to harm the native fish fauna. For example native fish and introduced brown trout were never found in the same section of a river (TOWNSEND & CROWL, 1991; cited in: SOTO, D. *et al.* 2006).

ARENA (1978) observed that predation on native fish by *Oncorhynchus mykiss* was only observed when the species sizes were larger than 30 cm. The introduced fish species in UQR, however, were much smaller than 30 cm.

In line with the study of SOTO *et al.* (2006), where introduced fish constitutes the highest abundance and main biomass in river and lakes in Chile, are the findings of the present study. However, as this study also considers that crustacean species serve as a vital source of prey for the southern river otter, they form the main biomass in the UQR (see Fig. 5.3.11; p. 150).

The biomass calculated in 2003 showed a significant difference to 2004 (see Tab. 5.3.3; p. 154), which is assumed to be as a result of the previous flooding in 2004. In contrast to THEILING *et al.* (1999), the river sections did not

immediately show a recruitment neither an increase of native fish diversity. However, electrofishing was not done directly before the flooding and species diversity, abundance and biomass may have already changed compared to 2003. Nevertheless, I presume that flooding would form new habitat structures as large amounts of woody debris and areas of gravel and stones disappeared in several sections and newer woody debris emerged which had to be recolonised by fish and crustaceans. All fish species showed a decrease in abundance after flooding, except for *Salmo trutta fario*. This is consistent with ORTLEPP & MÜRLE (2003) where fish abundance of *Salmo trutta fario* was not reduced by an experimental flooding and supports the findings of TEW *et al.* (2002), who report that species were affected differently by the impact of a typhoon in a mountain stream in Taiwan. Furthermore TEW *et al.* (2002) show that species abundance did not recover immediately but took a period of 14 to 17 months.

In addition to the previous factors, water quality is also important as it can influence prey species diversity and abundance (REASH & PIGG, 1990) and therefore will have an impact on the habitat suitability for the otter. Not all parameters which were measured may be important for the assessment of the river as an otter habitat, but they provide a comprehensive insight into the physico-chemical situation for the UQR and can be used for comparison for further studies on other rivers.

In general, the water of the UQR is characterized by its low hardness and low conductivity, but high oxygen concentration. The pH is on average slightly acid, which may be normal in rivers without carbonate rocks such as limestone and dolomite, whereby the very low alkalinity results, which stands for the low buffering possibility of the water. However, the pH values are still in the appropriate range for normal development of freshwater fish (EIFAC, 1969).

The measured temperatures show the typical fluctuations regarding the seasons which are typical for the rithral, where the maximum temperature does not exceed 20 °C (SCHWOERBEL, 1994).

Typical environmental pollution parameters are correlated to villages which discharge their waste water directly into the river, being higher in these areas compared to undisturbed areas. Thus station Q_{WS} 04 and Q_{WS} 05 show higher values in chloride, phosphate, sulphate, nitrate, N_{org}, ammonia, conductivity and

turbidity as well as in chemical oxygen demand. However, high variations were also demonstrated for the other station throughout the year and may result from the varying use of a forest camp site by lumber men and the school during the year, where waste water is also discharged directly into the river.

The two sites in Mahuidanche River, which were measured for comparison showed similar values compared to the Queule River. However, site M_{WS} 02 is situated close to pasture land with stock farming and has a seasonal very low water current. Animal excrements may discharge into the water section M_{WS} 02 and therefore values of nitrogen compound, phosphate and chemical oxidant demand were in general higher than for station M_{WS} 01.

All measured physico-chemical parameters showed values below that required for critical or toxic effects on fish (SVOBODOVÁ & VYKUSOVÁ, 1991) and may also not be critical for crustaceans. However, through the very low buffer possibility, this lotic habitat is interference sensitive to any changes and an increase of H⁺ concentration could threaten the egg and larvae development of fish (e.g. PETERSON *et al.*, 1981; WHITNEY & WRIGHT, 1975) and crustaceans respectively.

5.4.3 Diet composition

The most reliable estimation of prey in faeces is given by weight or volume, although frequency of occurrence (either as percentage or relative frequency) provides at least an accurate rank order of prey classes (CARSS & PARKINSON, 1996; JACOBSEN & HANSEN, 1996; WISE *et al.*, 1981). Frequency of occurrence is the most commonly used method and provides data for comparison to previous work on diet analysis on otters. However, inaccuracies in faecal analysis still exist.

Malacostracan, in particular *S. spinifrons* dominated the diet of the southern river otter in the study area (see Tab. 5.3.5; p. 156). These findings are consistent with previous studies on southern river otter diet in freshwater habitat in several publications (e.g. CHEHÉBAR *et al.*, 1986; GONZALEZ LAGOS, 2006; MEDINA-VOGEL *et al.*, 2003). The abundance of *S. spinifrons* in the diet of *L. provocax* is

consistent with the results of prey availability where *S. spinifrons* is the most dominant aquatic prey species in the UQR. Similar to the findings of MEDINA-VOGEL *et al.* (2003), which were conducted in a nearby area of the Queule River, is the poor abundance of *A. abtao*. A higher abundance of *Aegla spec.* is registered in lakes and Andean rivers, where *Aegla spec.* is also more abundant in southern river otter diet (CHEHÉBAR, 1985; MEDINA, 1997; MEDINA, 1998). The habitat in the Andean region for *A. abtao* may not be influenced by increased sedimentation in the river by deforestation, like it occurs in the mountain range, and therefore the preferred rocky aquatic habitat of *A. abtao* is not diminished.

Similar to previous studies on the diet of *L. provocax* fish form a minor part of otter faeces (e.g. CHEHÉBAR *et al.*, 1986; GONZALEZ LAGOS, 2006; MEDINA-VOGEL *et al.*, 2003). In contrast to the findings of prey availability, three species of fish, *C. galusdai*, *G. australis* and *T. areolatus*, were not discovered in faeces. Usually operculum, vertebrae and scales are used for fish determination (FELTHAM & MARQUISS, 1989; HAJKOVA *et al.*, 2003; JENKINS & HARPER, 1980; MIRANDA *et al.*, 2005; WISE *et al.*, 1981), however, these key items were mostly absent which resulted in only three fish species being determined, a high frequency of undeterminable fish species and no categorization of fish size. Surprisingly, scales were almost never detectable; even though other remains of fish were present.

Lutra lutra starts to consume the fish from head (ERLINGE, 1968; RUIZ-OLMO *et al.*, 1998), which may be serve to kill the prey rapidly, and consequently, remains for fish determination are absorbed. RUIZ-OLMO (1998) noted that fish with less than 100g were eaten completely. However when larger fish are captured by *L. lutra*, no starting priority seems to exist, it has been observed to start from the side or tail of the fish and may leave the head (CARSS *et al.*, 1990; KRUUK & MOORHOUSE, 1990; RUIZ-OLMO *et al.*, 1998). This is contrary to observations on housed *L. provocax* (Chapter 2), where provided fish was always eaten from tail as the starting point and head was consistently left, independent of size of provided fish and important parts for fish determination were thereby excluded. Nevertheless it has to be taken into consideration that this observation of fish feeding was done in captivity and *L. provocax* was fed with dead fish. No behavioural observation of fish consumption on free ranging *L. provocax* exists and no remains of fish or crustacean on land were left by *L. provocax* as it is

known for *L. lutra* (RUIZ-OLMO *et al.*, 1998). On several occasions *L. provocax* was observed feeding on crustaceans. At the time of consumption the southern river otter always stayed in the river and consumed the crustacean entirely on the water surface.

Diet composition on *L. provocax* is similar to *A. capensis* (Cape clawless otter) where crustacean also dominate the diet in freshwater habitats (PARKER *et al.*, 2005; PERRIN & CARUGATI, 2000; ROWE-ROWE & SOMERS, 1998). In contrast, fish was relatively unimportant for *A. capensis* but amphibians were second most prevalent in the diet. The importance of amphibians as a staple prey is also known for *L. lutra* in northern Europe, especially in river habitats (BRZEZINSKI *et al.*, 1993; CLAVERO *et al.*, 2005; JEDRZEJEWSKA *et al.*, 2001; LANSZKI *et al.*, 2006; SULKAVA, 1996). The abundance of amphibians in otter diet was higher when their availability increased (JEDRZEJEWSKA *et al.*, 2001). Amphibians as prey for *L. provocax* were not detected in this study, which may be due to the absence of good amphibian habitats and resultant low abundance. However, *L. provocax* is also known to prey on amphibians, but these seem to have a minor importance as they only occur in faecal samples in small numbers (GONZALEZ LAGOS, 2006; MEDINA, 1997; MEDINA-VOGEL *et al.*, 2003).

On four occasions the remains of the bivalve *Diplodon chilensis* is recorded in the otter faeces. This common occurring mussel in southern Chilean rivers (PARADA & PEREDO, 2002) may be taken as a secondary food source or accidentally as it is found in only small numbers which is consistent with the findings of MEDINA (1997). However the importance of freshwater mussels may be underestimated as they comprise more soft parts compared to other prey species. It is unknown if *L. provocax* has the ability to open and only feed on the inner part of the mussel. On some occasions piles of shells on small river islands of *D. chilensis* were found but the shells were not damaged. Since *L. provocax* feed on crustaceans complete with exoskeleton, shells of mussels should not be a problem as they are relatively soft. *Lontra provocax* did not feed on *D. chilensis* when it was provided to the caged animals during the trapping season for telemetry.

There was no evidence of predation noted on mammals, frogs, birds and insects during this study as it is known for several other otter species like *L. lutra*, *L. canadensis*, *A. capensis* (e.g. CARSS, 1995; MELQUIST & HORNOCKER,

1983; PARKER *et al.*, 2005) and also described in previous studies for *L. provocax* (GONZALEZ LAGOS, 2006; MEDINA, 1998). However it has to be considered that a lack of appearance in faecal samples does not necessarily represent a lack of consumption (KRUIK & MOORHOUSE, 1990) as it is possible that the otters may generally defecate in water (JACOBSEN & HANSEN, 1996; KRUIK *et al.*, 1986; KRUIK, 1995) and therefore information on southern river otter prey may be inaccurate. Furthermore the prey availability has to be considered otherwise it is not possible to draw any conclusions as to whether the investigated animal is a food specialist/generalist or compelled to nourish on the only available prey.

Southern river otter deaths from car accidents are not reported as they are for *L. lutra* in Europe (e.g. HAUER *et al.*, 2002) and findings of carcasses by chance are seldom. Therefore is a significant diet analysis for *L. provocax* out of stomach content not practicable. The two dead southern river otters analysed do not provide additional information, as only the crustacean species *S. spinifrons* was detected in stomach and intestines.

JEDRZEJEWSKA *et al.* (2001) show that the habitat where the studied otter lives influences the diet composition. Thus European otters living in a seashore environment show a strong fish based diet composition which decreases and becomes more variable for otters living in inland waters. In some crayfish-rich habitats crayfish was the dominant diet throughout the year for *L. lutra* (JEDRZEJEWSKA *et al.*, 2001). These results may also be transferable to *L. provocax* as southern river otters which are living in shore areas also prey predominantly on fish (SIELFELD, 1983) and seems to switch to crustaceans in freshwater habitats (CHEHÉBAR *et al.*, 1986; GONZALEZ LAGOS, 2006; MEDINA, 1997; MEDINA-VOGEL *et al.*, 2003). Based on these results it is likely that *L. provocax* is not specialist on crustacean, but on prey species abundance.

However, in this study *L. provocax* is dependant upon the crustacean prey species being *S. spinifrons* as the prey diversity and abundance of other aquatic species was low in the area of investigation.

5.4.4 Seasonality

Marking frequency

The findings of low faecal samples in the summer season of 2003 when precipitation was low is consistent with several authors (MASON & MCDONALD, 1986; TAASTRØM & JACOBSON, 1999). However, the results are contrary to GONZALES LAGOS (2006) who studied faecal samples of *L. provocax* in a wetland system. His findings could be caused by low revisiting rate and heavy rainfall which washed faecal samples away between surveys. Nonetheless, it has to be considered that the number of faecal samples found between seasons of high and low precipitations do not differ significantly in this study and the number of faecal samples in 2004 were almost the same between seasons and incomplete.

Several authors have stated that the variation in the number of faecal samples can be attributed to manifold factors (e.g. KRUIK, 1992; PRENDA & GRANDADOLORENCIO, 1996). They have suggested that sprainting rates are based on prey availability and biomass, but also may depend upon the number of individuals which occupy a certain area (COPP & ROCHE, 2003; HUTCHINGS & WHITE, 2000; TAASTRØM & JACOBSON, 1999).

Contrary findings about intersexual marking frequencies exist. Thus argues CARSS (1995) that male otters mark more frequently with smaller faeces size as female otter do, whereas KRUIK (1992) did not find significant differences between the sexes. It has to be considered, that the time range of the present study may not be sufficient to draw conclusions about factors which influence marking frequencies.

Diet variation

Seasonal diet variation is influenced by multifaceted factors such as prey availability (ROWE-ROWE & SOMERS, 1998), activity of prey (KRUIK, 1995), local abundance (LANZKI *et al.*, 2006) and ability to catch the prey (ERLINGE, 1968). For example LANZKI *et al.* (2006) notes that *L. lutra* consumes European pond turtles *Emys orbicularis* when access to fish is low during winter. Likewise the predation on amphibians increases in winter when they hibernate in river beds, and during breeding season in spring when they are more abundant (JEDRZEJEWSKA *et al.*, 2001; SULKAVA, 1996). Introduced species are reported to influence prey

preference. MCCAFFERTY (2005) found that the introduced fish species ruff *Gymnocephalus cernuus* became the main prey of *L. lutra* in Loch Lomond, in Scotland, and DELIBES & ADRIAN (1987) demonstrated that the introduced crayfish *Procambarus clarki* changed the food habits of the otter in Spain. Furthermore alteration in seasonal fish prey may be related to changed fish activity (KRUUK & MOORHOUSE, 1990) and to migration of mature specimens like it is recorded for eels; which are abundant in summer but due to migration decrease in winter (MASON & MCDONALD, 1986). Water temperature may play an important part in the ability to catch fish prey as it assumed that low water temperature reduces the swimming ability of fish (CARSS, 1995; EMERY, 1973; cited in KRUUK & MOORHOUSE, 1990).

A seasonal fluctuation of the main prey *S. spinifrons* was not detectable in faeces samples in the present study. Whether a scarce abundance of crustacean exist in autumn to winter, like it is shown by BEJA (1996) in Portugal, or not, was not possible to determine due to the impossibility of electrofishing during the winter season. Frequent flooding and a stronger river current in the winter season may result in the drift of crustaceans being highest in this time, as crustacean are hiding in structures such as woody debris, which float downstream. Therefore *L. provocax* could have to change to other food sources, which could explain why fish, as the second food source occurs significantly more often in faeces of *L. provocax* in the wet season compared with the dry season (Fig. 5.4.1).

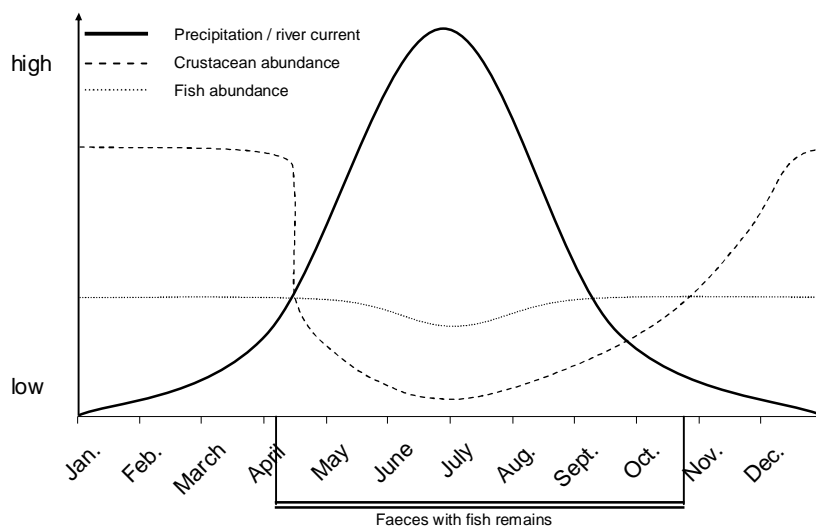


Fig. 5.4.1: Model of crustacean and fish availability in correlation with precipitation

The results are similar to ROWE-ROWE (1977) where *A. capensis*, which feeds mainly on crustaceans, also consumes more fish during winter than in summer (PERRIN & CARUGATI, 2000). However, this is contrary to the findings of previous studies on seasonal variation in the southern river otter diet, where a higher fish occurrence is noted in dry seasons (GONZALEZ LAGOS, 2006; MEDINA, 1998). As mentioned before, a low revisiting frequency of marking spots by previous studies may lead to different results.

The food-limitation hypothesis, which predicts that the consumption of sub-optimal food and the resulting mortality would be highest during the season with low prey availability, may not be supported in this study, as *L. provocax* seems to prey on fish which has higher food quality concerning the kcal content (Appendix 10.4; Tab. E).

5.4.5 Required quantity of staple prey

Calculation of consumed biomass from faecal samples is questioned by several authors (RUIZ-OLMO et al., 1998) as some parts of prey may be left by the animal. In this study not the consumed biomass was calculated, but rather the numbers of crustaceans a southern river otter needs for its daily metabolic requirement by measuring the size and quantity of prey found in the faecal samples.

The daily energy requirement of an active southern river otter is not known and the calculated results are based on caged animals which had a very limited possibility of movement (see chapter 3). Therefore it is assumed that the metabolic requirements in free-ranging southern river otters are much higher and consequently they have an increased prey requirement. However the results of the present study give the first general survey of energy requirements of southern river otters.

The factor of digestibility of crustaceans was not considered in the calculation. BEJA (1996) calculated this to be 0.5 but this factor seems to be related to felines. Conversely MÅRTENSSON (1994) noted an 81 % - 83 % of digestibility efficiency of crustacean species by harp seals. Digestibility factors which are calculated for different species may not be transferable as digestive processes of predators may have evolved to be more efficient with their main prey (JACKSON *et al.*, 1987). For example *A. capensis* shows an adaptation of molariform teeth related to

geographical variation in their main prey and the size of molluscs and crustaceans (DAVIS, 1978; cited in LARIVIÈRE, 2001).

The time a southern river otter would need in order to obtain sufficient food can not be answered, as data of capture rates do not exist and the observation of *L. provocax* is very difficult. RUIZ-OLMO (1998) describes that *L. lutra* needs 2-3 hours of fishing daily to obtain sufficient food, assuming that an otter needs 12-15 % of its corporal biomass as noted by KRUUK (1995). The average time taken for movement behaviour, which includes travelling, hunting and marking, is 6:30 h as measured by the radio tracking of three southern river otters (Chapter 3). Usually otters have to increase foraging time when the availability of food decreases, which usually occurs in winter, in order to meet metabolic requirements (KRUUK, 1995). This implies that southern river otters should use less time for foraging in the spring-summer season, however this still has to be proven, as in this study the radio-tracking took place in the autumn-winter season.

The majority of *S. spinifrons* that was caught by electrofishing weighed less than the average individual found in faecal samples of *L. provocax*, which is the same for *A. abtao*. Consequently the following conclusions could be drawn: that in order to obtain sufficient food: 1) *Lontra provocax* has to hunt in several different areas on crustaceans, and/or 2) other food sources, which were not detected in faecal samples, play an important role.

While radio tracking southern river otters, it was noted that foraging took place in several home range sections. The kind of prey which was consumed can only be suggested, as sometimes the typical crushing noise by feeding on crustacean was noted. However, I assume that *L. provocax* is foraging regularly on fish to optimize his metabolic requirements, as fish also has higher food quality in contrast to crustaceans; as reported by KRUUK (1995); and additionally provides more kcal per consumed prey unit. A further assumption is that faeces which contain fish remains are usually not used for marking as they are fluid, highly ephemeral and therefore are defecated into the water. This assumption is based on observations on caged animals, where only fish was provided to *L. provocax* which resulted in fluid faeces. This is similar to the findings in the field, where only faeces of crustacean remains consistently showed a compact cylindrical structure. However,

to maintain markings in the rainy season, when most faeces are flushed away in a relatively short time, all types of faeces may be used.

5.4.6 Diet – mink versus otter

The diet of the American mink in the UQR (rodents and crustacean) was similar to the findings of MEDINA (1997) in Chile. Preying of mink on rodents and crustaceans, revealed in UQR, was reported from other regions as well and wherever crustaceans were abundant they constituted an important part of the diet (e.g. BRZEZINSKI & ZUROWSKI, 1992; GERELL, 1967; JEDRZEJEWSKA *et al.*, 2001; RACEY & EULER, 1983).

The American mink is a generalist predator and known to exploit prey on land as well as in water habitats where its diet includes mammals, fish, amphibians, birds and crustaceans (JEDRZEJEWSKA *et al.*, 2001). In this study the absence of fish in mink faecal samples is noteworthy as consumption of fish can vary between the seasons but was always present in other diet studies (e.g. FERRERAS & MACDONALD, 1999; GERELL, 1967; HAMMERSHOJ *et al.*, 2004; WISE *et al.*, 1981). As the proportion of prey in the mink diet increases with prey abundance (JEDRZEJEWSKA *et al.*, 2001), it may be concluded that the UQR has a very low fish abundance, or that the mink has changed its diet because of high otter density (BONESI *et al.*, 2004) to avoid conflicts with the southern river otter in this area. In contrast to the otter, the American mink cannot dive and swim for a long time (DUNSTONE, 1979, in BONESI *et al.* 2004) and this may also influence its success in catching fish.

PERSSON (1985) argues that the competition highly favours the European otter, as its body ratio is 7:1 (weight) compared with the mink, and this would be higher for southern river otters as they are in average heavier than the European otter. Furthermore SCHRÖPFER & PALIOCHA (1989) assume that a coexistence of the European otter and American mink should be possible by applying the Hutchinson-rule, due to the significant body size difference, competition may therefore be improbable. This suggestion may be transferable to the southern river otter as the American mink is the only other semi-aquatic mammal which occurs on the ecotone bank in the study area. Both species seems to present the guild of megacarnivorous in the study area.

However, food competition may be seasonal, as REUTHER (1993) reports regarding food competition occurring between the American mink and the European otter in winter, when prey availability is lower. However the low faecal sample size of *M. vison* in this study makes examination of seasonal variation difficult.

Furthermore the results of this study are supported by the assumption of MEDINA (1997) that no food competition exists between *L. provocax* and *M. vison*, as the Renkonen Index for similar food resources is relatively low. However a low abundance of mink is suggested by the poor number of faecal samples and this may be a further reason for no findings of food competition. The situation of food composition may change with higher mink density.

5.5 Prospects

In the present study it is assumed that *L. provocax* depends upon the crustacean prey species *S. spinifrons*, because of the low prey diversity and abundance of other aquatic species in the study area.

However, whether the southern river otter is a food specialist and consumes primarily crustaceans, or a generalist which consumes the most abundant prey species still has to be proven. Further research could be done in areas where abundance of crustaceans are low and in areas where fish, fish farming or ponds with a year-round fish stocking exist which could provide sufficient food for *L. provocax*.

The results of calculations regarding quantities of crustaceans needed for metabolic requirements are based on caged animals with limited possibility of movement and provide new basic information. For further studies on energy requirements and digestibility of several prey items, animals should be kept in big enclosures in which they are able to swim.

6 Age determination of male southern river otter *Lontra provocax* (THOMAS 1908)

Abstract

Four male skulls of the southern river otter *L. provocax* were examined for age determination. Tooth wear; tooth abrasions, dental pulp; relative width of dental pulp, incremental cementum lines; number of lines, and sutures of the skull; visible sutures, were used for age determination. By using the methods tooth wear, incremental cementum lines and relative width of dental pulp it was possible to classify the animals as juvenile (n=1), subadult-adult (n=1) and senior (n=2). However, as only the juvenile showed sutures, it was not possible to distinguish between subadult – adult to senior and therefore sutures on skulls provide information about age, but have to be used in combination with the other presented methods for more accurate classification.

6.1 Introduction

Until today the otter species *Lontra provocax* has been hardly studied. This is due to the cryptic behaviour of the species, the difficulty of trapping and its population declination as a result of its vanishing habitat (MEDINA-VOGEL, 1996).

First home range and spacing pattern studies have been conducted only recently. However, scarce information is available on the demography of *L. provocax* which is crucially needed for conservation and wildlife management (ALEXANDER, 1958; MEDINA-VOGEL, 1996; VAN HORN *et al.*, 2003).

Age estimation is an important tool for obtaining information about the demography of a species (e.g. longevity, mortality) and to monitor population dynamics (SPINAGE, 1973). Different techniques for age estimation such as changes of cranial proportion and sutures, eye lens mass, tooth wear, baculum weight, ossification, coat colour etc., have been used on several carnivores (ANSORGE, 1995; CATLING *et al.*, 1991; GEIGER *et al.*, 1977; KRÜGER, 1995; LAWS, 1952). Nevertheless, methods of age determination can be often subject to error (FIERO & VERTS, 1986); e.g. according to ANSORGE & STUBBE (1995) the age estimation for Eurasian otters *Lutra lutra* by tooth abrasion is not even

suitable for rough age classification. Therefore multiple methods have to be compared and verified.

In our preliminary study of feasibility in age estimation we used four different methods: Tooth wear, dental pulp, incremental cementum lines and sutures of the skull.

6.2 Methods

A total of four male otter skulls were obtained for age determination from the Museum of Ecology and Evolution, University Austral of Chile, Valdivia (Museo del Instituto de Ecología y Evolución de la Universidad Austral de Chile, Valdivia, Chile). All skulls were collected during 2000 – 2004 when studies on home range and behaviour patterns were conducted and were provided by the.

As no data is available for the southern river otter tooth wear, only a rough estimate in age classes was performed. Tooth wear was separated in three age classes according to KRÜGER (1995) by considering the degree of abrasion:

1. Age class: no abrasion visible (juveniles to subadults).
2. Age class: small to medium abrasion (younger adults to grown adults).
3. Age class: heavy abrasion (seniors).

For examination of the dental pulp the right upper canine was extracted from its alveolus with dentist forceps without damage from four prepared otter skulls, stored and labelled in glass vials until further preparation. Due to their size canine teeth are usually preferred for dental pulp (*Pulpa dentis*) width measurements in carnivores (KRÜGER, 1995). Teeth were X-rayed with different times, X-ray paper and strength. Best results were obtained by using X-ray paper Agfa dentus M2 comfort, Speed Group E, dental film. Technical settings were: 50 KV, 7 mAs, exposure distance 20 cm, time of exposure 0.2 sec. X-ray films were digitally scanned and dental pulp width and tooth diameter digitally measured with tpsDig 2 (ROHLF, 2006). The relative width of the dental pulp was calculated as percentage proportion of the major tooth diameter.

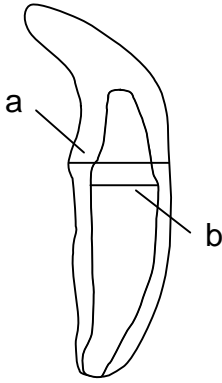


Fig. 6.2.1: Measurements for calculation of the relative dental pulp width on a canine. a = maximum tooth width; b = maximum dental pulp width. Adapted and modified after KRÜGER (1985).

For further examinations of age structure canine teeth were longitudinal cut with a low-speed diamond saw as described by DRISCOLL (1984) and ANSORGE (1995). Obtained sections were glued onto a microscope slide and analysed by counting the incremental cementum lines as recommended by HEGGBERGET (1984).

Additional sutures in the cranium were used to differentiate between juvenile and adult animals.

6.3 Results

All captured southern river otter in the study of radio telemetry ($n=5$), independent of sex and age, showed a dental formula of $3\ 1\ 4\ 1 / 3\ 1\ 3\ 2 = 36$, where the incisors form an anterior and a posterior row in the mandible (see Fig. 6.3.1 of M 04/x1). In all captured otters, independent of sex, the anterior and posterior row of incisors was always separate.

Tooth wear

The tooth wear of the four southern river otters' denture showed different abrasions (Fig. 6.3.1). Animal M 04/x2 did not show any visible abrasion on neither the canines nor incisors and therefore it was classified as juvenile. Whereas the animal M 04/x1 was aged as subadult to adult as its tooth wear already showed small to medium abrasion on both (upper and lower) canines as well as on the lower incisors. M 03/x1 displays a strong abrasion on the canines. The dental pulp of the broken lower right canine is visible. The lower left canine was missing and no lower incisors were left. Animal M 03/x1 was aged as a senior. Animal M 01/06

also showed strong abrasion on the mandibular incisors and the canine including dental pulp exposure. M 01/06 is therefore also aged as senior.

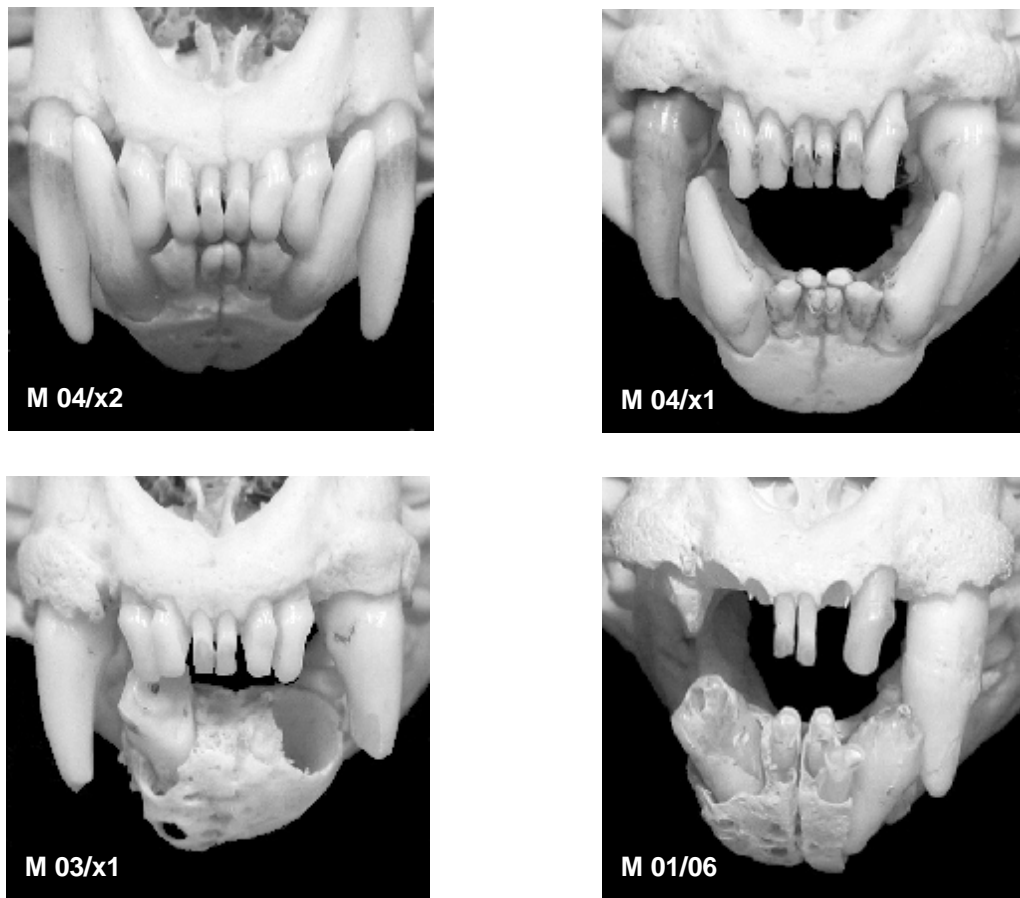


Fig. 6.3.1: Abrasion of incisors and canines for four southern river otters. M = male, followed by year, x = died in captivity; following / = radio transmitter channel of radio tracked animal. Darker shading of right upper canine of M 04/x1 results from extracting before otter skull was prepared

Dental pulp

All four X-rayed canines showed different dental pulp width (Appendix 10.5; Tab. A). The largest dental pulp width was measured in the canine of M 04/x2 at 5.17 mm , followed by M 04/x1 at 1.92 mm , for this reason they were aged as juvenile and subadult – adult respectively. We classified M 03/x1 with 1.44 mm and M 01/06 with 1.04 mm as seniors as they showed lowest dental pulp width. Additionally the decrease in abrasion of the tip of the canine (from left to right) can be seen (see Fig. 6.3.2). Relative width of dental pulp is presented in Tab. 6.3.1 where all results are summarised.

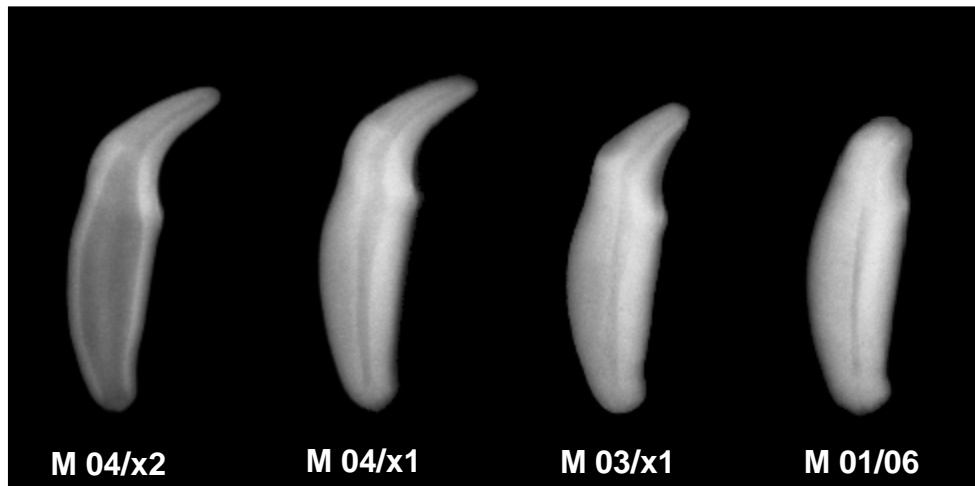


Fig. 6.3.2: X-ray of upper canines of four different *L. provocax* individuals

Incremental cementum lines

In contrast to the other examined animals' canines, no incremental cementum lines were found for animal M 04/x2. The number for incremental cementum lines were found for animal M 04/x1 was three; eight for M 03/x1 and M 01/06 respectively (Tab. 6.3.1). However the incremental cementum lines for M 01/06 were not as distinct as for the other southern river otters.

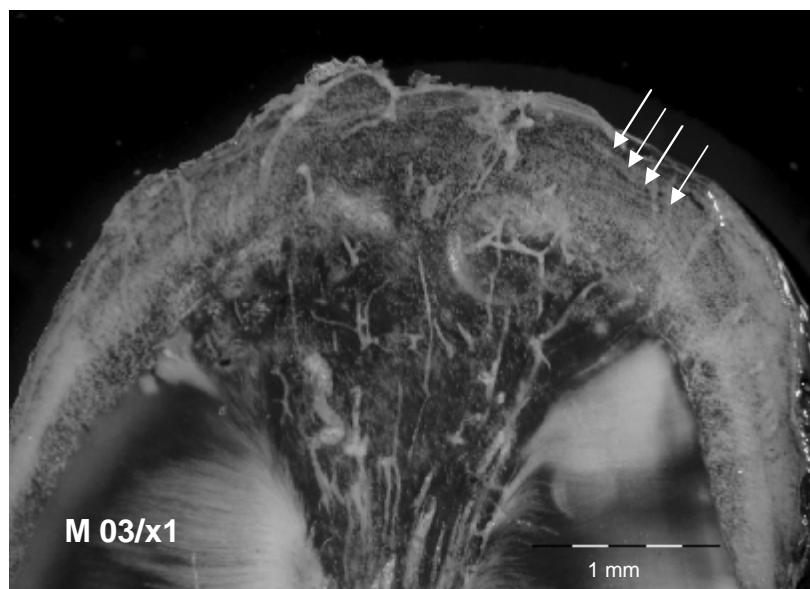


Fig. 6.3.3: Tooth root tip (40x magnified) with several incremental cementum lines in M 03/x1 (arrows)

Sutures of skull

Only the skull of animal M 04/x2 showed patent sutures (Appendix 10.5; Fig. A, B, C) and was aged as juvenile. The other three skulls were classified as adults. Furthermore, the skull of M 03/x1 showed a shot gun pellet in the mandible which was already incorporated prior to death. New calcification is visible around the impact area and the shot gun pellet was coated with a thin calcification layer. It is assumed that the mandibular trauma occurred at juvenile or subadult state.

Tab. 6.3.1: Measurements of tooth wear, increment cementum layers and relative width of dental pulp

Animal	Tooth wear age class	Incremental cementum lines	Relative width of dental pulp in %	Resulting age estimation
M 04/x2	1	0	66.7	Juvenile
M 04/x1	2	3	24.8	Subadult – Adult
M 03/x1	3	8	18.1	Senior
M 01/06	3	8	12.8	Senior

6.4 Discussion

As age determination can provide an inside into the demography of species, four methods were verified. However, there are some restrictions regarding the findings of analysed individuals. Results of age determination can statistically not be tested, as the samples were limited to only four individuals and only male animals were examined.

Morphological features such as body size and weight, cannot be used for age estimation as juvenile to subadult male southern river otters can attain the size and weight of adult females or old animals (termed here as seniors) which will have lost weight.

Tooth wear

Age determination by tooth wear is the easiest method and the most common criteria for age classification used on mammals (KRÜGER, 1995). The crown of the teeth is covered by enamel, which can show some age related changes, like loss in permeability, an increase in brittleness and abrasion which results in an irreversible loss of enamel (VANDEVOORT *et al.*, 2004).

Lontra provocax showed abrasion according to their age but there may be individual variations due to differences between habitat and populations, which can result in errors as is known for other mammals (ANSORGE & STUBBE, 1995; FIERO & VERTS, 1986; HARRIS, 1978; STANDER, 1997). For red foxes *Vulpes vulpes* and badgers *Meles meles* (VAN BREE *et al.*, 1974) as well as for gray fox *Urocyon cinereoargenteus* (NICHOLSON & HILL, 1986) the concordance of tooth wear estimate and other age criteria were significantly different. Likewise tooth eruption and consequential tooth wear can vary significantly intersexually (SMUTS *et al.*, 1978).

Two *L. provocax* dentitions (M 03/x1; M 01/06) show tooth fracture of their canine teeth. Tooth breakage is normal and is infrequently accompanied by severe pathologies in lions *Panthera leo* (PATTERSON *et al.*, 2003). According to VAN VALKENBURGH (1988), most commonly broken teeth are canines and more than 25 percent of various carnivores have broken teeth during their life, which is a function of age, feeding pressure and meat consumption that includes bones. An intersexual difference was found by STANDER (1997) as a higher frequency of broken canines in male leopards *Panthera pardus* than females were observed.

He assumed that smaller females with smaller teeth possess a greater precision when consuming meat with bones, which is similar to the assumption of VAN VALKENBURGH (1988) that carnivores which fed on large prey have a greater risk of accidental fracture during killing than the small prey consumer. However, FENTON *et al.* (1998) disagreed with the above suggestions as 1) the selection of examined species by VAN VALKENBURGH (1988) affected the results, 2) tooth breakage was strongly influenced by body size in carnivore species and 3) bats which consumed insects, fruit, nectar, pollen and blood did not show a lower incidence of broken teeth than carnivores as predicted. Thus it appears that lifespan is a better predictor of tooth breakage instead of diet (FENTON *et al.*, 1998). As *L. provocax* mainly feeds on crustacean and presumably fish of small size (MEDINA, 1998), the canines may not be damaged by its prey items as they were relatively easily killed or crushed. Therefore our findings support the hypothesis of FENTON *et al.* (1998). It can thus be concluded that tooth wear can be used for a rough age classification.

Dental pulp

The teeth of mammals continue to grow throughout life, and as the secondary dentine serves to extensively close the dental pulp (KLEVEZAL & KLEINENBERG, 1967) it can be used as an age indicator (KVAAL *et al.*, 1995; TUMLISON & MCDANIEL, 1984; VANDEVOORT *et al.*, 2004). Measuring dental pulp width seems to be a more precise method, which is not that strongly influenced by external factors as tooth wear may be. The results show that a broad difference between measured dental pulps was found and therefore a classification into three age classes could be conducted. However, a more precise classification or estimation of age was not possible due to a low sample number. Furthermore it is not known if in the first year of life of *L. provocax* the dental pulp narrows more quickly, with a slower rate later in life, as is demonstrated in the Mustelidae *Meles meles* (GRAF & WANDELER, 1982).

However, in several mammals (KRÜGER, 1995; NAGORSEN *et al.*, 1988; ZAPATA *et al.*, 1997), including humans (e.g. KVAAL *et al.*, 1995), canine pulp width has been used for age determination and could be vitally important for further studies on *L. provocax* as it can also be used on living animals.

Incremental cementum lines

In several mammals over the past decades age determination using incremental cementum lines has been carried out. First enumerations of annuli lines were done on cervids (EIDMANN, 1933) where annual lines were easily identifiable. For carnivores it is more difficult to achieve meaningful results and some methods include the decalcification of the tooth (BODKIN *et al.*, 1997). Furthermore the interpretation of the incremental cementum lines needs experience and verification should be done by more than one person (pers. comm., ANSORGE).

On several otter species age determination by incremental cementum lines has already been applied, for example European otter *Lutra lutra* (e.g. HAUER *et al.*, 2002; HEGGBERGET, 1984), sea otter *Enhydra lutris* (e.g. BODKIN *et al.*, 1997; GARSHELIS, 1984) and Northern river otter *Lontra canadensis* (e.g. BAITCHMAN & KOLLIAS, 2000; GROVE *et al.*, 2003; STEPHENSON, 1977). The results show that incremental cementum lines exist and are different in number. Based on the results a rough classification was conducted. Line formation seems to be analogue to the European otter *L. lutra* (HEGGBERGET, 1984) and *L. canadensis* (STEPHENSON, 1977). However, as no data exists on incremental cementum lines of *L. provocax*, it is not known if the lines are formed annually and represent life years. Presuming cementum lines represent annual lines, the two adult southern river otters (seniors) reached an age of eight years.

For verification if cementum lines are formed annually calciphilic biomarkers such as tetracycline can be used (JOHNSTON *et al.*, 1987). That means animals have to be held in captivity, or wild animals, which are captured as juveniles, have to be recaptured. On recaptured animals the vestigial single-rooted first premolar could be removed and age determined as GARSHELIS (1984) and BODKIN *et al.* (1997) described for *E. lutris*. However, it still has to be proven whether the first premolar is suitable for age determination in *L. provocax*. Furthermore the capture of this species is very difficult and planned recapture almost impossible.

Sutures of skull

The otter skulls have only been used to distinguish between juvenile and adult animals. No differences in sutures were found between subadult – adult to seniors. We estimate the age of M 04/x1 at 6 – 7 months, as juveniles stay first months in den and were usually first seen in August – September and this otter was trapped

at the beginning of February. Furthermore I assume that the juvenile southern river otter already had a permanent dentition, as at 5 months all permanent teeth were developed in *L. lutra* (HEGGBERGET & CHRISTENSEN, 1996).

In conclusion, the applied methods show promising results as all four individuals can be classified by each method, i.e. tooth wear, dental pulp, incremental cementum lines and sutures of skull into the same age class. However, suture method can only be used to determine between the juvenile and adult stage.

More material is needed for statistical procedures and for a more precise age classification an animal with known age has to be investigated.

7 Summary

The southern river otter *Lontra provocax* belongs to the genus *Lontra* (American river otters) and is distributed along southern Chile and Argentina. The southern river otter, once widely distributed in Chile, is today in freshwater habitats limited to only few isolated areas. The southern river otter is listed in CITES Appendix I; in the EU by law 338/97 in Annex A; and in the IUCN Red List of vertebrates as 'endangered'.

The conducted study presents for the first time substantial data and analyses on preferred habitat components, activity pattern, prey availability, diet composition and potential food competitors, as well as a first attempt in age determination, which is essential for demographic studies. The principle aim of the study is to gain knowledge of the behaviour and the factors which may effect the distribution and abundance of the southern river otter.

Three southern river otter, two female and one male, were successful equipped with radio transmitter and radio tracked. Both female southern river otters were classified as resident, as they met the asymptote for home range stabilisation. However the male southern river otter was classified as temporary resident, as he stayed for 4 months in the study area and then disappeared.

As only the home range of one female was accessible for a habitat composition survey, her preferred habitat structures were analysed. Thus the plant Quila *Chusquea quila* is most important for den sites in anthropogenic modified areas, as it is very dense and provides protection. Two accidentally found dens in the ombrophilous swamp forest were encountered under big trees and overhanging roots. Therefore it is assumed that vegetation type for den sites depends upon the degree of anthropogenic influence.

The investigated hunting areas in the anthropogenic modified region had considerably more woody debris than in non-hunting areas. This can be explained by the use of woody debris by the crayfish *Samastacus spinifrons*, the main prey of *L. provocax*, which hides in this substrate. Furthermore the appearance of the substrate gravel is correlated with woody debris, and this provides hiding places for *Aegla abtao*, another crustacean species that *L. provocax* preys upon.

Investigations of marking sites used by *L. provocax* show that latrines close to the water line and in conspicuous and open vegetation structures, such as soil/stones and grass/herbs, were preferred, as other southern river otters may be able to find these markings easily.

Most of their time southern river otter spent in dens (60 %). When being active, the time bouts of movement behaviour averaged 2:18 hours and the distance covered in that time averaged 914 m. By analysing the activity pattern of *L. provocax*, cathemeral behaviour was detected. However, the predominant reason for cathemeral activity cannot be identified in the present study.

As one female southern river otter gave birth in the time of investigations, her activity pattern and home range changed. In the postnatal period home range was reduced and undisturbed tributaries were used. As the cubs aged, all river sections previously used by the mother were visited regularly. The activity pattern of the female with cubs changed significantly, as she spent time outside of the den more frequently.

Amphibian samplings and electrofishing was carried out in the study area to determine potential prey species and prey availability, taking into consideration the influencing factors, for the southern river otter. To draw conclusions of diet composition, competition and seasonal changes, 606 faecal samples of *L. provocax* and 24 of *M. vison* were analysed.

Amphibian diversity and abundance was low due to strong anthropogenic modified area and resultant inadequate amphibian habitats. The crustacean species *S. spinifrons* was the most encountered aquatic prey species in abundance and in total biomass in the investigated river. For the occurrence of *S. spinifrons* the river bed composition of woody debris as well as trees/roots was most important. Flooding seems to influence prey availability negatively, as abundance and biomass of aquatic species decreased significantly after this occurred.

The investigated river is characterized by its low hardness, low conductivity but high oxygen concentration. Even in water samples taken close to villages, physico-chemical parameter values were well below critical or toxic levels on aquatic species. However, due to the low buffer capacity of the river, it is sensitive to any changes which may increase the pH-value and threat egg and larvae development of fishes.

The diet of *L. provocax* consisted mainly of crustaceans, with a minor element of fish, which significant increase during the wet season. Even only few faeces with fish remains were detected, it is assumed that the southern river otter consumes fish regularly, as the animal would need to consume for its daily basic metabolic requirements on average 318 individuals of *S. spinifrons*. Faeces with fish remains may not be used for marking, as it is more ephemeral than faeces which contain crustacean remains.

The only possible food competitor for *L. provocax* which occurs in the study area is the American mink *Mustela vison*. However, a lack of food competition between *L. provocax* and *M. vison* is suggested, as compared food sources of both species demonstrate a relatively low similarity of diet.

Tooth wear; tooth abrasions; dental pulp; relative width of dental pulp, incremental cementum lines; number of lines, and sutures of the skull; visible sutures were used for age determination on four southern river otter skulls. By using the methods tooth wear, incremental cementum lines and relative width of dental pulp it was possible to classify the animals as juvenile (n=1), subadult-adult (n=1) and senior (n=2). However, as only the juvenile showed sutures, it was not possible to distinguish between subadult - adult to senior and therefore sutures on skulls provide information about age, but have to be used in combination with the other presented methods for more accurate classification.

In the present study it was possible to highlight and discuss behaviour patterns and present factors, which are of importance for southern river otter presence.

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10 Appendix

10.1 Methods

Calculation of the condition Index K , with linear regression

The relation of weight W , (measured in kg) and length, l , (measured in meters) of a southern river otter can be expressed by the function:

$$W = a \times L^b .$$

We are looking for the coefficients a and b , so that the real data are represented as accurately as possible by this relation.

By regarding the natural logarithm of the above equation and by using the logarithmic equations we get:

$$\begin{aligned}\ln W &= \ln(a \times l^b), \\ \ln W &= \ln a + \ln(l^b), \\ \ln W &= \ln a + b \times \ln l.\end{aligned}$$

With the following notation

$$X := \ln l, Y := \ln W, q := \ln a \text{ und } p := b,$$

we can derive the simple linear function

$$Y = p \times X + q,$$

with the unknown parameters p and q .

Let x_i and y_i be the natural logarithm of the length and the weight, respectively, of animal i .

By the least square method we are looking for the minimum of the following function:

$$Q(p, q) = \sum_{i=1}^k (y_i - (p \times x_i + q))^2,$$

where k is the sample size.

Finding the minimum of Q , the first partial derivatives must be equal zero.

$$\frac{\partial Q(p, q)}{\partial q} = \sum_{i=1}^k 2(y_i - px_i - q)(-1) = 0, \quad (1)$$

$$\frac{\partial Q(p, q)}{\partial p} = \sum_{i=1}^k 2(y_i - px_i - q)(-x_i) = 0. \quad (2)$$

By rearranging these equations we get

$$(1) \quad kq + p \sum_{i=1}^k x_i = \sum_{i=1}^k y_i,$$

$$(2) \quad q \sum_{i=1}^k x_i + p \sum_{i=1}^k x_i^2 = \sum_{i=1}^k x_i y_i.$$

It is

$$\bar{x} = \frac{1}{k} \sum_{i=1}^k x_i \quad \text{und} \quad \bar{y} = \frac{1}{k} \sum_{i=1}^k y_i,$$

$$s_{xy} = \frac{1}{k} \sum_{i=1}^k (y_i - \bar{y})(x_i - \bar{x}) = \frac{1}{k} \sum_{i=1}^k y_i x_i - \bar{y}\bar{x},$$

and

$$s_x^2 = \frac{1}{k} \sum_{i=1}^k (x_i - \bar{x})^2 = \frac{1}{k} \sum_{i=1}^k x_i^2 - \bar{x}^2.$$

Now, we can calculate the unknown parameters p and q :

$$q = \bar{y} - p\bar{x}, \quad p = \frac{s_{xy}}{s_x^2}$$

After a back-transformation we get a and b .

10.2 Home range and activity patterns of the southern river otter

Tab. A: Matrix of means and standard errors of den site

	Sand; Stones	Grass; Herbs	Bushes	Trees	Big trees	Roots	Overh. Roots	Quila
Sand; Stones		-1.012 ± 0.953	-2.061 ± 1.226	-3.812 ± 1.079	-3.470 ± 0.565	-3.371 ± 0.565	-2.893 ± 0.628	-6.631 ± 1.279
Grass; Herbs	1.012 ± 0.953		-1.049 ± 0.375	-2.800 ± 1.374	-2.458 ± 0.912	-2.359 ± 0.912	-1.880 ± 0.697	-5.618 ± 2.032
Bushes	2.061 ± 1.226	1.049 ± 0.375		-1.751 ± 1.596	-1.408 ± 1.062	-1.310 ± 1.062	-0.831 ± 1.067	-4.569 ± 2.236
Trees	3.812 ± 1.079	2.800 ± 1.374	1.751 ± 1.596		0.342 ± 1.117	0.441 ± 1.117	0.919 ± 1.110	-2.819 ± 1.901
Big trees	3.470 ± 0.565	2.458 ± 0.912	1.408 ± 1.062	-0.342 ± 1.117		0.098 ± 0.000	0.577 ± 0.886	-3.161 ± 1.333
Roots	3.371 ± 0.565	2.359 ± 0.912	1.310 ± 1.062	-0.441 ± 1.117	-0.098 ± 0.000		0.479 ± 0.886	-3.259 ± 1.333
Overh. Roots	2.893 ± 0.628	1.880 ± 0.697	0.831 ± 1.067	-0.919 ± 1.110	-0.577 ± 0.886	-0.479 ± 0.886		-3.738 ± 1.691
Quila	6.631 ± 1.279	5.618 ± 2.032	4.569 ± 2.236	2.819 ± 1.901	3.161 ± 1.333	3.259 ± 1.333	3.738 ± 1.691	

Tab. B: Matrix of means and standard errors of hunting area

	Sand	Gravel	Stones	Rocks	Woody debris
Sand		1.238 ± 0.646	3.600 ± 0.514	3.125 ± 0.469	-0.907 ± 0.436
Gravel	-1.238 ± 0.646		2.362 ± 0.611	1.886 ± 0.617	-2.145 ± 0.593
Stones	-3.600 ± 0.514	-2.362 ± 0.611		-0.476 ± 0.202	-4.507 ± 0.567
Rocks	-3.125 ± 0.469	-1.886 ± 0.617	0.476 ± 0.202		-4.031 ± 0.565
Woody debris	0.907 ± 0.436	2.145 ± 0.593	4.507 ± 0.567	4.031 ± 0.565	

Tab. C: Correlation of right side riparian vegetation structure and bank angle. Specified are r_s , $t(n-2)$, and p values. Significant values are shown in bold numeric ($n=75$).

Variable		Bank angle (right side)				Riparian vegetation structure (right side)									
		<15°	15° -45°	>45°	90°	Sand, Stones	Grass, Herbs	Bushes	Trees	Big trees	Roots	Overh. roots	Quila	Dead trees	
Bank angle (left side)	<15°	-0.070	-0.116	-0.048	0.161	-0.253	-0.081	0.246	0.074	0.256	0.405	-0.079	-0.079	-0.049	
		-0.599	-0.995	-0.410	1.389	-2.237	-0.694	2.169	0.638	2.261	3.787	-0.675	-0.675	-0.417	
		0.551	0.323	0.683	0.169	0.028	0.490	0.033	0.526	0.027	0.000	0.502	0.502	0.678	
	15° -45°	-0.098	-0.052	0.188	-0.108	-0.188	0.132	-0.077	0.042	0.019	-0.005	0.189	-0.111	-0.069	
		-0.856	-0.443	1.633	-0.926	-1.634	1.138	-0.656	0.362	0.158	-0.044	1.647	-0.952	-0.588	
	>45°	0.401	0.659	0.107	0.358	0.107	0.259	0.514	0.719	.875	0.965	0.104	0.344	0.559	
		-0.010	-0.016	0.102	-0.087	0.115	-0.125	-0.109	-0.093	-0.202	-0.054	-0.063	0.257	0.159	
	90°	-0.081	-0.134	0.875	-0.748	0.989	-1.077	-0.938	-0.801	-1.760	-0.460	-0.537	2.269	1.376	
		0.936	0.894	0.384	0.457	0.326	0.285	0.351	0.426	0.083	0.647	0.593	0.026	0.173	
	Riparian vegetation structure (left side)	Sand, Stones	0.135	0.132	-0.240	0.088	0.179	0.087	0.034	0.026	0.057	-0.187	-0.033	-0.256	-0.096
			1.161	1.140	-2.111	0.751	1.552	0.744	0.292	0.226	0.489	-1.624	-0.280	-1.346	-0.828
			0.250	0.258	0.038	0.455	0.125	0.459	0.771	0.822	0.626	0.109	0.780	0.183	0.411
Grass, Herbs		0.036	-0.042	-0.237	0.249	0.46	0.211	-0.171	-0.150	-0.003	0.223	0.051	-0.236	-0.029	
		0.313	-0.364	-2.095	2.213	1.266	1.861	-1.496	-1.308	-0.030	1.964	0.443	-2.086	-0.249	
		0.755	0.717	0.040	0.030	0.209	0.067	0.139	0.195	0.976	0.053	0.659	0.040	0.804	
Bushes		0.158	0.108	-0.231	0.085	-0.011	-0.038	0.304	0.005	0.034	0.091	-0.047	-0.063	-0.151	
		1.375	0.933	-2.044	0.736	-0.096	-0.327	2.744	0.042	0.289	0.785	-0.402	-0.545	-1.310	
		0.173	0.354	0.045	0.464	0.924	0.745	0.008	0.966	0.773	0.435	0.689	0.587	0.194	
Trees		-0.004	0.050	0.054	-0.087	0.004	-0.004	0.113	-0.134	-0.099	0.026	0.116	-0.126	0.244	
		-0.036	0.434	0.467	-0.751	0.033	-0.030	0.978	-1.164	-0.860	0.220	1.003	-1.090	2.162	
		0.972	0.665	0.642	0.455	0.973	0.976	0.331	0.248	0.39	0.827	0.319	0.279	0.034	
Big trees	0.058	-0.105	0.201	-0.155	0.105	-0.064	-0.114	0.044	-0.243	-0.119	-0.187	-0.147	0.043		
	0.501	-0.910	1.763	-1.348	0.908	-0.554	-0.990	0.380	-2.160	-1.031	-1.636	-1.283	0.372		
	0.618	0.366	0.082	0.182	0.367	0.581	0.326	0.705	0.034	0.306	0.106	0.204	0.711		
Roots	0.259	0.116	-0.168	-0.029	0.133	-0.044	0.050	-0.069	-0.059	-0.065	-0.054	-0.054	-0.033		
	2.305	1.002	-1.468	-0.249	1.152	-0.382	0.432	-0.593	-0.511	-0.556	-0.463	-0.463	-0.287		
	0.024	0.320	0.146	0.804	0.253	0.703	0.667	0.555	0.611	0.580	0.645	0.645	0.775		
Overh. roots	0.073	0.064	-0.120	0.043	0.353	-0.013	-0.167	-0.269	-0.120	0.010	-0.109	-0.109	0.166		
	0.626	0.551	-1.039	0.370	3.244	-0.113	-1.454	-2.407	-1.040	0.089	-0.942	-0.942	1.444		
	0.533	0.583	0.302	0.713	0.002	0.910	0.150	0.019	0.302	0.930	0.349	0.349	0.153		
Quila	0.177	-0.032	-0.198	0.139	-0.006	0.100	0.123	-0.052	-0.023	-0.037	0.002	-0.141	0.059		
	1.548	-0.273	-1.736	1.208	-0.050	0.867	1.065	-0.452	-0.195	-0.321	0.014	-1.226	0.824		
	0.126	0.786	0.087	0.231	0.960	0.389	0.290	0.653	0.846	0.749	0.989	0.224	0.413		
Dead trees	-0.075	-0.124	0.195	-0.075	-0.151	-0.164	-0.210	0.145	0.087	-0.101	-0.084	0.449	-0.052		
	-0.647	-1.073	1.707	-0.651	-1.318	-1.434	-1.846	1.259	0.747	-0.875	-0.728	4.323	-0.450		
	0.520	0.287	0.092	0.517	0.191	0.156	0.069	0.212	0.457	0.384	0.469	0.000	0.654		
	---	---	---	---	---	---	---	---	---	---	---	---	---		

10.3 Rearing cubs: effect on home range and activity pattern of a female southern river otter (*Lontra provocax* Thomas 1908)

Tab. A: Calculated velocity of radio tracked southern river otter F 03/36 without and with cubs

ID	Velocity (km/h)		Maximum velocity (km/h)
	\bar{x}	SE	
without cubs	1.47	0.09	10.64
with cubs	0.90	0.05	11.21
Average (\bar{x})	1.08	0.05	10.93

Tab B: Dens and resting sites used antenatal and postnatal

	without cubs (April – June)	with cubs (Aug. – Sept.)	with cubs (Oct. – Nov.)
Dens and resting sites	10 (4)*	5 (3)*	14 (5)*
Distance from natal den to furthest den	---	3250 m	7813 m

* (x) = exclusively used in total time of radio-tracking

Tab. C: Hypothetical reproduction cycle of the southern river otter

Occurrence	Duration	Month	Season
Period of conception	5 month	Dec. – April	Spring – Autumn
Gestation*	<i>variable delayed implantation</i>	Dec. – July	Spring – Winter
Birth	---	July	Autumn – Winter
Cub-rearing	7-8 month	July – Feb.	Winter – Spring
Travelling with mother	5 month	Sept. – Feb.	Winter – Summer

*= assumption

10.4 Prey availability, diet composition and food competition

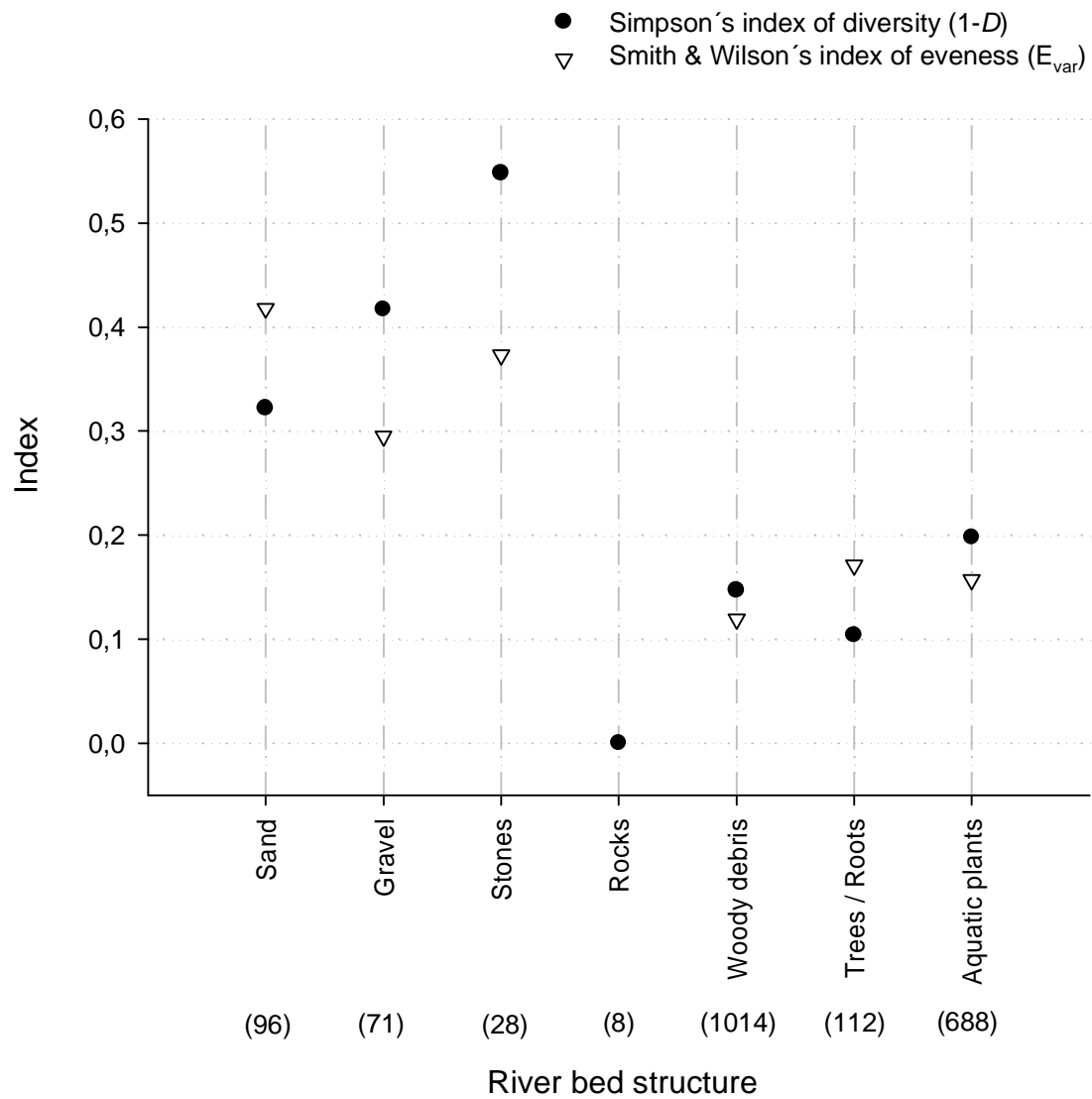


Fig. A: Evenness and species diversity of all electrofished sites

Tab. A: Levins's measure of standardized niche breadth and number of frequently used resources of electrofished species (n.m. = not measurable)

Species	Standardized niche breadth (B_A)	Number of frequently used resources
<i>A. abtao</i>	0.515	3
<i>S. spinifrons</i>	0.065	2
<i>Brachygalaxias bullocki</i>	n.m.	1
<i>Cheirodon galusdai</i>	n.m.	1
<i>Galaxias maculatus</i>	n.m.	1
<i>Geotria australis</i>	0.298	2
<i>Oncorhynchus mykiss</i>	n.m.	1
<i>Percichthys trucha</i>	n.m.	1
<i>Salmo trutta fario</i>	0.357	4
<i>Trichomycterus areolatus</i>	0.669	5

Tab. B. Standardized selection index (B_i); *A.a.* = *A. abtao*; *S.s.* = *S. spinifrons*; *B.b.* = *Brachygalaxias bullocki*; *C.a.* = *Caudiverbera cuadiverbera*; *C.g.* = *Cheirodon galusdai*; *G.a.* = *Geotria australis*; *G.m.* = *Galaxias maculatus*; *O.m.* = *Oncorhynchus mykiss*; *P.t.* = *Percichthys trucha*; *S.t.f.* = *Salmo trutta fario*; *T.a.* = *Trichomycterus areolatus*

Species / Substrate	<i>A.a.</i>	<i>S.s.</i>	<i>B.b.</i>	<i>C.c.</i>	<i>C.g.</i>	<i>G.m.</i>	<i>G.a.</i>	<i>O.m.</i>	<i>P.t.</i>	<i>S.t.f.</i>	<i>T.a.</i>
Sand	0.000	0.005	0.000	0.000	0.000	0.000	0.477	0.000	0.000	0.071	0.000
Gravel	0.238	0.006	0.000	0.000	0.000	0.000	0.016	0.000	0.000	0.019	0.159
Stones	0.438	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.345
Rocks	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Woody debris	0.300	0.597	0.000	0.000	1.000	0.000	0.000	0.000	1.000	0.415	0.066
Trees/roots	0.023	0.255	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.387	0.276
Aquatic plants	0.000	0.037	1.000	1.000	0.000	1.000	0.508	1.000	0.000	0.108	0.153

Tab. C: River bed characteristics, species density and presence of eleven electrofished sites (2003)

Section	Substrate Type in m ³							Number of captures ^a										
	Sand	Gravel	Stones	Rocks	Woody debris	Trees / Roots	Aquatic plants	A.a.	S.s.	B.b.	C.c.	C.g.	G.m.	G.a.	O.m.	P.t.	S.t.f.	T.a.
Q 01	17	33	20	0	30	0	0	3	96	0	0	0	0	12	0	0	3	0
Q 02	10	50	3	5	32	0	0	67	133	0	0	0	0	7	0	0	2	1
Q 03	100	0	0	0	0	0	0	0	1	0	0	0	0	17	0	0	0	0
Q 04	10	27	0	16	47	0	0	8	147	0	0	0	0	6	0	2	2	1
Q 05	63	33	0	0	4	0	0	11	168	0	0	0	0	16	0	0	3	0
Q 06	56	17	17	0	10	0	0	12	60	0	0	0	0	3	0	0	1	1
Q 07	0	83	0	0	17	0	0	12	54	0	0	0	0	10	0	1	4	0
Q 08	35	42	0	0	23	0	0	8	300	0	0	1	0	9	0	1	9	2
Q 09	60	0	0	0	20	20	0	1	78	0	0	1	0	0	0	0	4	1
Q 10	20	0	0	0	40	40	0	1	49	0	0	0	0	0	0	0	0	0
M 01	0	0	0	0	5	0	95	0	24	20	2	2	615	22	2	0	2	1
Total	371	285	40	21	228	60	95	123	1110	20	2	4	615	102	2	4	30	7
Presence	81.8	63.6	27.3	18.2	90.1	18.1	9.1	81.8	100	9.1	9.1	27.3	9.1	81.8	9.1	27.3	81.8	54.5

Q = Upper Queule River

M = Mahuidanche River

^a Species: *A. abtao*, *S. spinifrons*, *Brachygalaxias bullocki*, *Caudiverbera caudiverbera*, *Cheirodon galusdai*, *Galaxias maculatus*, *Geotria australis*, *Oncorhynchus mykiss*, *Percichthys trucha*, *Salmo trutta fario*, *Trichomycterus areolatus*

Tab. D: Measurements of physical and chemical water analysis of UQR and Mahuidanche River (2003 – 2004)

Station		Q _{WS} 01 ^a	Q _{WS} 02 ^a	Q _{WS} 03 ^a	Q _{WS} 04 ^a	Q _{WS} 05 ^a	M _{WS} 01 ^b	M _{WS} 02 ^b
Parameter	Units	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c	Annual mean ± std. (Range) ^c
Current	m s ⁻¹	0.9 ± 0.7 (0.1 – 2.0)	0.8 ± 0.3 (0.3 – 1.9)	0.4 ± 0.2 (0.1 – 0.7)	0.8 ± 0.3 (0.3 – 1.4)	0.7 ± 0.6 (0.2 – 0.6)	0.3 ± 0.1 (0.2 – 0.6)	0.3 ± 0.2 (0.0 – 0.9)
Temperature	°C	11.2 ± 2.0 (6.8 – 14.0)	11.6 ± 2.2 (7.9 – 16.0)	11.6 ± 3.1 (7.2 – 18.6)	12.3 ± 3.3 (7.1 – 17.8)	12.2 ± 3.2 (7.9 – 18.5)	11.7 ± 2.9 (7.0 – 16.9)	11.5 ± 2.7 (7.2 – 17.1)
pH		6.5 ± 0.1 (6.2 – 6.7)	6.4 ± 0.4 (5.9 – 7.1)	6.8 ± 0.4 (6.1 – 7.5)	6.6 ± 0.3 (5.9 – 6.9)	6.8 ± 0.3 (6.1 – 7.3)	6.5 ± 0.3 (5.9 – 6.9)	6.3 ± 0.4 (5.7 – 6.9)
Conductivity	µS cm ⁻¹	15.2 ± 4.9 (6.0 – 23.0)	17.2 ± 4.1 (11.0 – 22.0)	22.8 ± 13.8 (11.0 – 59.0)	29.4 ± 8.7 (18.0 – 47.0)	24.7 ± 8.2 (11.0 – 43.0)	25.8 ± 34.3 (6.0 – 128.0)	23.3 ± 10.9 (15.0 – 52.0)
Salinity	g l ⁻¹	0.10 ± 0.00 (0.09 – 0.11)	0.10 ± 0.00 (0.10 – 0.11)	0.11 ± 0.01 (0.10 – 0.14)	0.11 ± 0.01 (0.10 – 0.13)	0.11 ± 0.01 (0.10 – 0.12)	0.11 ± 0.03 (0.09 – 0.19)	0.11 ± 0.01 (0.10 – 0.13)
Turbidity	mg l ⁻¹	2.5 ± 0.5 (2.0 – 4.0)	2.6 ± 0.4 (2.0 – 4.0)	2.6 ± 0.3 (2.0 – 3.0)	3.5 ± 1.2 (2.5 – 7.0)	3.2 ± 0.8 (2.5 – 5.0)	2.6 ± 0.4 (2.5 – 4.0)	3.5 ± 1.6 (2.5 – 7.0)
Oxygen	mg l ⁻¹	11.71 ± 1.54 (8.10 – 14.21)	11.36 ± 1.16 (9.00 – 13.59)	11.74 ± 1.98 (9.66 – 16.63)	11.28 ± 1.20 (8.97 – 13.87)	11.13 ± 1.62 (8.14 – 14.21)	11.51 ± 2.53 (8.56 – 17.73)	11.42 ± 2.05 (7.87 – 16.28)
Chemical oxygen demand (COD)	mg l ⁻¹	6.3 ± 6.1 (1.0 – 19.3)	6.9 ± 4.8 (0.5 – 16.0)	8.3 ± 5.9 (2.4 – 23.0)	10.0 ± 5.8 (2.8 – 21.6)	11.0 ± 6.5 (3.3 – 25.8)	5.2 ± 2.1 (1.4 – 8.5)	8.8 ± 5.7 (1.0 – 21.6)
N-NO ₃ ⁻	µg l ⁻¹	61.4 ± 36.6 (23.5 – 153.5)	62.4 ± 41.4 (15.5 – 182.5)	53.7 ± 23.9 (14.5 – 94.5)	85.2 ± 38.2 (29.5 – 182.5)	82.8 ± 32.5 (43.5 – 153.5)	33.8 ± 10.7 (11.5 – 49.5)	48.6 ± 24.8 (23.5 – 117.5)
N-NO ₂ ⁻	µg l ⁻¹	0.66 ± 0.60 (0.03 – 2.11)	0.47 ± 0.34 (0.08 – 1.31)	0.44 ± 0.18 (0.25 – 0.88)	1.04 ± 0.52 (0.25 – 2.24)	1.14 ± 0.57 (0.15 – 2.11)	0.45 ± 0.25 (0.03 – 0.85)	0.95 ± 0.90 (0.20 – 3.72)
N-NH ₃ ⁺	µg l ⁻¹	6.2 ± 7.0 (0.3 – 17.7)	7.5 ± 14.7 (0.3 – 52.5)	4.8 ± 7.6 (0.0 – 27.6)	11.7 ± 15.1 (0.3 – 52.5)	8.8 ± 13.9 (0.0 – 50.0)	1.4 ± 2.5 (0.0 – 7.7)	26.8 ± 50.3 (0.3 – 174.3)
N _{org}	µg l ⁻¹	35.4 ± 12.8 (12.5 – 53.2)	50.8 ± 32.9 (8.0 – 123.4)	57.6 ± 36.9 (8.0 – 132.5)	58.4 ± 35.8 (8.0 – 132.5)	64.4 ± 29.4 (5.7 – 123.4)	80.2 ± 48.1 (8.0 – 152.8)	62.5 ± 45.1 (5.7 – 150.6)
P-PO ₄ ³⁻ (TP)	µg l ⁻¹	23.9 ± 23.5 (2.3 – 70.0)	47.3 ± 39.8 (16.2 – 132.4)	38.6 ± 21.0 (0.7 – 76.4)	72.2 ± 36.8 (31.3 – 180.1)	48.2 ± 23.2 (0.9 – 97.7)	39.9 ± 54.3 (2.1 – 209.5)	42.5 ± 22.4 (6.9 – 87.5)
SiO ₂	mg l ⁻¹	3.17 ± 1.10 (1.98 – 5.86)	3.05 ± 1.13 (1.98 – 6.12)	2.93 ± 0.81 (1.98 – 4.65)	3.17 ± 0.81 (1.98 – 5.00)	3.40 ± 0.90 (2.32 – 4.91)	3.28 ± 1.38 (2.06 – 6.72)	3.44 ± 1.49 (2.06 – 6.55)
SO ₄ ²⁺	mg l ⁻¹	1.2 ± 2.1 (0.0 – 7.1)	1.8 ± 3.2 (0.0 – 11.8)	1.2 ± 0.9 (0.0 – 2.4)	3.0 ± 3.5 (0.0 – 11.8)	2.4 ± 1.8 (0.0 – 7.1)	1.3 ± 0.8 (0.0 – 3.2)	2.5 ± 2.9 (0.0 – 9.1)
Cl ⁻	mg l ⁻¹	3.29 ± 0.53 (2.82 – 4.03)	3.05 ± 0.68 (2.11 – 4.03)	2.97 ± 0.70 (1.81 – 3.52)	3.47 ± 0.46 (3.02 – 4.03)	3.90 ± 0.75 (3.02 – 5.04)	2.92 ± 0.54 (2.22 – 3.52)	2.49 ± 0.44 (2.01 – 3.02)
Alkalinity	meq l ⁻¹	0.25 ± 0.03 (0.20 – 0.32)	0.27 ± 0.05 (0.20 – 0.38)	0.30 ± 0.11 (0.22 – 0.64)	0.29 ± 0.03 (0.26 – 0.36)	0.29 ± 0.04 (0.24 – 0.40)	0.27 ± 0.03 (0.20 – 0.32)	0.29 ± 0.10 (0.22 – 0.60)
HCO ₃ ⁻	mg l ⁻¹	15.25 ± 1.91 (12.20 – 19.52)	16.53 ± 3.22 (12.20 – 23.18)	18.41 ± 6.93 (13.42 – 39.04)	17.63 ± 1.67 (15.86 – 21.96)	17.75 ± 2.67 (14.64 – 24.40)	16.23 ± 1.97 (12.20 – 19.52)	17.52 ± 6.16 (13.42 – 36.60)
Total hardness	mmol l ⁻¹	0.05 ± 0.01 (0.03 – 0.06)	0.05 ± 0.02 (0.02 – 0.10)	0.05 ± 0.01 (0.03 – 0.07)	0.06 ± 0.01 (0.04 – 0.10)	0.06 ± 0.01 (0.04 – 0.07)	0.05 ± 0.01 (0.04 – 0.06)	0.06 ± 0.03 (0.04 – 0.13)

^a = Water Sample Station at UQR; ^b = Water Sample Station at Mahuidanche River; ^c = minimum – maximum range

Tab. E: Energy content (Kcal/100g) of crustacean and fish

Species	Kcal/100g
Crustacean	
<i>Samastacus spinifrons</i>	99
<i>Aegla abtao</i>	88
Fish	
<i>Salmo trutta fario</i>	157
<i>Odontesthes regia</i>	125

10.5 Age determination of male southern river otter *Lontra provocax* (Thomas 1908)

Tab. A: Measurements of dental pulp

Animal	max. pulp width in mm	max. dental width in mm	relative width in %
M 04/x2	5.17	7.75	66.70
M 04/x1	1.92	7.75	24.80
M 03/x1	1.44	7.94	18.10
M 01/06	1.03	8.07	12.80

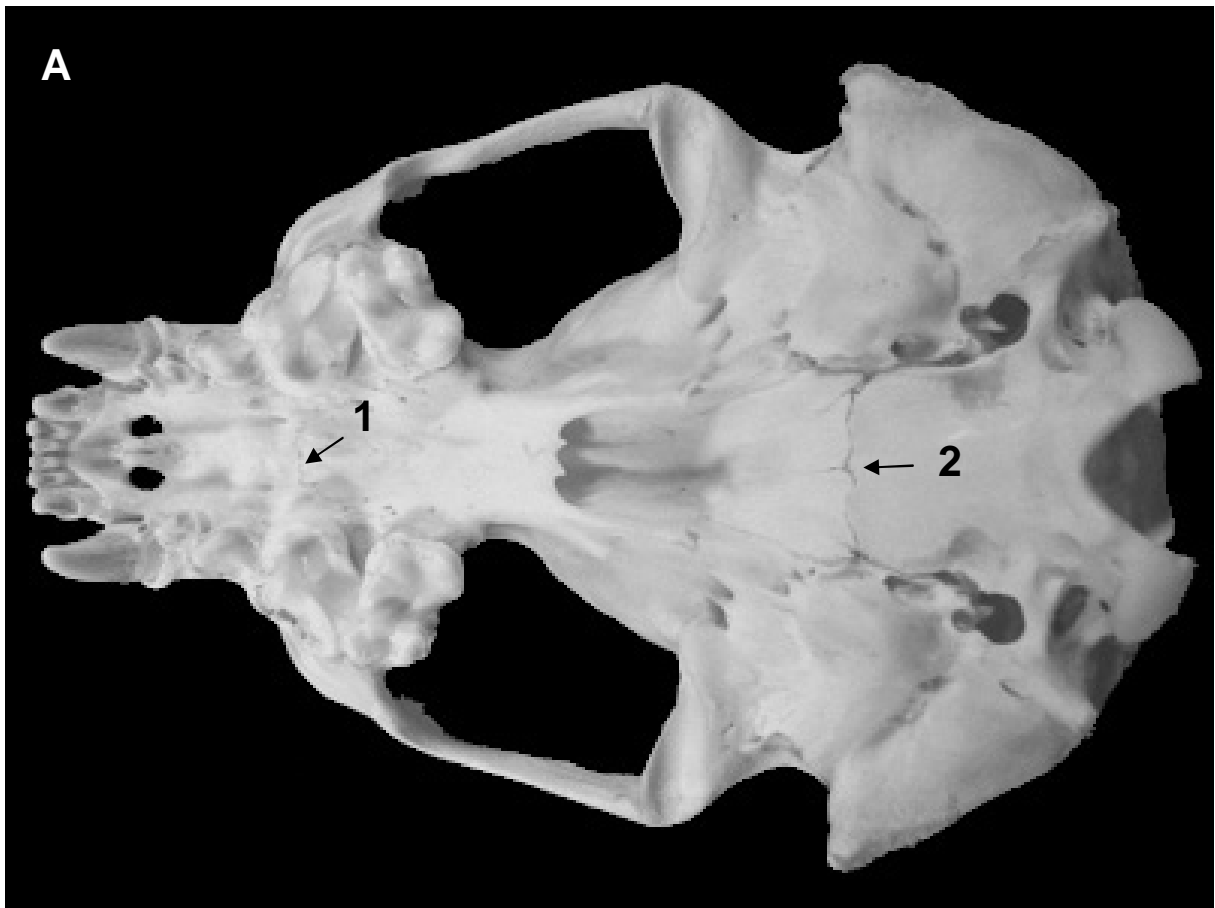


Fig. A: Skull of M 04/x2:

1 = transverse palatine suture (*Sutura palatina transversa*)

2 = sphenoid-occipital synchondrosis (*Synchondrosis sphenoid-occipitalis*)

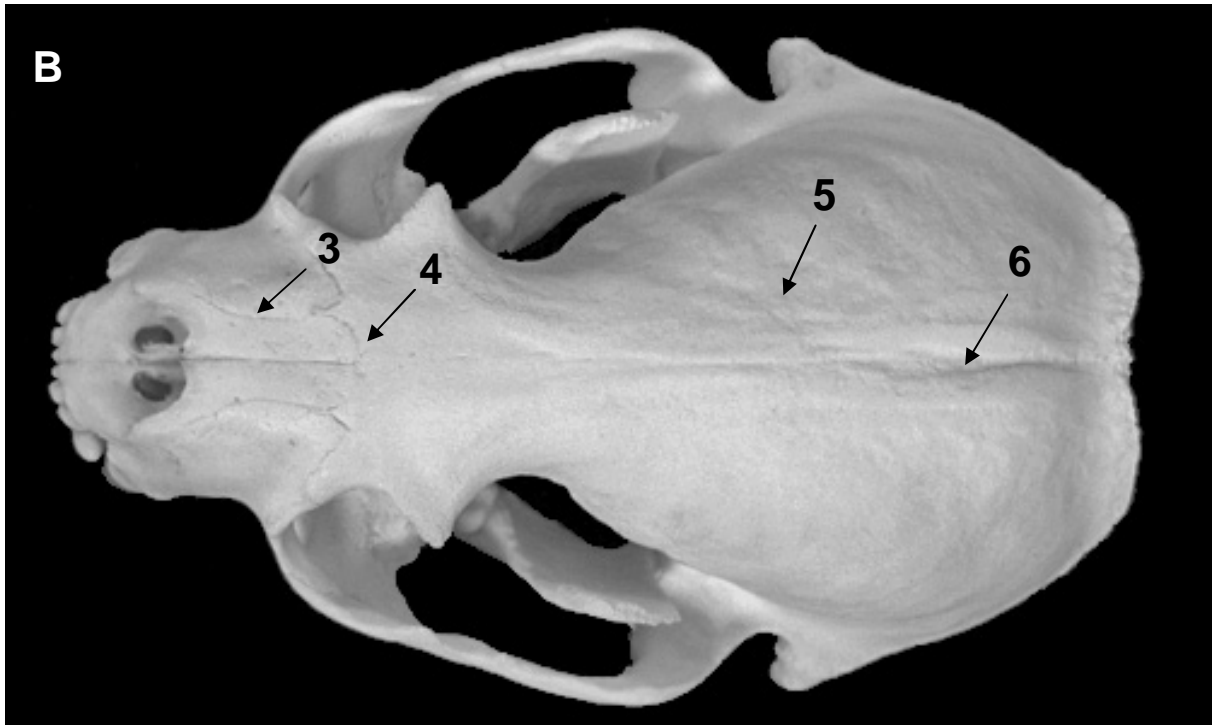


Fig. B: Skull of M 04/x2:

3 = naso-maxillary suture (*Sutura nasomaxillaris*)

4 = frontonasal suture (*Sutura frontnasalis*)

5 = coronal suture (*Sutura coronalis*)

6 = sagittal suture (*Sutura sagittalis*)

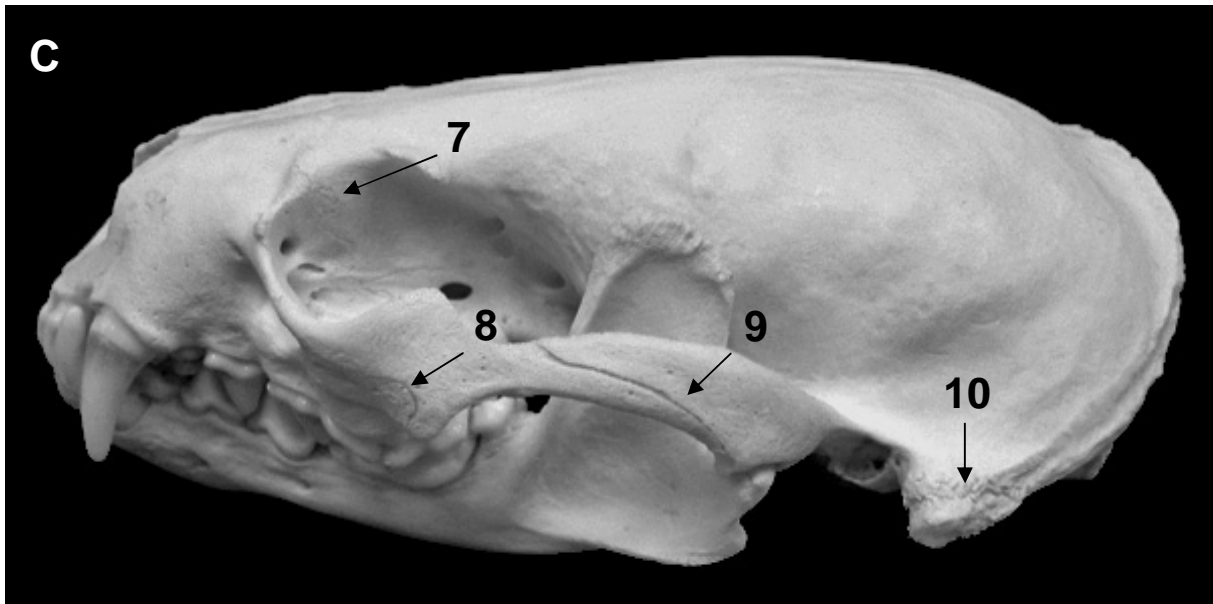


Fig. C: Skull of M 04/x2:

7 = frontozygomatic suture (*Sutura frontozygomatica*)

8 = maxillozygomatic suture (*Sutura zygomaticomaxillaris*)

9 = zygomatico-temporal suture (*Sutura temporozygomatica*)

10 = squamomastoid suture (*Sutura squamosomastoidea*)

CURRICULUM VITAE



Name: Renato Luis-Goetz Reyes Küppers

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Topic of thesis:
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Lontra provocax THOMAS 1908 in Chile"

MSc (May 2000)
Topic of thesis:
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Studies of Biology
Zoology (Ecology), Hydrobiology and Fisheries Science,
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