The Fox Tapeworm (*Echinococcus multilocularis*) and the Red Fox (*Vulpes vulpes*) in the Urban Habitat: Ecological and Epidemiological Aspects and an Evaluation of an Intervention Strategy

Dissertation

zur
Erlangung der naturwissenschaftlichen Doktorwürde
(Dr. sc. nat.)

vorgelegt der
Mathematisch-naturwissenschaftlichen Fakultät
der
Universität Zürich

von

Daniel Hegglin

von Menzingen ZG

Begutachtet von

Prof. Dr. Peter Deplazes
Dr. Thomas Romig
Prof. Dr. Paul I. Ward

Zürich 2003

Die vorliegende Arbeit wurde von der
Mathematisch-naturwissenschaftlichen Fakultät der Universität Zürich
auf Antrag von
Prof. Dr. Paul I. Ward
und
Prof. Dr. Andrew D. Barbour
als Dissertation angenommen.

Dank

Ein herzliches Dankeschön geht an alle, die mit ihrer Hilfe und Unterstützung zu meiner Dissertation beigetragen haben. Prof. Dr. Peter Deplazes danke ich ganz herzlich für seine Unterstützung und die gute und immer sehr anregende Zusammenarbeit. Prof. Dr. Paul I. Ward danke ich sehr für seine Bereitschaft meine extern durchgeführte Dissertation zu betreuen und für seine statistische und konzeptionelle Hilfe.

Ein herzliches Dankeschön geht an alle MitarbeiterInnen des Instituts für Parasitologie, insbesondere an Dr. Claudia Stieger für die schöne und gute Zusammenarbeit und an Rita Bosshart, Lucia Kohler, Sasa Stefanic und Isabelle Tanner für die super Hilfe bei den vielen Laborarbeiten. Weiter sind mir Dr. Mohammed Ebeid, Prof. Dr. Johannes Eckert, Dr. Sonja Hofer, Prof. Dr. Peter Köhler, Dr. Alexander Mathis, Dr. Uwe Müller-Doblies, Janet Skaggs, Dr. Paul Torgerson und Marc Wälti mit Rat und Tat zur Seite gestanden.

Den MitarbeiterInnen des Zoologischen Museums danke ich für ihre Gastfreundschaft. Speziell danke ich Dr. Wolf Blankenhorn und Dr. David Hosken für ihre Anregungen und Gioia Schwarzenbach, der ich viel Support bei den Feld- und Laborarbeiten verdanke.

Christian Stauffer und den Wildhüter der Stadt Zürich Hermann Aerne, Stefan Dräyer, Erwin Nüesch und Bruno Zweifel, möchte ich herzlich für den grossen Einsatz und die gute Zusammenarbeit danken, ohne ihre Hilfe wäre das Projekt nicht möglich gewesen.

Ein herzlicher Dank geht an Dr. Uli Müller, Dr. Urs Breitenmoser und das KORA Team für den anregenden Gedankenaustausch und ihren „Fotofallen-Support“. Matthias Ulrich und Markus Leuenberger danke ich herzlich für ihre wertvolle Hilfe bei den Fuchssektionen.

Bei Dr. Thomas Romig möchte ich mich herzlich für sein Gutachten zu meiner Dissertation bedanken.

Die vorliegende Dissertation wurde im Rahmen des Integrierten Fuchsprojektes IFP, einem Forschungs- und Kommunikationsprojekt über die zunehmenden Fuchspopulationen in der Schweiz durchgeführt. An allen, die in diesem Projekt mitgearbeitet haben, geht mein herzlicher Dank. Besonders erwähnen möchte ich die grosse Hilfe bei der Feldarbeit durch Lukas Barth, Claudia Bohl, Hanspeter Brun, Andreas Christoffel, Pascale Contesse, Patrick Fischer, Christina Furrer, Martin Hemmi, Therese Hotz, Claudia Kistler, Anja Klingenböck, Kathi Märki,

Reto Wyss und Jann Romer, der zudem mit grossem Einsatz die technischen Tücken der Fotofallen meisterhaft löste.
Ganz speziell möchte ich mich bei Fabio Bontadina und Sandra Gloor bedanken. Der immer anregende Gedankenaustausch, der vielfältige Support in allen Phasen meiner Arbeit und vor allem die sehr schöne Zusammenarbeit war für mich sehr wertvoll.
Ein riesiges Merci auch an Gianni, Manu, Aire und Geronimo, an Kudi, an Roli und Myriam für allerlei Support! Und zum Schluss ein grosses Dankeschön an meine Mutter Margrith Hegglin-Meyer für ihre grosse Unterstützung auf meinem beruflichen Werdegang.

Die Studie wurde finanziell unterstützt durch das Bundesamt für Veterinärwesen (Projekt Nr. 1.99.03), den Schweizerischen Nationalfonds (Projekt-Nr. 31-47031.96) und das Bundesamt für Bildung und Wissenschaft im Rahmen des EU-FAIR-Projektes CT97-3515 (BBW Nr. 97.0586) und des EchinoRisk Projektes QLK2-CT-2001-001995 (BBW Nr. 00.0586-2).

Table of contents

Zusammenfassung

In verschiedenen Europäischen Ländern sind während den letzten Jahren die Populationen des Rotfuchses (*Vulpes vulpes*) stark angewachsen. Besonders ausgeprägt war diese Entwicklung in städtischen Gebieten, wo heute Füchse oft in nächster Umgebung zu Mensch und Haustier leben. Die silvatische Tollwut ist in Europa nicht ausgerottet und der kleine Fuchsbandwurm *Echinococcus multilocularis* – ein Helminth, der eine schwere Lebererkrankung des Menschen, die Alveoläre Echinokokkose, verursacht – ist in europäischen Fuchspopulationen weit verbreitet. Es stellt sich daher die Frage, wieweit diese Entwicklung mit einer Zunahme zoonotischer Risiken verbunden sein könnte.

Das Ziel dieser Dissertation war (a) die Urbanisierung der Rotfüchse darzustellen, (b) die Bedeutung des natürlichen und anthropogenen Futterangebot für Stadtfüchse zu klären, (c) die Prävalenz von *E. multilocularis* in den urbanen End- und Zwischenwirten zu bestimmen, (d) Faktoren zu eruieren, die die Dynamik des urbanen Zyklus von *E. multilocularis* beeinflussen, und (e) zu evaluieren, ob durch eine Intervention mit Entwurmungs–Köder für Füchse der Infektionsdruck von *E. multilocularis* im städtischen Lebensraum gesenkt werden kann.

Die Befragung der zuständigen Behörden ergab, dass im Jahr 1999 in 28 der 30 grössten Schweizer Städte Füchse registriert wurden. In 20 dieser Städte waren Fuchsbaue mit Jungenaufzucht im Siedlungsraum bekannt. Im Verlauf der oralen Immunisierungskampagnen gegen die Tollwut, begannen in der Stadt Zürich die städtische Fuchspopulation ab 1985 markant anzusteigen. Dieser Anstieg war ausgeprägter in den urbanen Gebieten als in den umliegenden ländlichen Gebieten. Magenanalysen von 402 Stadtfüchsen zeigten, dass mehr als die Hälfte eines durchschnittlichen Mageninhaltes anthropogene Nahrung war. Der Anteil anthropogener Nahrung war höher in Mägen vom Stadtzentrum als in Mägen des peripheren Stadtgebietes, wo entsprechend eine gegenläufige Tendenz zu mehr natürlicher Nahrung, wie Nager, andere Wildtiere und Wildfrüchte, beobachtet wurde. Das in der Stadt Zürich erhobene anthropogene Nahrungsangebot würde ausreichen, um eine wesentlich höhere Anzahl von Füchsen zu ernähren, als aktuell vorhanden ist, und erklärt möglicherweise den kontinuierlichen Anstieg der urbanen Fuchspopulationen.

Um die Prävalenz von *E. multilocularis* in Stadtfüchsen zu bestimmen, wurden die Dünndärme von 388 Füchsen aus der Stadt Zürich auf Helminthen untersucht. Die Prävalenz von *E. multilocularis* bei Füchsen, welche während des Winters gesammelt wurden, wies eine signifikante Zunahme von 47% in städtischen Gebieten zu 67% in den angrenzenden periurbanen Gebieten auf. Ebenso wurde mit einem Koproantigen Sandwich–ELISA in Fuchslosungen aus der periurbanen Zone

häufiger *E. multilocularis* nachgewiesen als in Fuchslosungen aus der urbanen Zone. Im Winter gesammelte Fuchslosungen waren zudem häufiger Koproantigen–positiv als Losungen aus anderen Saisons. Die Prävalenz im Zwischenwirt *Clethrionomys glareolus* betrug 2.4% und 9.1% bei *Arvicola terrestris,* bei der 3.5% der Tiere auch Protoscoleces hatten. Infizierte *A. terrestris* konnten in 9 von 10 Fanggebieten entlang des Stadtrandgebietes nachgewiesen werden, was auf einen hohen Infektionsdruck in dieser Zone hinweist.

Die Köderaufnahme von Füchsen wurde mit Hilfe von Fotofallen in der Stadt Zürich überprüft. 48% der verschwundenen Köder wurden durch Füchse aufgenommen. Die übrigen Köder konsumierten Igel (*Erinaceus europeus*), Schnecken, Hunde und Nager. Hauskatzen, Steinmarder (*Martes foina*) und Dachse (*Meles meles*) haben keine Köder angenommen. Die höchste Köderaufnahmerate durch Füchse wurde während des Sommers, bei Komposthaufen, für Praziquantel–haltige Köder und an Plätzen mit hoher Fuchsaktivität festgestellt.

In der Stadt Zürich wurden in sechs 1–km^2 Flächen und in einer 6–km^2 Fläche monatlich 50 Praziquantel–haltige Köder pro km^2 ausgebracht. Der Anteil Koproantigen–positiver Fuchslosungen änderte sich in den sechs Kontrollflächen nicht, während er in den beköderten 1–km^2 Flächen von 38.6% auf 5.5% und in der beköderten 6–km^2 Fläche von 66.7% auf 1.8% abfiel. Im Verlauf des ersten Jahres der Beköderung ist die Prävalenz im Zwischenwirt *Arvicola terrestris* nicht gesunken. Jedoch wurde in den beköderten Gebieten ein kleineres, relatives Milzgewicht und eine höhere Prävalenz mit Ektoparasiten festgestellt, was auf eine veränderte Aktivität des Immunsystems als Folge eines reduzierten Infektionsdrucks durch *E. multilocularis* Eier hinweist. Während dem zweiten Jahr der Beköderung wurde dann auch beim Zwischenwirt *A. terrestris* ein bedeutender Rückgang der *E. multilocularis* Prävalenz in den beköderten Gebieten nachgewiesen.

Die verschiedenen Arbeiten haben gezeigt, dass die Urbanisierung von Füchsen ein generelles Phänomen vieler Städte ist, wo ein reiches anthropogenes Futterangebot hohe Fuchspopulationen ernähren kann. In der Folge expandiert *E. multilocularis* zunehmend in städtische Gebiete. Die höchste Prävalenz konnte in urbanen Füchsen des Stadtrandgebietes gefunden werden, wo geeignete Habitate für Zwischenwirte mit hohen Fuchsdichten überschneiden. Da diese Flächen intensiv für Freizeitaktivitäten genutzt werden, sollten mögliche Massnahmen zur Reduktion des Infektionsdruckes von *E. multilocularis* in erster Linie auf diese Stadtrandgebiete fokussieren. Die kontrollierte Beköderungs–Studie zeigte, dass der urbane Infektionsdruck durch *E. multilocularis* deutlich gesenkt werden kann. Für eine Entscheidung zu einer Intervention müssen jedoch verschiedene politische, ökologische und ökonomische Aspekte berücksichtigt werden.

Summary

In several European countries a distinct increase of red fox (*Vulpes vulpes*) populations has been observed in recent years, particularly in urban areas. As a result, foxes live today in close vicinity to humans and their pets in many cities on the European Continent. As silvatic rabies is not yet extinct in Europe, and the small fox tapeworm *Echinococcus multilocularis* – a helminth that causes Alveolar Echinococcosis (AE), a severe human liver disease – is widespread in European fox populations, there is a serious concern about possibly emerging zoonotic risks caused by the current fox population dynamics.

The aims of this dissertation were (a) to characterise the urbanisation of red foxes, (b) to assess the importance of anthropogenic food supply for urban fox populations, (c) to determine *E. multilocularis* prevalence in final and intermediate hosts, (d) to investigate factors affecting the dynamic of an urban cycle of *E. multilocularis* and (e) to evaluate an intervention strategy based on the delivery of anthelmintica-containing fox baits in order to reduce the infection pressure with *E. multilocularis* eggs in urban areas.

Inquiry by town officials in 1999 showed that foxes are observed in 28 out of the 30 largest Swiss cities and breeding dens are known in 20 of these cities. In the course of oral rabies vaccination campaigns, the hunting statistics of Zurich city indicate from 1985 onwards a dramatic increase in the fox population, which was more pronounced in the urban areas than in the adjacent rural areas. A stomach analysis of 402 urban foxes revealed that more than half of an average stomach content was anthropogenic food. The proportion was higher in stomachs from the city centre compared with stomachs from the periurban area. Accordingly, an opposite tendency was observed for natural food, such as rodents, other wild animals and wild fruits. The anthropogenic urban food supply was found to be sufficient to feed a much higher number of foxes than currently present in the city of Zurich, which could explain the ongoing increase of urban fox population densities.

To estimate the prevalence of *E. multilocularis* in urban foxes of Zurich, 388 foxes were examined for intestinal infections with helminths. The prevalence in foxes sampled in winter increased from 47% in the urban to 67% in the adjacent periurban area. The proportion of fox faeces positive for *E. multilocularis* coproantigens was also distinctly higher in the periurban area than in the urban area. Furthermore, samples collected in the urban border zone had more coproantigen-positive results during winter than during the rest of the year. Prevalence of *E. multilocularis* in intermediate hosts was 2.4% for *Clethrionomys glareolus* and 9.1 % for *Arvicola terrestris,* which harboured in 3.5% protoscoleces. *E. multilocularis*-infected

A. terrestris were found in 9 of 10 trapping sites in the border zone of the city, indicating a high infection pressure in the urban periphery.

Bait uptake of urban foxes was evaluated using camera traps in Zurich city. 48% of the baits accepted were taken by foxes, but baits were also consumed by hedgehogs (*Erinaceus europeus*), snails, dogs and rodents. Domestic cats, stone martens (*Martes foina*) and badgers (*Meles meles*) never accepted the baits. Highest bait uptake frequency by foxes was during summer, at compost heaps, for baits containing the anthelmintic agent Praziquantel and at places where a high general fox activity was detected.

An anthelmintic intervention was tested by the monthly distribution of 50 praziquantel-containing baits per km^2 in six 1-km^2 bait areas and one 6-km^2 bait area. There was a distinct effect of baiting and the proportion of *E. multilocularis* coproantigen-positive fox faecal samples decreased significantly in the 1-km^2 bait areas from 38.6% to 5.5%, and in the 6-km^2 bait area from 66.7% to 1.8%. *E. multilocularis* prevalence in the intermediate host *Arvicola terrestris* did not decrease during the first year of baiting. However, a lower relative spleen mass and an increased prevalence of mites in *A. terrestris* of baited areas indicated changes in its immunological activity due to a reduced exposition to *E. multilocularis* eggs. Thereafter, a pronounced decrease of *E. multilocularis* prevalence was detected in baited areas during the second year of baiting.

The different investigations have shown that the urbanisation of foxes is a general phenomenon in many European cities, where rich anthropogenic food resources can sustain high fox population densities. As a consequence, *E. multilocularis* is expanding its range to urban areas and *E. multilocularis* egg contamination can be found in the middle of densely populated areas. The highest prevalence in foxes is found in the urban periphery, where suitable intermediate host habitats intersect with high fox population densities. Since these areas are intensively used by the public for recreational activities interventions into the *E. multilocularis* cycle should focus on these urban border areas. The controlled baiting study demonstrated that a reduction of urban *E. multilocularis* infection pressure by the distribution of anthelmintica-containing fox baits is feasible. The decision for an intervention remains, however, a political, ecological and economical issue.

Glossar

Alopex	Gattung aus der Familie der Hundeartigen, z.B. Polarfuchs
alveoläre Echinokokkose (AE)	Durch die Larve (Metacestode) des kleinen Fuchsbandwurm (*Echinococcus multilocularis*) verursachte Erkrankung
Anthelmintika	Entwurmungsmittel
anthropogen	durch menschliche Einwirkungen verursacht
Arvicola terrestris	Ostschermaus, Nager aus der Familie der Arvicolidae
Arvicolidae	Familie der Wühlmäuse
Bioindikator	Tier- oder Pflanzenarten, die bestimmte Eigenschaften oder Veränderungen der Umwelt anzeigen (Zeigerart), z. B. Eutrophierung oder Gifteinwirkungen
Canide	Familie der Hundeartigen
Cestode	Bandwürmer, Klasse parasitischer Würmer
Clethrionomys glareolus	Rötelmaus, Nager aus der Familie der Arvicolidae
Cricetidae	Familie der Hamster
Echinococcus multilocularis	der kleine Fuchsbandwurm
endemisch	nur in einem bestimmten Gebiet natürlich vorkommend
Epizootie	Tierseuchen bei Verbreitung über grössere Gebiete
Fotofallen	automatisch auslösender Fotoapparat
Ikterus	Gelbfärbung der Haut, der Schleimhäute, des Harns u. a. Körperflüssigkeiten durch Übertreten von Gallenfarbstoff ins Blut und ins Gewebe
Inappetenz	Appetitlosigkeit
Inzidenz	Anzahl neuer Erkrankungsfälle einer bestimmten Krankheit in einem definierten Zeitraum
Koproantigentest	Immundiagnostisches Verfahren für den Nachweis von Parasiteninfektionen im Stuhl
Losung	Kot

Metacestode	Zweites Larvenstadium verschiedener Bandwürmer, das sich im Zwischenwirt ausbildet. Beim kleinen Fuchsbandwurm besteht der Metacestode aus kleinen, flüssigkeitsgefüllten Blasen, in denen sich neue Kopfanlagen (Protoscoleces) bilden können
polychlorierte Biphenyle (PCB)	chlorierte Kohlenwasserstoffe aus dem Grundstoff Biphenyl (z. B. DDT oder Lindan)
Prädation	räuberische Ernährungsweise
Prävalenz	Der Anteil von Individuen in einer Population die eine bestimmte Krankheit haben
Praziquantel	Ein gegen viele Cestoden wirksames Anthelmintika (Entwurmungsmittel)
Protoscoleces	Kopfanlagen, die sich Metacestoden des Zwischenwirts ausbilden und sich im Endwirt zu adulten Bandwürmern entwickeln können
Resektion	chirurgisches Herausschneiden von Teilen eines kranken Organs bzw. Körperteils
Sandwich-ELISA	ELISA, Abk. für enzyme linked immunosorbent assay. Der Sandwich-ELISA misst die Menge von Antigenen zwischen zwei Schichten von Antikörpern. Nachweisverfahren, dass sich besonders bei niedrigen Antigenkonzentrationen oder bei starker Verunreinigung durch andere Proteine eignet
silvatische Tollwut	Über Fuchs und andere Wildkarnivoren übertragene Tollwut (im Unterschied zur urbanen Tollwut und Fledermaustollwut)
Taeniiden	Familie der Bandwürmer (z. B. Echinococcus sp., Taenia sp.)
Vulpes vulpes	Rotfuchs
Wurmbürde	Anzahl Würmer pro Tier
Zoonose	auf den Menschen übertragbare Tierkrankheit

Einleitung

Echinococcus multilocularis: Erreger der Alveolären Echinokokkose

Die alveoläre Echinokokkose (AE) ist eine bedeutende Zoonose, der nördlichen Breiten, die früher meist letal verlief (Ammann und Eckert 1996). Heute ist bei frühzeitiger Diagnose eine vollständige Heilung möglich, häufig erfordert die Erkrankung jedoch eine lebenslange Therapie, die die Lebensqualität der Betroffenen bedeutend einschränkt.

Der Erreger der AE ist der kleine Fuchsbandwurm (*Echinococcus multilocularis*), ein 3-4 mm grosser Cestode aus der Familie der Taeniiden, dessen Adultstadium im Dünndarm von Karnivoren, hauptsächlich der beiden Caniden–Gattungen Alopex und Vulpes, lebt. Mit den über Kot ausgeschiedenen Endgliedern des Parasiten gelangen infektiöse Eier in die Umwelt. Nach der Aufnahme der Eier durch einen Zwischenwirt, hauptsächlich Nager der Familien Arvicolidae und Cricetidae, kann sich der Parasit in dessen Leber zum Metacestoden entwickeln, in dem sich neue infektiöse Kopfanlagen (Protoscoleces) bilden. Durch die Prädation von Karnivoren schliesst sich der Lebenszyklus und der Parasit gelangt in einen neuen Endwirt (Eckert et al. 2001). Neben Wildkarnivoren können sich auch mausende Hunde und Hauskatzen infizieren und so zu Ausscheidern von *E. multilocularis* Eiern werden (s. Abbildung 1).

Bei Aufnahme von infektiösen Fuchsbandwurm–Eiern kann *E. multilocularis* auch im Menschen Metacestoden ausbilden und so AE verursachen (s. Abbildung 1). Das Wachstum des Parasitengewebes verläuft beim Menschen ausgesprochen langsam, so dass zumeist erst nach 5-15 Jahren erste Symptome wie diffuse Oberbauchschmerzen, Inappetenz, Müdigkeit oder Ikterus auftreten (Ammann und Eckert 1996). Wie bei den Zwischenwirten setzt sich der Parasit im Menschen meistens in der Leber fest. Bei ausbleibender Behandlung wächst das Metacestodengewebe kontinuierlich weiter, und die Leberfunktionen werden nach und nach eingeschränkt. Ist eine vollständige Resektion des Metacestoden nicht möglich, verhindert oft nur die dauernde Einnahme von Medikamenten (Benzimidazolderivate) das weitere Fortschreiten der Krankheit (Ammann und Eckert 1995).

Die jährliche Inzidenz ist meist gering und variiert in Zentraleuropa und Japan zwischen 0.02 und 1.4 neuen Erkrankungen pro 100‘000 Personen (Eckert und Deplazes 1999). Bei sehr hohem Infektionsdruck kann die Prävalenz aber dennoch stark ansteigen. So wurde bei einer ruralen Gemeinschaft der chinesischen Provinz

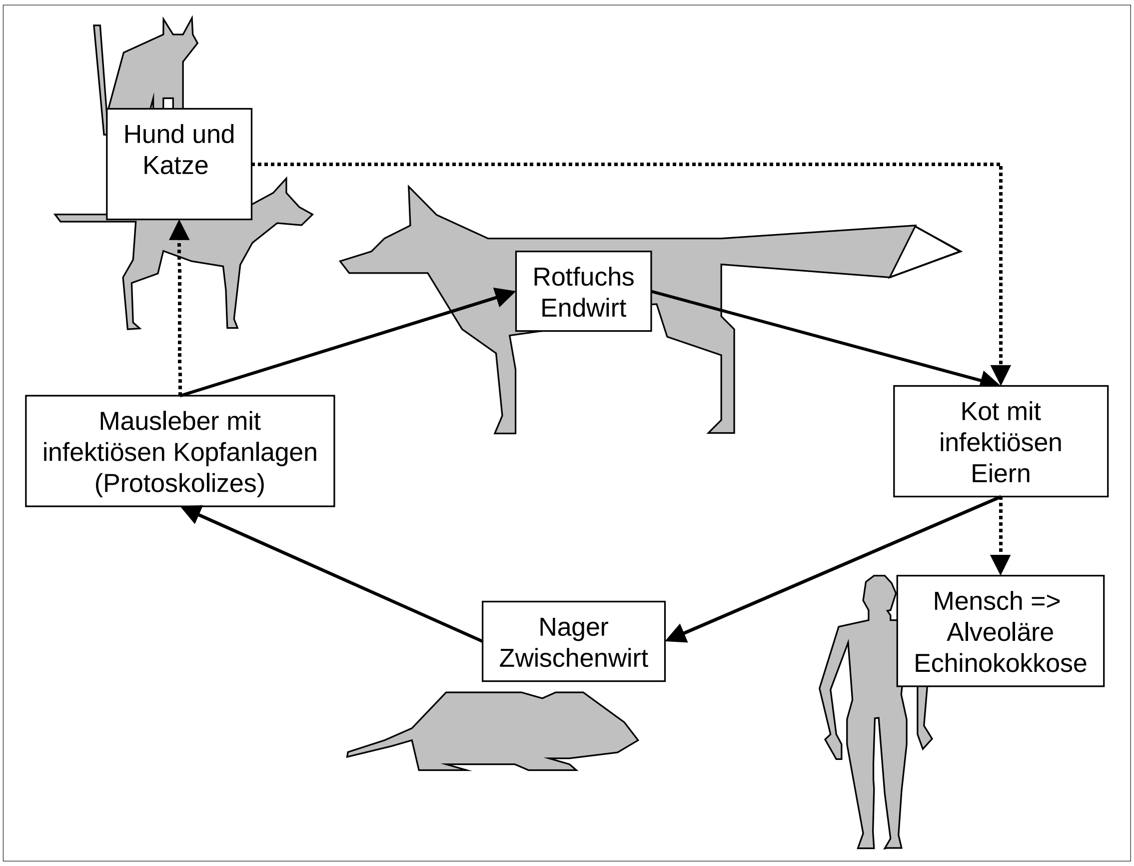


Abbildung 1: Schematische Darstellung des Zyklus von *Echinococcus multilocularis* (Beschreibung siehe Text).

Gansu, wo Hunde in einem synanthropen Zyklus als Hauptüberträger agieren, bei 4% von 3'331 untersuchten Personen AE diagnostiziert (Craig et al. 2000).

Urbanisierung des Rotfuchses als zoonotisches Risiko?

Der Rotfuchs (*Vulpes vulpes*) ist in Mitteleuropa der wichtigste Überträger der silvatischen Tollwut und des kleinen Fuchsbandwurmes. In hochendemischen Gebieten konnten für *E. multilocularis* Prävalenzen von bis zu 75% festgestellt werden und es gibt Hinweise, dass die Befallsraten beim Fuchs zunehmen (Romig et al. 1999a; Romig et al. 1999b). Die Tollwut verursachte in den 70er und 80er Jahren einen starken Rückgang der mitteleuropäischen Fuchspopulationen (Chautan et al. 2000). Mit oralen Immunisierungskampagnen wurde die Tollwut erfolgreich bekämpft und die Schweiz ist seit 1999 tollwutfrei (Zanoni et al. 2000). In der Folge sind die Fuchsbestände vielerorts wieder stark angewachsen (Breitenmoser et al. 2000; Chautan et al. 2000) und sind heute z. T. höher als vor der Tollwut–Epizootie (Breitenmoser und Müller, in prep.). Parallel zu dieser Entwicklung dringen Füchse heute vermehrt in den urbanen Lebensraum vor (Gloor 2002), ähnlich wie dies auf den britischen Inseln bereits vor rund sechzig Jahren beobachtet wurde (Teagle

1967). Viel stärker als in Grossbritannien, wo *E. multilocularis* und die silvatische Tollwut nicht vorkommen, stellt sich in Kontinental–Europa bei der Urbanisierung dieser Art die Frage nach den zoonotischen Risiken, die mit dieser Entwicklung verbunden sein können. Während früher urbane Gebiete noch Barrieren für die Ausbreitung der Tollwut darstellten (Steck et al. 1980), könnten heute hohe Fuchsbestände inmitten dicht besiedelter Gebiete bei einer erneuten Tollwut–Epizootie ein zusätzliches Infektionsrisiko für den Menschen darstellen. Und die Kontamination urbaner Gebiete mit *E. multilocularis* Eiern, die mit den Losungen infizierter Füchse abgesetzt werden, könnte zu einer Zunahme der AE führen.

Inhaltsübersicht

Die Tatsache, dass mitten im Siedlungsraum, Füchse leben und ihre Jungen aufziehen stösst in der Öffentlichkeit auf grosses Interesse. Der Fuchs gilt als schlau und gewitzt und wird oft als sympathisches und faszinierendes Tier wahrgenommen. Gleichzeitig ist der Rotfuchs aber auch als Hauptüberträger der Tollwut und des Fuchsbandwurm bekannt, was Verunsicherungen und Ängste auslöst. Der starke Anstieg der Fuchspopulationen und das Vordringen in die Städte gab deshalb Anlass zu einem interdisziplinären Forschungs- und Kommunikationsprojekt – dem Integrierten Fuchsprojekt (IFP). In diesem Projekt setzen sich seit 1996 Wissenschaftlerinnen und Wissenschafter aus den Bereichen Wildbiologie, Veterinärmedizin und Sozialforschung mit verschiedenen Fragen dieser Entwicklung auseinander.
Die vorliegende Dissertation wurde ihm Rahmen des IFP initiiert, mit dem Ziel die Urbanisierung des Zyklus von *E. multilocularis* zu untersuchen, Faktoren zu eruieren, die diesen Zyklus mitbestimmen und daraus eine mögliche Interventionsstrategie abzuleiten und zu evaluieren. Die Arbeit setzt sich aus Manuskripten zusammen, die in verschieden Fachzeitschriften bereits publiziert oder eingereicht worden sind, oder zur Einreichung vorbereitet sind. In einem ersten Teil wurde untersucht, ob das Vordringen des Rotfuchses in den urbanen Lebensraum eine allgemeingültige Entwicklung ist, oder ob sich dieser Prozess nur auf einzelne Städte beschränkt (**Manuskript A**). In der zweiten Arbeit wurde die Rolle der natürlichen und anthropogenen Nahrungsressourcen für die Urbanisierung des Füchse untersucht (**Manuskript B**). Eine parasitologische Untersuchung von Stadtfüchsen gibt Aufschluss über die *E. multilocularis* Befallshäufigkeiten und Befallsintensitäten in Stadtfüchsen und in einer urbanen Population des Zwischenwirts *Arvicola terrestris* (**Manuskript C**). Um die Kontamination des urbanen Gebietes durch Losungen von mit *E. multilocularis* infizierten Füchsen zu erfassen, wurde ein Koproantigen–Sandwich-ELISA evaluiert. Zudem wurden Faktoren, die den Zyklus von *E. multilocularis* beeinflussen, untersucht und die

Bedeutung verschiedener Zwischenwirtsarten abgeklärt (**Manuskript D**). In einer Übersichtsarbeit werden, unter Einbezug der Resultate der Manuskripte A–D, verschiedene Aspekte des urbanen Zyklus von *E. multilocularis* dargelegt und im Hinblick auf eine mögliche Intervention diskutiert (**Manuskript E**). Wieweit können Füchsen im urbanen Raum Köder und somit Wirkstoffe (Tollwutimpfstoff, Entwurmungsmittel) verabreicht werden? Diese Frage wurde mit Hilfe von Fotofallen geklärt (**Manuskript F**). In einer experimentellen Feldstudie wurde dann überprüft, wieweit die Auslage von Ködern, die das Anthelmintika Praziquantel enthalten, den Infektionsdruck von *E. multilocularis* im urbanen Raum reduzieren kann (**Manuskript G**). Parallel wurden bei dieser Feldstudie auch immunologische Effekte der Beköderung auf den Zwischenwirt *Arvicola terrestris* untersucht (**Manuskript H**).

Im Rahmen der interdisziplinären Zusammenarbeit des IFP war ich auch an Publikationen beteiligt, die über das eigentliche Thema meiner Dissertation hinausgehen. Dazu gehören zwei toxikologische Arbeiten, in denen Stadtfüchse als Bioindikatoren auf Schwermetalle und polychlorierte Biphenyle untersucht wurden (**Anhang I und II**) und zwei Arbeiten in denen anhand einer Informationskampagne zu Stadtfüchsen (INFOX) verschiedene Aspekte der Kommunikation zu Füchsen im Siedlungsraum dargestellt werden (**Anhang III und IV**).

Mein Beitrag zu den verschiedenen Manuskripten war unterschiedlich. Tabelle 1 gibt einen Überblick, welche Arbeiten ich für die verschiedenen Manuskripte geleistet habe und wieweit die verschieden Manuskripte bereits veröffentlicht sind.

Tabelle 1: Beitrag zu den verschiedenen Arbeiten und Publikations–Status der Manuskripte.

	Manuskript:								Anhang:			
	A	B	C	D	E	F	G	H	I	II	III	IV
Forschungsdesign / Konzept	*	*		*	*	**	**	*			*	*
Feldarbeiten, Datenerhebung	*			*	*	**	**	*			*	*
Laboranalysen / Sektionen	-	*	*	*	*	-	*		*	*	-	-
Datenaufbereitung			*	*	*	**	**	*	*	*	-	-
Auswertungen	*	*	*	*	*	**	**					
Manuskript schreiben	*	*	*	*	*	**	**	*	*	*	*	*
Publikations-Status	pub.	acc.	pub.	pub.	pub.	sub.	sub.	prep.	pub.	prep.	pub.	

*geleistete Arbeiten: ** Hauptarbeit, * Mitarbeit, - keine Arbeiten notwendig*

Publikations-Status: pub. = publiziert, acc. = akzeptiert, sub. = eingereicht, prep. = zur Einreichung vorbereitet

Die Entstehung urbaner Fuchspopulationen in der Schweiz

(Zusammenfassung Manuskript A)

Seit Mitte der 1980er-Jahren werden zunehmend Füchse inmitten von Schweizer Städten beobachtet. Die Befragung der zuständigen Behörden ergab, dass heute in 28 der 30 grössten Schweizer Städte Füchse registriert werden. In 20 dieser Städte sind Fuchsbaue mit Jungenaufzucht im Siedlungsraum bekannt. Dabei werden Stadtfüchse überproportional häufiger in grösseren Städten als in kleineren Ortschaften beobachtet. In Zürich, der grössten Schweizer Stadt, waren gemäss der Jagdstatistik bis zu Beginn der 1980er Jahre Stadtfüchse sehr selten. Erst ab 1985 begann die städtische Fuchspopulation markant anzusteigen. Auch die umliegenden ländlichen Gebiete verzeichnen ab 1984 eine deutliche, allerdings weniger starke Zunahme der Fuchsbestände, die u.a. mit der erfolgreichen Tollwutbekämpfung zusammenhängt. Als Erklärung der Präsenz von Füchsen im Siedlungsraum, einem bisher vor allem aus Grossbritannien bekannten Phänomen, schlagen wir zwei alternative Hypothesen vor, welche einerseits den Populationsdruck in ländlichen Gebieten, andererseits stadtspezifische Verhaltensanpassungen der Füchse ins Zentrum stellen. Fuchspopulationen im Siedlungsraum beeinflussen das Verhalten und die Einstellung der Bevölkerung gegenüber Wildtieren und haben Konsequenzen für das Fuchsmanagement und den Umgang mit Zoonosen, wie Tollwut und alveoläre Echinokokkose.

Die Nahrung von Rotfüchsen (Vulpes vulpes) und das Angebot anthropogener Nahrungsressourcen in der Stadt Zürich, Schweiz

(Zusammenfassung Manuskript B)

In der Stadt Zürich wurde die Ernährung von Stadtfüchsen und das Angebot anthropogener Nahrung untersucht. Magenanalysen von 402 Füchsen, die zwischen Januar 1996 und März 1998 erlegt oder tot aufgefunden wurden, zeigten eine grosse Vielfalt der Nahrungskomponenten urbaner Füchse, wobei sich ein Grossteil aus Fleisch- und Knochenresten, anderen Abfällen und kultivierten Früchten und Feldfrüchten zusammensetzte. Mehr als die Hälfte eines durchschnittlichen Mageninhaltes war anthropogen. Der Anteil anthropogener Nahrung war höher in Mägen vom Stadtzentrum – vor allem dank einem erhöhten Anteil von Fleisch- und Knochenresten – gegenüber dem Inhalt aus Mägen des peripheren Stadtgebietes. Es wurden saisonale Schwankungen der Nahrungskomponenten Invertebraten, Vögel und kultivierte Früchte sowie Feldfrüchte gefunden, die alle häufiger im Sommer aufgenommen wurden.

Gemäss einer schriftliche Umfrage unter den EinwohnerInnen eines Stadtquartiers bestand für Füchse bei 85% der Haushalte Zugang zu anthropogenen Nahrungsquellen. Dieses Nahrungsangebot setzte sich zu drei Vierteln aus fressbarem Abfall und Kompost zusammen und wurde durch Früchte und Beeren, sowie in geringerem Ausmass durch Futter für Haustiere, Vögel und weitere Wildtiere ergänzt. Das anthropogene Nahrungsangebot in Schrebergärten bestand hauptsächlich aus Beeren, aber auch aus Früchten, Kompost und Vogelfutter. Mittels Transekten bestimmten wir zusätzlich das anthropogene Nahrungsangebot des öffentlichen Raums. Das anthropogene Nahrungsangebot von Haushalten, Schrebergärten und öffentlichem Raum zusammen könnte viel mehr Füchse ernähren, als gegenwärtig im Untersuchungsgebiet vorhanden sind. Dieses Überangebot an Nahrungsressourcen erklärt möglicherweise, warum die Populationsdichten von Füchsen im Siedlungsraum gegenwärtig weiter ansteigen.

Hohe Prävalenz von *Echinococcus multilocularis* bei urbanen Rotfüchsen (*Vulpes vulpes*) und Schermäusen (*Arvicola terrestris*) in der Stadt Zürich, Schweiz (Zusammenfassung Manuskript C)

Während 26 Monaten, von Januar 1996 bis Februar 1998, wurden 388 Füchse aus der Stadt Zürich von Wildhütern abgeliefert und auf Dünndarminfektionen mit *Echinococcus multilocularis* und anderen Helminthen untersucht. Die Prävalenz von *E. multilocularis* bei im Winter angefallenen Füchsen wies eine signifikante Zunahme von 47% in städtischen Gebieten zu 67% in angrenzenden ländlichen Gebieten auf, während die Prävalenz von anderen Helminthen für beide Gebiete gleich gross war. Saisonale Unterschiede der Prävalenz von *E. multilocularis* wurden bei urbanen, subadulten Rüden gefunden, welche signifikant seltener im Sommer als im Winter infiziert waren. Die Verteilung der Biomasse von *E. multilocularis*, erfasst in Anzahl Wurmindividuen pro Fuchs, wurde bei 133 infizierten Füchsen untersucht, welche zufällig aus den im Winter gesammelten Füchsen ausgewählt wurden. Zehn Füchse (8%) waren mit mehr als 10’000 Individuen infiziert und enthielten 72% der gesamten erfassten *E. multilocularis*–Biomasse. Die Wurmbürden waren signifikant höher bei subadulten als bei adulten Füchsen. Bezüglich Alter und Geschlecht konnten diesbezüglich keine signifikante Unterschiede gefunden werden. Aufgrund morphologischer Merkmale und mit PCR wurden *E. multilocularis*–Metacestoden bei Schermäusen (*Arvicola terrestris*) identifiziert, welche in einem Stadtpark von Zürich gefangen wurden. Die Prävalenz bei den 60 Schermäusen aus dem Jahr 1997 betrug 20% und 9% bei den 75 Schermäusen von 1998. Protoscoleces wurden in zwei *A. terrestris* gefunden.

Räumliche und zeitliche Aspekte der urbanen Übertragung von *Echinococcus multilocularis*

(Zusammenfassung Manuskript D)

In einer früheren Studie wurde eine hohe Prävalenz von *Echinococcus multilocularis* in Rotfüchsen aus der Stadt Zürich nachgewiesen. Um die Übertragung des Parasiten im urbanen Lebensraum zu charakterisieren, wurde ein Koproantigen–ELISA für den *E. multilocularis* Nachweis in Fuchslosungen, die im Feld gesammelt wurden, evaluiert. Zudem wurden verschiedene Nagerarten auf *E. multilocularis* Metacestoden untersucht. Ein Vergleich der Parasitenspektren von Proben, die im Feld als Fuchs- bzw. als Hundelosungen angesprochen wurden, zeigte, dass die Beurteilung äusserlicher Merkmale eine verlässliche Identifikation von Fuchslosungen im Feld ermöglicht. Von 604 Fuchslosungen waren 156 Koproantigen–positiv (25.8%). Von der urbanen zur periurbanen Zone hin wurde ein signifikanter Anstieg des Anteils positiver Proben nachgewiesen. Im Winter waren die in der Stadtrandzone gesammelte Losungen signifikant häufiger Koproantigen–positiv. Die Prävalenz in *Clethrionomys glareolus* betrug 2.4%. *Arvicola terrestris* war in 9.1% der Fällen infiziert und 3.5% der Tiere hatten Protoscoleces. Infizierte *A. terrestris* konnten in 9 von 10 Fanggebieten entlang des Stadtrandgebietes nachgewiesen werden. Dies weist auf einen hohen Infektionsdruck in diesen Zonen hin, der möglicherweise auch für den Menschen und dessen Hunde und Katzen ein erhöhtes Infektionsrisiko darstellt. Massnahmen zur Reduktion des Infektionsdruckes sollten deshalb besonders auf diese Stadtrandzonen fokussieren.

Urbane Übertragung von *Echinococcus multilocularis*

(Zusammenfassung Manuskript E)

In verschiedenen Europäischen Ländern wurde in den vergangenen 15 Jahren einen deutliche Zunahme der Populationen des Rotfuchses (*Vulpes vulpes*) verzeichnet, die in städtischen Gebieten besonders ausgeprägt war. Die Anzahl geschossener oder tot aufgefundener Füchse in der Stadt Zürich nahm zwischen 1985 und 1997 um das 20-fache zu. Diese Tatsachen waren Anlass für ein interdisziplinäres Projekt, in welchem ökologische und parasitologische Aspekte der Fuchspopulationen in urbanen Gebieten untersucht wurden.

Ökologische Resultate zeigen, dass in städtischen Gebieten die Populationsdichten hoch und die Aktivitätsgebiete der Füchse klein sind. Die Prävalenz des Kleinen Fuchsbandwurmes *Echinococcus multilocularis* nahm ab von 67% in den Naherholungsgebieten unmittelbar am Rand des Siedlungsraums auf 47% im Gebiet innerhalb der Stadtgrenzen.

Um die Kontamination der städtischen Gebiete durch Eier von *E. multilocularis* zu schätzen, wurden Kotproben von Füchsen gesammelt und mit einem Koproantigen–ELISA untersucht. Die räumliche Verteilung der Koproantigen–positiven Kotproben stimmte mit der Prävalenz, welche bei sezierten Füchsen gefunden wurde, überein. Bei Nagetieren, welche in den an den Siedlungsraum angrenzenden ländlichen Gebieten gefangen wurden, wurden *E. multilocularis*-Metacestoden mittels morphologischen Untersuchungen, EmG11-antigen ELISA und PCR festgestellt. Die Prävalenz bei 781 Schermäusen *Arvicola terrestris* war 9.2%. Bei 24 *A. terrestris* (3.1%) wurden vollständig entwickelten Protoscoleces nachgewiesen. Somit konnte ein urbaner Parasitenzyklus von *E. multilocularis* nachgewiesen werden. Dies bedeutet ein potentielles Risiko nicht nur für die städtische Bevölkerung sondern auch für Heimtiere wie Hunde und Katzen. Aufgrund dieser neuen epidemiologischen Situation und der damit zusammenhängenden wachsenden öffentlichen Sensibilisierung betreffend dieser Zoonose empfiehlt sich eine Evaluation lokaler Interventionen in den Lebenszyklus von *E. multilocularis*.

Köderauslage für Stadtfüchse: Eine Foto–Fallen–Studie

(Zusammenfassung Manuskript F)

In den letzten Jahren sind die anwachsenden Rotfuchs–Populationen (*Vulpes vulpes*) Zentral- und Westeuropas mehr und mehr in den städtischen Lebensraum vorgedrungen. In vielen Städten leben heute Füchse in nächster Umgebung zu Mensch und Haustier. Die silvatische Tollwut ist in Europa nicht ausgerottet und der kleine Fuchsbandwurm *Echinococcus multilocularis* – ein Helminth, der eine schwere Lebererkrankung des Menschen, die Alveoläre Echinokokkose, verursachen kann – ist in europäischen Fuchspopulationen weit verbreitet. Daher besteht ein wachsendes Bedürfnis nach effektiven Beköderungsstrategien für Füchse im Siedlungsraum. In der Stadt Zürich wurde die Köderaufnahme mit Hilfe von Fotofallen überprüft. Köder mit und ohne das Anthelmintika Praziquantel wurden auf verschiedene Arten (exponiert, bedeckt, eingegraben), an verschiedenen Orten (Fuchsbaue, Komposthaufen, Fuchspässe) und zu verschiedenen Saisons (Frühsommer, Sommer, Winter) ausgelegt. Während 756 Fotofallen–Nächten verschwanden 91 der 252 (36%) überwachten Köder innerhalb von jeweils 3 Tagen. Gegenüber dem Kontrollversuch ohne Fotofallen war die totale Verschwinderate der Köder mit Fotofallen kleiner. 48% der verschwundenen Köder wurden durch Füchse aufgenommen. Die anderen Arten, die Köder genommen haben, waren Igel (*Erinaceus europeus*, 17 Köder), Schnecken (9), Hunde (8) und Nager (4). In 9 Fällen war eine Identifikation der Art, die den Köder aufgenommen hat, nicht möglich. Hauskatzen, Steinmarder (*Martes foina*) und Dachse (*Meles meles*) haben keine Köder angenommen. Eine logistische Regression erbrachte signifikante Unterschiede in der Köderaufnahme von Füchsen abhängig von Ort, Saison, Ködertyp und von der generellen Aktivität von Füchsen. Die höchste Köderaufnahmerate durch Füchse wurde während des Sommers, bei Komposthaufen, für Praziquantel–haltige Köder und an Plätzen mit hoher Fuchsaktivität festgestellt. Um möglichst artspezifisch für Füchse zu beködern, sollten Köder leicht eingegraben werden. Eine kurze Gewöhnungsperiode (6 Tage) an die Köder erhöht die Köderaufnahmerate nicht, aber der Zusatz von Praziquantel kann die Konkurrenz um Köder durch andere Arten verringern. Eine Zugabe von Praziquantel zu Tollwutköder würde daher die Effizienz einer oralen Immunisierungskampagne gegen Tollwut nicht verringern.

Kleinräumige Auslage Anthelmintika–haltiger Köder für Rotfüchse verringert die Kontamination des städtischen Lebensraum mit Eiern von *Echinococcus multilocularis*

(Zusammenfassung Manuskript G)

Aufgrund der kleinräumig heterogenen Verteilung von geeigneten Zwischenwirts–Habitaten und der geringen räumlichen Dynamik von Füchsen im städtischen Lebensraum scheint eine Reduktion des Infektionsdruckes durch *Echinococcus multilocularis* Eier in eng umgrenzten, urbanen Risikoflächen möglich zu sein. In der Stadt Zürich wurden von April 2000 bis Oktober 2001 monatlich in sechs 1–km^2 Flächen und in einer 6–km^2 Fläche 50 Praziquantel–haltige Köder pro km^2 ausgebracht. Der Anteil Koproantigen–positiver Fuchslosungen änderte sich in den sechs Kontrollflächen nicht, während er in den beköderten 1–km^2 Flächen von 38.6% auf 5.5% und in der beköderten 6–km^2 Fläche von 66.7% auf 1.8% abfiel. Die Prävalenz im Zwischenwirt *Arvicola terrestris* sank ebenfalls signifikant in den beköderten Flächen, aber nicht in den Kontrollflächen. Diese kontrollierte Beköderungs–Studie zeigt, dass eine starke Reduktion der Kontamination mit *E. multilocularis* Eiern in urbanen hoch endemischen Gebieten möglich ist.

Ein experimenteller Feldversuch zu Parasitismus und Immunabwehr bei Wühlmäusen

(Zusammenfassung Manuskript H)

Der Fuchsbandwurm *Echinococcus multilocularis* wird vom Rotfuchs als Endwirt auf verschiedene Nagerarten übertragen. In fünf Flächen von je einem Quadratkilometer wurden Köder für Füchse ausgebracht, die ein sehr wirksames Medikament gegen Cestoden (Praziquantel) enthielten. Der häufigste Zwischenwirt, die Wühlmaus *Arvicola terrestris*, wurde in fünf beköderten und fünf nicht beköderten Gebieten gefangen. Die Beköderung der Füchse reduzierte den Anteil *E. multilocularis* positiver Fuchslosungen in den beköderten Gebieten, aber die Prävalenz in den Wühlmäusen unterschied sich im Verlaufe des ersten Jahrs der Beköderung nicht zwischen beköderten und nicht beköderten Gebieten. Allerdings hatten die Wühlmäuse aus beköderten Gebieten signifikant kleinere Milzgewichte und waren signifikant häufiger mit Ektoparasiten befallen, was auf eine unterschiedlich Aktivität der Immunabwehr hinweist. Der experimentelle Feldversuch weist darauf hin, dass die Kontamination mit *E. multilocularis* Eiern, und möglicherweise anderen Bandwürmer, das Immunsystem des Zwischenwirts *A. terrestris* im Freiland beeinflussen kann.

Schlussfolgerung

Der kleine Fuchsbandwurm *Echinococcus multilocularis* hat sich mit dem Vordringen des Rotfuchses in urbane Gebiete einen neuen Lebensraum erschlossen und ist heute mitten in dichtbesiedeltem Raum anzutreffen. Möglicherweise geht von dieser Entwicklung ein für den Menschen allgemein erhöhtes Risiko aus, an Alveolärer Echinokokkose zu erkranken. Es hat sich gezeigt, dass Stadtfüchse, dank einem sehr hohen Angebot von anthropogenem Futter, hohe Dichten erreichen und ihren Nahrungsbedarf entsprechend in relativ kleinen Streifgebieten abdecken können. Die daraus resultierende geringe räumliche Dynamik urbaner Fuchspopulationen kann erklären, dass die Prävalenz von *E. multilocularis* über kurze Distanzen deutlich variiert. Im Grenzgebiet zwischen ruralem und urbanem Lebensraum überschneiden sich hohe Dichten von Füchsen und gute Habitate für Wühlmäuse. Die Resultate dieser Studie weisen darauf hin, dass deshalb der Zyklus von *E. multilocularis* in diesem Grenzraum zu einem hohen Infektionsdruck führt. Da gerade diese Stadtrandzone von einer breiten Öffentlichkeit intensiv für Freizeitaktivitäten genutzt werden, und die Dichte an Hauskatzen und Hunden, die sich an infizierten Mäusen anstecken können, hoch ist, sollten Interventionsstrategien zur Senkung des Infektionsdruckes vor allem auf diese Stadtrandgebiete fokussieren. Wie sich erwiesen hat, ist es im urbanen Raum möglich, gezielt auf räumlich eng definierten Flächen den Infektionsdruck deutlich zu senken. Falls mit der Urbanisierung der Stadtfüchse tatsächlich eine Zunahme der Alveoläre Echinokokkose einher geht, könnte die Auslage von Praziquantel–Köder für Füchse ein Instrument zur Risikominimierung sein. Die Anwendung einer solchen Massnahme ist ein politischer Entscheid, bei dem verschiedene Faktoren, wie Kosten–Nutzen Verhältnis, öffentliches Sicherheitsbedürfnis, alternative Strategien und mögliche ökologische Auswirkungen, zu berücksichtigen sind.

Conclusions

Due to the colonisation of urban areas by red foxes, the small fox tapeworm *Echinococcus multilocularis* gained a new habitat, and therefore nowadays occurs in the middle of densely populated areas. As a possible consequence this development has caused an increased infection risk for human Alveolar Echinococcosis. It has been shown that due to a high anthropogenic food supply urban foxes can achieve high population densities and correspondingly can cover their nutritional requirements within small home ranges. The resulting low spatial dynamics of urban fox populations is supposed to be the reason for the occurrence of pronounced *E. multilocularis* prevalence changes within small distances. In the borderland between rural and urban habitat high fox population densities intersect with suitable habitats for voles. The results of this study point out that the cycle of *E. multilocularis* leads to a high infection pressure in the urban periphery. At the same time, this area is intensively used by a broad public for recreational and other activities, and densities of domestic cats and dogs, which can acquire the parasite by preying on infected voles, are high. Therefore, possible intervention strategies to lower the infection pressure should focus primarily on this urban periphery. It was demonstrated that a pronounced reduction of the infection pressure in small defined urban areas is feasible. If in fact, the urbanisation of foxes goes parallel with a significant increase of Alveolar Echinococcosis, anthelmintic baiting of foxes is a possible tool to minimise the infection risk. Nevertheless, the application of such an intervention is a political decision, which has to consider different factors, as cost-benefit analyses, security need of the public, alternative strategies and possible ecological consequences.

Literatur

Ammann R, Eckert J. 1995. Clinical Diagnosis and Treatment of Echinococcosis in Humans. In: Thompson RCA, Lymbery AJ, editors. Echinococcus and Hydatid Disease. Australia: CAB International.

Ammann RW, Eckert J. 1996. Cestodes: Echinococcus. Parasitic Diseases of the Liver and the Intestines: Gastroenterology Clinics of North America, W. B. Saunders Company, Philadelphia. p 655-689.

Breitenmoser U, Müller U, Kappeler A, Zanoni RG. 2000. Die Endphase der Tollwut in der Schweiz. Schweizer Archiv für Tierheilkunde 142(8):447-54.

Chautan M, Pontier D, Artois M. 2000. Role of rabies in recent demographic changes in red fox (Vulpes vulpes) populations in Europe. Mammalia 64:391-410.

Craig PS, Giradoux P, Shi D, Bartholomot G, Barnish G, Delattre P, Quere JP, Harraga S, Bao G, Wang Y and others. 2000. An epidemiological and ecological study on human alveolar echinococcosis transmission in Gansu, China. Acta Tropica 77:167-177.

Eckert J, Deplazes P. 1999. Alveolar echinococcosis in humans: the current situation in Central Europe and the need for countermeasures. Parasitology Today 15(8):315-9.

Eckert J, Rausch RL, Gemmell MA, Giraudoux P, Kamiya M, Liu F-J, Schantz PM, Romig T. 2001. Epidemiology of *Echinococcus multilocularis*, *Echinococcus vogeli* and *Echinococcus oligarthus*. In: Eckert J, Gemmel MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE Manual on echinococcosis in humans and animals. Paris. p 164-194.

Gloor S. 2002. The rise of urban foxes (*Vulpes vulpes*) in Switzerland and ecological and parasitological aspects of a population in the recently colonised city of Zurich [Dissertation]. Zurich: University of Zurich.

Romig T, Bilger B, Dinkel A, Merli M, Mackenstedt U. 1999a. *Echinococcus multilocularis* in animal hosts: new data from western Europe. Helminthologia 36:185-191.

Romig T, Kratzer W, Kimmig P, Frosch M, Gaus W, Flegel WA, Gottstein B, Lucius R, Beckh K, Kern P. 1999b. An epidemiologic survey of human alveolar echinococcosis in southwestern Germany. Romerstein Study Group. American Journal of Tropical Medicine & Hygiene 61(4):566-73.

Steck F, A. W, Nydegger B, Manigley C, Weiss M. 1980. Die Tollwut in der Schweiz 1967-1978. Schweizer Archiv für Tierheilkunde 122:605-636.

Teagle WG. 1967. The fox in London suburbs. The London Naturalist 46:44-68.

Zanoni RG, Kappeler A, Müller UM, Müller C, Wandeler AI, Breitenmoser U. 2000. [Rabies-free status of Switzerland following 30 years of rabies in foxes]. Schweizer Archiv für Tierheilkunde 142(8):423-429.

Manuskript A (Mammalian Biology):
The rise of urban fox populations in Switzerland

Sandra Gloor[1,2], Fabio Bontadina[2], Daniel Hegglin[1,2], Peter Deplazes[3] and Urs Breitenmoser[4]

[1] Zoological Museum of the University of Zurich, Switzerland.
[2] Urban Ecology and Wildlife Research, Zurich, Switzerland.
[3] Institute of Parasitology of the University of Zurich, Switzerland.
[4] Swiss Rabies Centre, Institute of Veterinary Virology, University of Bern, Switzerland.

Key words: *Vulpes vulpes*, urban habitat, invasion, adaptation.

Gloor S, Bontadina F, Hegglin D, Deplazes P, Breitenmoser U. The rise of urban fox populations in Switzerland. Mammalian Biology 2001;66:155-164.

Abstract

Since 1985 more and more foxes have been recorded from cities in Switzerland. The inquiry of town officials showed that foxes are observed in 28 out of the 30 largest Swiss cities today and breeding dens are known in 20 of these cities. Urban foxes are observed more often than one would expect in larger cities than in smaller towns. In Zurich, the largest city in Switzerland, urban foxes were very scarce until the early 1980s. According to the hunting statistics, from 1985 onwards, there was a drastic increase of the urban fox population. In the adjacent rural areas, there also was a clear but less extreme increase of the fox population from 1984 onwards due to successful vaccination campaigns against rabies. As an explanation for the presence of foxes in human settlements we suggest two alternative hypotheses, which focus either on the population pressure in the rural areas or on the behavioural adaptations of urban foxes. The presence of foxes in urban areas influences behaviour and attitudes of people towards urban wildlife and it has consequences for the fox management and the treatment of zoonoses such as rabies and the alveolar echinococcosis.

Introduction

Since 1985 fox populations have experienced a drastic increase in Switzerland (Breitenmoser et al. 2000). Apart from this development in rural areas, more and more foxes have been recorded from large Swiss conurbations and cities such as Zurich or Geneva. Game wardens and wildlife biologists observed foxes in urban areas, people having noticed foxes in their gardens turned to local officials for information, pictures and articles about foxes in the middle of residential areas were published. Are these records just occasional observations or do they indicate the colonisation of a new habitat by the red fox?

Red foxes living in urban areas are known from Great Britain where urban foxes have been observed in cities like London since the 1930s (Teagle 1967; Beames 1969, 1972; Page 1981). In the 1970s and 1980s, fox populations in British cities reached densities of up to five fox family groups per km^2 (representing 12 adults on average), densities which had never been observed so far (Harris 1981a, Harris and Rayner 1986a). Similar fox population densities were nowhere recorded in urban areas outside of Great Britain, neither on the European continent nor in other parts of the distribution area of the red fox. Therefore, urban foxes were thought to be a British phenomenon (Harris 1977; Macdonald and Newdick 1982).

In the 1970s and 1980s, the fox population on the European continent experienced a heavy rabies epizootic, which reached Switzerland in 1967 (Steck et al. 1980; Müller et al. 2000). Fox densities decreased drastically, and, as seen from the Swiss hunting bag, reached a low in 1984 (Breitenmoser et al. 2000). After the success of oral vaccination campaigns against rabies, started in Switzerland in 1978 (Wandeler et al. 1988), the fox population recovered again from 1985 onwards (Kappeler 1991, Breitenmoser et al. 2000). At that same time, foxes were increasingly observed in human settlements.

Our objectives in this study are to investigate the present situation in large Swiss settlements, to evaluate the recent development of the fox population in Zurich, the largest conurbation of Switzerland, and to compare it with the trend in surrounding rural areas.

Material and methods

Study area

Switzerland is a diverse and mountainous country. 24% of its total area of 40 000 km^2 (excluding lakes), are above 2 000 meters where fox population density is low. The remaining 76% of the country form a heterogeneous and mostly good quality habitat for the red fox.

In Switzerland there are 30 cities with more than 20 000 inhabitants, where 19% of the 6.9 million inhabitants live. The largest conurbation of Switzerland is the area of Zurich with some 1 000 000 inhabitants. However, only 352 200 of them live in the actual “city“, the political community of Zurich. The political community of Zurich (92 km^2) – which we refer to when we are talking about the “city of Zurich“ in the following pages – consists of 53% urban area, 24% forest, 17% agricultural areas and 6% water (Federal Office of Statistics 1998). Forest and agricultural areas surround the urban area and are referred to as the rural area of the city in the following pages.

As far as hunting is concerned, the city of Zurich is organised as a game sanctuary. The city of Zurich belongs to the canton of Zurich, one of the most densely populated cantons of Switzerland (area 1661 km^2, 683 inhabitants per km^2).

The present distribution of urban foxes in Switzerland

During a television series about urban foxes in spring 1997, the public was called to report fox sightings in Swiss cities. The sightings were recorded personally by collaborators of the Integrated Fox Project. Only fox sightings within human settlements were recorded. As the call on TV was biased towards the German speaking part of Switzerland, the few information from the French and Italian speaking regions of the country were excluded from further analyses.

The program actus (Estabrook and Estabrook 1989) was used for the statistical test, which performs randomised contingency tables and gives probabilities for deviations from expected values.

In spring 1999 we carried out a phone inquiry with people or institutions in charge of wildlife management in all 30 Swiss cities (communities) with more than 20 000 inhabitants (Federal Office of Statistics 1998). The experts were asked about occurrence and abundance of urban foxes, evidence of breeding dens in the urban area, the year of the first urban fox sightings and the current trend in the urban fox population. In cities with official game wardens (18 out of 30), they were interviewed, in all other cities we questioned non–professional hunters and the nature conservation officials. In the conurbation of Geneva (three communities with >20 000 inhabitants) our contacts were wildlife biologists running an urban fox project, in Zurich we knew the situation from our own project.

Development of the urban fox population in the city and the canton of Zurich

There are no direct figures on the red fox population available. Therefore its development has to be shown indirectly through the hunting bag and other recorded causes of death. Long-time figures for an urban area are available for the city of Zurich, because it has been a game sanctuary since 1929. All wildlife management tasks in

Tab. 1: Reported sightings of foxes in urban areas from the German speaking part of Switzerland (randomisation test).

Size of township	Accumulated number of inhabitants	Number of fox reports	Expected number of fox reports according to numbers of inhabitants	Significance
> 50'000	958’746	97	60	higher ($p<0.01$)
20'000 – 50'000	335’192	10	21	ns
10'000 – 20'000	897’430	31	57	lower ($p<0.05$)
Total	2’191’368	138	138	

the city are exclusively performed by official game wardens, therefore the hunting bag is recorded and the locations of dead foxes (shot or found dead) are known.
For the comparison of the data from the canton and the city of Zurich, we used the HIPD (hunting indicator of population density; Bögel et al. 1974). We defined the HIPD as the annual number of foxes hunted per km^2 excluding lakes and areas above 2 000 meters. We did not include data on foxes with other death causes than hunting because generally these data have only been available since 1968.
To compare data from urban and adjacent rural areas within the city of Zurich, we used a total number of foxes shot or found dead (available from 1960 to 1997), and additionally numbers of the two mortality factors ”shot” and ”found dead” (mostly road casualties; for the whole city available since 1960, for urban and adjacent rural areas separately available since 1984). To analyse the development of the fox population in the city of Zurich we performed simple linear regressions because the fit of regression of the two mortality factors on the years 1984 to 1997 did not improve by exponential or logistic functions.

Results

The present occurrence of urban foxes in Switzerland

After the call for urban fox sightings on Swiss Television in spring 1997, 194 sightings from 78 different towns and villages of the German speaking part of Switzerland were reported. 138 sightings came from towns with more than 10 000 inhabitants (Tab. 1). Of those, more sightings than expected concerned cities with more than 50 000 inhabitants (randomisation test, $p<0.01$), and less sightings than expected towns with 10 000 – 5 0000 inhabitants ($p<0.05$; Tab. 1).

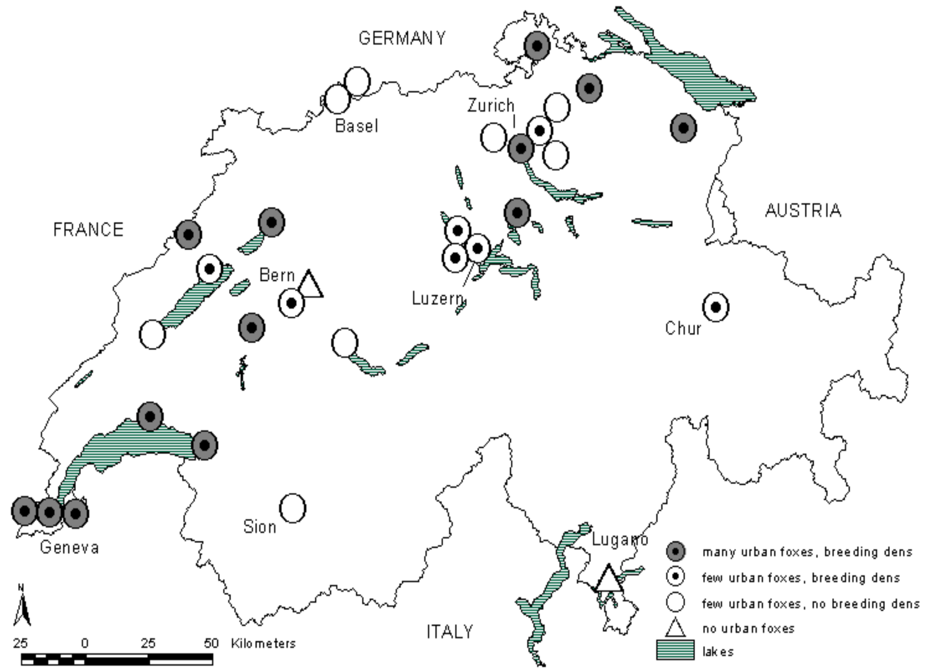


Fig. 1: Distribution of urban foxes in 30 cities with more than 20'000 inhabitants according to local wildlife management experts. Circles of adjacent cities are shifted to avoid overlapping.

According to our inquiry among institutions in charge of wildlife management in 8 out of 9 cities with >50 000 inhabitants, and in 18 of the 19 cities with 20 000 – 50 000 inhabitants, foxes were occasionally found or common (Fig. 1, Tab. 2). Foxes seem not to be present in two towns only: in Bern, situated on the Swiss Plateau, and in Lugano, a city in the southern Alps.

In all 13 towns where foxes were reported to be common, they were observed throughout the urban area (including the centre), and they were breeding in the urban area, too (Tab. 2). In 4 cities with more than 50 000 inhabitants (Zurich, St. Gallen, Luzern, Biel), breeding dens are known even in the very city centre. In most cities (17 out of 28), urban foxes have been perceived as a recent phenomenon since 1985. No geographical trend can be recognised as far es the beginning of settlement in different cities is concerned.

Only in the conurbation of Geneva, with three cities (communities) with >20 000 inhabitants (Geneva, Lancy, Vernier; Tab. 2) the population is said to decrease because of an outbreak of sarcoptic mange in 1996 (C. Fischer, pers. comm.).

Tab. 2: Occurrence and trend of urban fox populations in 30 Swiss cities, according to an inquiry among people/institutions in charge of wildlife management. The two cities where no urban foxes were observed (Bern, Lugano) are excluded.

Questions	Answers	Cities with many urban foxes (n=13)	Cities with few urban foxes (n=15)
Where are the urban foxes observed?	whole of the city	13	4
	outskirts only	0	11
Are there any urban breeding dens?	yes	13	7
	no	0	8
Since when have urban foxes been present?	1985–1999	10	7
	< 1985	3	3
	not known	0	5
How do you judge the trend of the urban fox population?	increasing	8	5
	stable	2	10
	decreasing	3	0

Development of the urban fox population in the city of Zurich

The HIPD of the canton of Zurich and the city of Zurich correlate significantly (Spearman, r=0.66, p<0.001; Fig. 2a), the HIPD in the canton always being higher than in the city. Additionally, the HIPD of canton and city are strongly influenced by rabies trends between 1967, the year when rabies reached Switzerland, and 1985, the year with the last cases of rabies found on foxes in the canton of Zurich (Fig. 2a, b).

According to the HIPD, the fox population in the city of Zurich and in the whole area of the canton of Zurich seems to have developed in parallel at least since the beginning of the 1970s. Both HIPDs are higher after the rabies epizootic than before. The average of the HIPD from 1993 to 1997 compared to the average of the HIPD from 1960 to 1964 is by 1.7 times higher (2.02 vs. 1.19) in the canton and 13.7 times higher (1.26 vs. 0.09) in the city of Zurich, indicating a stronger population increase in the city than in the canton. The increase of the HIPD started in the canton in 1984 and in the city in 1985, respectively.

However, the development of the fox population in the whole city of Zurich (with urban as well as adjacent rural areas) is not the same as the development of the population within the urban area. The first peak of the HIPD in 1967 (Fig. 2) only occurred in the records of foxes from the rural part of the city (Fig. 3), whereas in the urban part of the city fox numbers remained low during the 1960s and 1970s. The trend to an increasing urban fox population in fact just started from 1985 onwards.

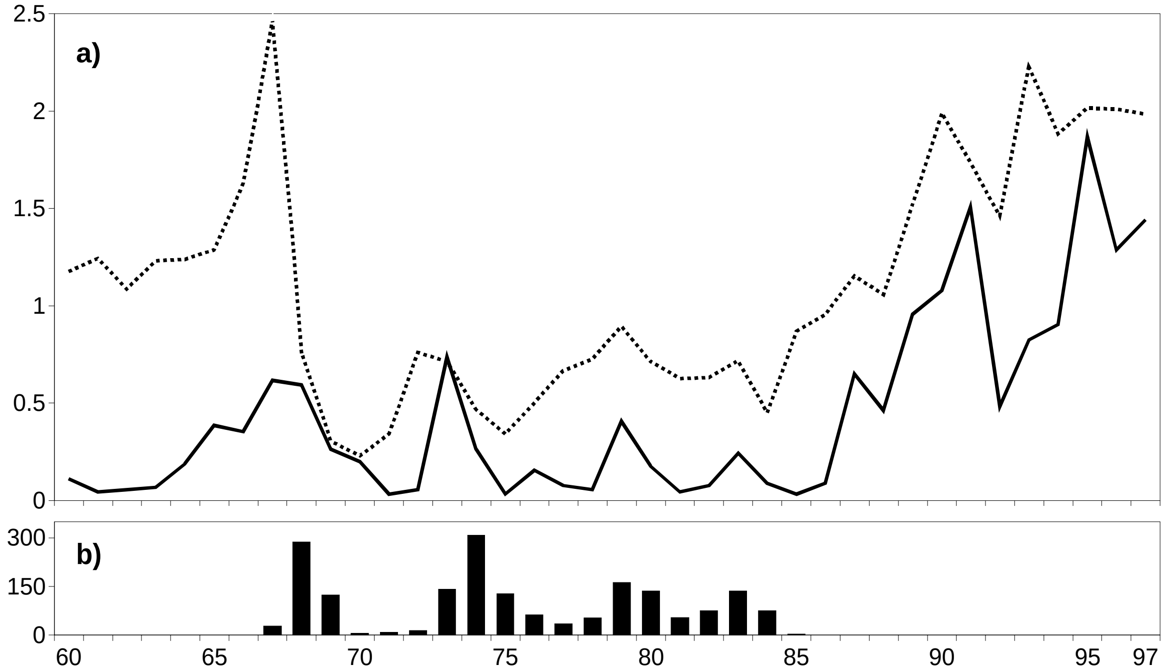


Fig. 2: a) Hunting indicator of population density (HIPD) for the city of Zurich (straight line) and the canton of Zurich (dotted line) from 1960 to 1997. b) Rabies cases in the canton of Zurich from 1960 to 1997.

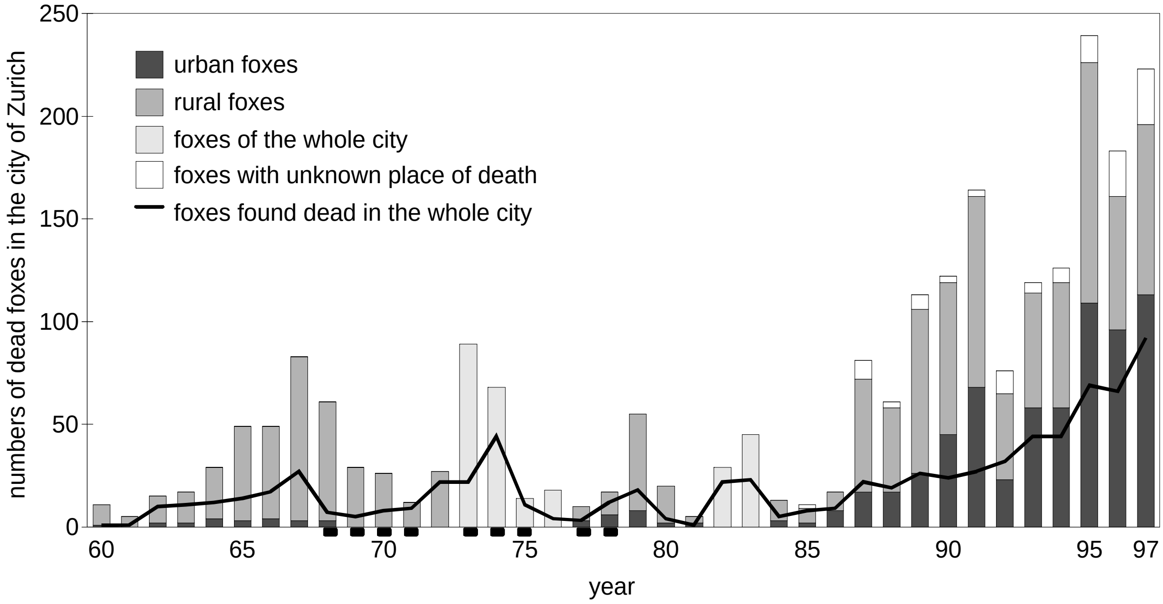


Fig. 3: Fox mortality (animals shot or found dead) in urban and rural areas in the city of Zurich from 1960 to 1997. Of the years 1973 – 1976 and 1982 – 1983 there are only total numbers of dead city foxes available (light grey bars). No precise locations of death are available of some recorded foxes from 1984 onwards (white bars). The years with rabies cases within 5 km of the city centre (Kappeler 1991) are marked with black bars.

Tab. 3: The increase of numbers of recorded dead foxes within the city border of Zurich, described by the linear regression of the two mortality factors "shot" and "found dead" (mostly road casualties) from 1984 to 1997.

Foxes of urban areas			
Mortality factor	Coefficient	R^2	p<=
Shot	5.215	0.78	0.001
Found dead	3.310	0.85	0.001
Foxes of adjacent rural areas			
Mortality factor	Coefficient	R^2	p<=
Shot	4.842	0.46	0.01
Found dead	0.831	0.74	0.001

Before 1985, most of the few foxes of the urban area were only recorded at the border of the city, apart from two foxes, one young fox near the city centre in August 1964 and one young fox in the fairly central railway station Enge in June 1967.
Rabies cases were recorded in the city of Zurich from 1967 to 1983 (Fig. 3). The prophylactic culling of foxes was carried out as intensively as possible from 1965 to 1995. The numbers of foxes found dead and shot, analysed separately for the whole city correlate significantly (Spearman, $r=0.73$, $p<0.001$). According to these numbers, the population remained low for almost 20 years after the rabies outbreak, and only in 1985, two years after the last rabies cases were recorded in the area, the fox population started to increase, both in the urban and in the adjacent rural part of the city. From 1985 to 1997 the number of foxes shot or found dead in the whole city increased by 20 times from 11 to 223. This trend is true for both mortality factors "shot" and "found dead" and examined separately for urban and adjacent rural areas (Tab. 3). Yet the increase in the number of foxes found dead was stronger in the urban than in the rural area (difference of coefficients, $t24=4.11$, $p<0.001$).

Discussion

Today, urban foxes are recorded in almost all cities of Switzerland. The presence of breeding dens in urban areas up to the city centres indicates that foxes really live in the cities and are not just occasional roamers from the vicinity. We ascribe differences in population densities in Swiss cities of today mainly to the fact that urban foxes have been a recent phenomenon and the development still goes on.
Our call for fox sightings on Swiss television revealed that more foxes are recorded from larger towns than from smaller ones, a relation that was also observed by

Macdonald and Newdick (1982) in Great Britain. This could be because larger towns may have a higher proportion of suburban habitat, where the highest fox densities are found (Harris and Rayner 1986b).

Although red foxes generally avoid the direct presence of humans, some foxes have lived in the neighbourhood of people's settlements for a long time, shown e.g. by the naturalist Schinz (in Ineichen 1997), who noted in 1842, that red foxes had always lived in the moats surrounding the city of Zurich. The hunting statistics of the city of Zurich show that foxes have been present in the urban area since the early 1960s, but such observations remained isolated cases.

In 1985 the situation began to change. Due to successful oral vaccination campaigns against rabies, the fox population in Switzerland started to recover (Breitenmoser et al. 2000), which is recorded in other European countries, as well (e.g. Vos 1993; Artois et al. 1997). It was parallel to this general trend, when the urban fox population in the city of Zurich and in most other Swiss cities showed a drastic increase according to hunting statistics.

However, hunting statistics have to be interpreted cautiously, because they do not only correlate with the real fox populations but are also influenced by other factors such as the preferences of the hunters (Macdonald and Voigt 1985; Goszczynski 1989) or outbreaks of zoonoses (Kappeler and Wandeler 2000). A high hunting pressure most probably lasted during the whole period of rabies from 1967 till at least to the end of the 1980s. Therefore the low HIPD during this period presumably reflects low densities of fox populations. With the decrease of rabies the motivation to hunt foxes probably decreased drastically. The HIPD, on the other hand, was still increasing during the 1990s. We therefore suggest that the real trend of fox populations is underestimated by hunting statistics. The fox population in the canton of Zurich with its high degree of urbanisation must be even more underestimated by the HIPD, because foxes are hardly ever shot in most urban areas, where hunting generally is not permitted.

The game sanctuary of the city of Zurich is an exception, where a constant hunting regime is maintained by official game wardens. The significant correlation of the development of foxes "shot" and "found dead" within the city confirms, that the increasing numbers of dead foxes are not only the result of an increased shooting effort.

A similar development of urban foxes as in Switzerland recently took place in other parts of the distribution area of the red fox which is shown by reports e.g. from Oslo, Norway (Christensen 1985), Arhus, Denmark (Moller Nielsen 1990), Stuttgart, Germany (T. Romig, pers. comm.), Toronto, Canada (Adkins and Stott 1998) and Sapporo, Japan (K. Uraguchi, pers. comm.). The questions raise why the invasion of urban habitat started and which factors caused this new development.

According to Harris and Rayner (1986c), the colonisation of British towns already started in the 1930s. In these years there was a boom of private house construction resulting in large districts of middle–class suburbs with low–density housing, and medium–sized gardens. This is the type of habitat which Harris and Rayner (1986b) found to be favoured by foxes. Once established in these residential suburbs, foxes moved further into the city and also colonised less favoured habitats. Harris and Rayner (1986b) found urban foxes to be less common in areas consisting of council–rented housing, in city centres, and around industrial areas.

The colonisation of Swiss cities through foxes results in a similar phenomenon as it is known from Great Britain. However, the underlying cause for the rise of the urban fox populations seems to be different, because the development of Swiss cities in the past thirty years was unlike British cities in the 1930s. We propose two hypothetical explanations for the presence of urban foxes: The population pressure hypothesis (PPH) and, as an alternative, the urban island hypothesis (UIH).

The population pressure hypothesis PPH postulates that urban foxes are simply intruders from the adjacent rural areas. These foxes are in human settlements because of a high population density in rural areas. According to the PPH, urban areas would provide suboptimal habitats for foxes, the dynamics of an urban fox population would closely correlate with the trend of the fox population in the adjacent rural areas and the urban fox population would genetically not be different from the adjacent rural population (Rousset 1999).

The alternative urban island hypothesis UIH postulates that urban foxes have adapted to specific urban conditions such as high density of human population. Therefore, urban foxes would be able to use specific urban resources such as scavenged food items or special hiding places during daytime. The dynamics of such an urban fox population would be independent from the trend in the adjacent rural areas. The colonisation of urban areas could have been initiated by the behavioural adaptations of a few foxes that gave them access to exploit human settlements as a free niche. As only a few individuals founded the new urban population, we would expect it to be genetically isolated from the population in the rural surroundings.

The simultaneous emerging of urban foxes throughout Switzerland along with the increasing fox population indicates that the high population pressure has at least initiated the immigration of the founder individuals into the cities. Macdonald and Newdick (1982) suggested that there was no strict division between rural and urban foxes in Oxford, because they had radio–tracked foxes which regularly commuted between urban and rural areas. Nevertheless, living in the city requires special adaptations, and many anecdotal observations reveal that foxes indeed have adapted to this exceptional environment. Further research on resource exploitation and genetic structure of the urban fox population will allow to compare the two hypotheses.

The presence of foxes in human settlements raises the question of the impact of human behaviour and human attitudes on the urban fox population (Bontadina et al. 2000). Harris (1981b) and Doncaster et al. (1990) showed, that food directly or indirectly provided by humans can make up a major part of the diet of urban foxes. People feel ambivalent about urban foxes, being either fascinated by this wild carnivore in their neighbourhood or afraid of it because of zoonoses (Bontadina et al. 2000).

In fact, foxes in close vicinity to humans and pets could indicate new zoonotic risks (Hofer et al. 2000). The red fox is the main vector of rabies in Europe. Up to now urban areas were considered barriers to the spread of rabies (Steck et al. 1980), therefore the increase of urban fox populations calls for additional strategies in case of a new outbreak of rabies (Macdonald and Voigt 1985, Harris et al. 1988).

Furthermore, the zoonosis alveolar echinococcosis (AE), caused by the small fox tapeworm Echinococcus multilocularis, could become more important through the increase of urban fox populations. In Switzerland, the incidence rate of human AE has not significantly changed over the past 36 years, suggesting a stable epidemiological situation (Eckert and Deplazes 1999), but regarding the long incubation period of AE of 5–15 years, it would be advisable to study this zoonosis further, especially in urban areas. Results of such studies could have an important impact on the management of urban fox populations.

Acknowledgements

The authors thank all collaborators involved in the Integrated Fox Project. We especially thank Claude Fischer, who conducted the inquiry of game officials in the French part of Switzerland and provided useful information on the urban fox population of Geneva, and Christian Stauffer for his generous collaboration and for providing access to the data of the game sanctuary of Zurich. We thank Alexander Mathis, Claude Fischer, Christian Stauffer, and Jean–Marc Weber for comments on an earlier draft of the paper. We also thank the game wardens and people in charge of wildlife management in the 30 large cities of Switzerland.

This investigation was carried out within the context of the Integrated Fox Project, a research and communication project on the dynamics of the fox population in Switzerland. The study was supported by the Swiss National Science Foundation (grant no. 31–47031.96), the Fonds zur Förderung des akademischen Nachwuchses FAN of the Zürcher Hochschul–Verein and the Swiss Federal Office for Education and Science (EU FAIR Projekt CT97–3515 / BBW Nr. 97.0586).

References

Adkins, C. A.; Stott, P. (1998): Home ranges, movements and habitat associations of red foxes Vulpes vulpes in suburban Toronto, Ontario, Canada. J. Zool. (London) 244, 335-346.

Artois, M.; Langlais, M.; Suppo, Ch. (1997): Simulation of rabies control within an increasing fox population. Ecol. Mod. 97, 23-34.

Beames, I. R. (1969): Mammals in the London area, 1967. Lond. Nat. 48, 40-47.

Beames, I. (1972): The spread of the fox in the London area. Ecologist 2, 25-26.

Bögel, K., A.; Arata, A.; Moegle, H.; Knorpp, F. (1974): Recovery of reduced fox populations in rabies control. Zbl. Vet. Med. B 21, 401-412.

Bontadina, F.; Contesse, P.; Gloor, S. (2000): Beeinflusst die persönliche Betroffenheit die Einstellung gegenüber Stadtfüchsen? - Aspekte zur Akzeptanz eines Wildtieres im Siedlungsgebiet. Forest Snow and Landscape Research, (in press).

Breitenmoser, U.; Müller, U.; Kappeler, A.; Zanoni, R.G. (2000): Die Endphase der Tollwut in der Schweiz. Schweiz. Arch. Tierheilk. 147, 447-453.

Christensen, H. (1985): Urban fox population in Oslo. Rev. Ecol. (Terre Vie) 40, 185-186.

Doncaster, C. P.; Dickman, C. R.; Macdonald, D. W. (1990): Feeding ecology of red foxes (Vulpes vulpes) in the city of Oxford, England. J. Mammalogy 71, 188-194.

Eckert, J.; Deplazes, P. (1999): Alveolar Echinococcosis in Humans: The Current Situation in Central Europe and the Need for Countermeasures. Parasitol. Today 15, 315-319.

Estabrook, C. B.; Estabrook, G. F. (1989): Actus: a solution to the problem of small samples in the analysis of two-way contingency tables. Hist. Meth. 82, 5-8.

Federal Office for Statistics (1998): Statistik der Schweizer Städte. In: Stat. Jahrbuch des Schweizerischen Städteverbandes. Bern: Bundesamt für Statistik.

Goszczynski, J. (1989): Population dynamics of the red fox in central Poland. Acta Theriol. 34, 141-154.

Harris, S. (1977): Distribution, habitat utilization and age structure of a suburban fox (Vulpes vulpes) population. Mammal Rev. 7, 25-39.

Harris, S. (1981a): An estimation of number of foxes (Vulpes vulpes) in the city of Bristol, and some possible factors affecting their distribution. J. Appl. Ecol. 18, 455-465.

Harris, S. (1981b): The food of suburban foxes (Vulpes vulpes), with special reference to London. Mammal Rev. 11, 151-168.

Harris, S.; Rayner, J. M. V. (1986a): Urban fox (Vulpes vulpes) population estimates and habitat requirements in several British cities. J. Animal Ecol. 55, 575-591.

Harris, S.; Rayner, J. M. V. (1986b): Models for predicting urban fox (Vulpes vulpes) numbers in British cities and their application for rabies control. J. Animal Ecol. 55, 593-603.

Harris, S.; Rayner, J. M. V. (1986c): A discriminant analysis of the current distribution of urban foxes (Vulpes vulpes) in Britain. J. Animal Ecol.55, 605-611.

Harris, S.; Smith, G. C.; Trewhella, W.J. (1988): Rabies in urban foxes (Vulpes vulpes) - developing a control strategy. State Veterinary Journal 42: 149-161.

Hofer, S.; Gloor, S.; Müller, U.; Mathis, A.; Hegglin, D.; Deplazes, P. (2000): Urban cycle of Echinococcus multilocularis in the city of Zurich, Switzerland. Parasitology 120, 135-142.

Ineichen, S. (1997): Die wilden Tiere in der Stadt. Zur Naturgeschichte der Stadt. Frauenfeld: Im Waldgut.

Kappeler, A. (1991): Die orale Immunisierung von Füchsen gegen Tollwut in der Schweiz. Diss. thesis, University of Bern, Switzerland.

Kappeler, A.; Wandeler, A. I. (2000): Entwicklung der Strategien zur Feldanwendung der oralen Immunisierung von Füchsen gegen Tollwut. Schweiz. Arch. Tierheilk. 147, 439-446.

Macdonald, D. W.; Newdick, M. (1982): The distribution and ecology of foxes, Vulpes vulpes in urban areas. In: Urban Ecology. Ed. by R. Bornkamm, J. A. Lee, and M. R. Seeward. Oxford: Blackwell Scientific Publi. Pp. 123-135.

Macdonald, D. W.; Voigt, D. R. (1985): The biological basis of rabies models. In: Population Dynamics of Rabies in Wildlife. Ed. by P. J. Bacon. London: Academic Press. Pp. 71-103.

Moller Nielsen, S. (1990): The food of rural and suburban woodland foxes Vulpes vulpes in Denmark. Natura Jutlandica 23, 25-32.

Müller, U.; Kappeler, A.; Zanoni, R. G.; Breitenmoser, U. (2000): Der Verlauf der Tollwut in der Schweiz – Landschaft prägt die Ausbreitung einer Wildtierepidemie. Schweiz. Arch. Tierheilk. 142, 431-438.

Page, R. J. C. (1981): Dispersal and population density of the fox (Vulpes vulpes) in an area of London. J. Zool. (London) 194, 485-491.

Rousset, F. (1999): Genetic differentiation within and between two habitats. Genetics 151, 397-407.

Steck, F.; Wandeler, A.; Nydegger, B.; Manigley, C.; Weiss, M. (1980): Die Tollwut in der Schweiz 1967-1978. Schweiz. Arch. Tierheilk. 122, 605-636.

Teagle, W. G. (1967): The fox in the London suburbs. Lond. Nat. 46, 44-68.

Vos, A. (1993): Aspekte der Dynamik einer Fuchspopulation nach dem Verschwinden der Tollwut. Diss. thesis, University of Munich, Germany.

Wandeler, A. I.; Capt, S.; Kappeler; A.; Hauser, R. (1988): Oral immunization of wildlife against rabies: concept and first field experiments. Rev. infect. Diseases 10, 649-653.

Manuskript B (Mammalian Biology):
The diet of urban foxes (*Vulpes vulpes*) and the availability of anthropogenic food in the city of Zurich, Switzerland

Pascale Contesse[1,2], Daniel Hegglin[1], Sandra Gloor[3], Fabio Bontadina[3], Peter Deplazes[1]

[1] Institute of Parasitology of the University of Zurich, Switzerland
[2] Zoological Museum of the University of Zurich, Switzerland
[3] SWILD – urban ecology & wildlife research, Zurich, Switzerland

Key words: food supply, stomach analyses, adaptation

Contesse P, Hegglin D, Gloor S, Bontadina F, Deplazes P. Anthropogenic food resources allow increase in an Swiss urban fox (Vulpes vulpes) population. Mammalian Biology accepted.

Abstract

The diet of urban foxes and the availability of anthropogenic food were studied in the city of Zurich, Switzerland. A stomach analysis of 402 foxes, which were shot or found dead between January 1996 and March 1998, showed a broad variety in the diet of urban foxes, with a dominance of scavenged meat, other scavenge and cultivated fruit and crops. More than half of an average stomach content was anthropogenic. The proportion of anthropogenic food was increased in stomachs from the city centre –mainly due to the increasing proportion of scavenged meat– compared with stomachs from the periurban area. Significant seasonal variations in the diet were found for invertebrates, birds and for cultivated fruit and crops, which were all most frequently consumed in summer.

A written survey among the inhabitants of three municipal districts showed that 85% of the households provided anthropogenic food which was accessible to foxes. This food supply consisted of three quarters of rubbish and compost, completed by fruit and berries and, to a lesser extent, food provisions for pets, birds, and other wild animals. In contrast, the anthropogenic food supply of allotment gardens mainly consisted of berries, completed by fruit, compost and birdseed. The anthropogenic food supply in public areas was determined by transects. The overall food supply of households, allotment gardens and public areas would be sufficient to feed a much higher number of foxes than currently present. This overabundance of food resources could explain the continual increase of urban population densities. A possible further exploitation of anthropogenic food sources is discussed considering its specific characteristics and the necessary behavioural adaptations.

Introduction

In the early 1980s, foxes were observed to have started breeding in Swiss cities and conurbations (GLOOR et al. 2001). Since then, the urban fox populations have increased continuously, corresponding to the general increase of fox abundance in Switzerland (BREITENMOSER et al. 2000) as well as in many other European countries (CHAUTAN et al. 2000). The severe rabies epizootic that spread throughout central Europe reached Switzerland in 1967 and caused a drastic decrease of Swiss fox populations, but due to successful oral vaccination campaigns, they started to recover from 1984 onwards. The current fox population densities are higher than before the outbreak of rabies (BREITENMOSER et al. 2000). This development seems to be connected with the exploitation of new habitats. Indeed, all 30 Swiss cities with more than 20 000 inhabitants are colonised by foxes (GLOOR et al. 2001; GLOOR, unpubl. data). The current fox population of the city of Zurich, the largest Swiss conurbation, has reached densities of more than 10 adult foxes per km^2 (GLOOR 2002), which is more than any studied rural fox population in Switzerland.

Foxes breeding in urban habitats are recorded in many European and North American cities (e.g. HARRIS and RAYNER 1986; SCHOEFFEL and SCHEIN 1991; ADKINS and STOTT 1998). Considering the small home range sizes and the high population density of urban fox populations, human settlements generally seem to provide suitable habitats for foxes (HARRIS 1981b; MACDONALD and NEWDICK 1982). Since rural foxes are known to be shy and avoid human encounters whenever possible the colonisation of the free urban niches required behavioural ontogenetic adaptations. It therefore presumably needed a certain population pressure in the rural surroundings to initiate this development (GLOOR et al. 2001).

Food is considered to influence the fox population size (LLOYD 1980; LINDSTRÖM 1989) as well as their social organisation (MACDONALD 1983). In urban habitats its quality and abundance are strongly influenced by humans (BAKER et al. 2000). Scavenge was the main component of the diet of urban foxes in London (GB; HARRIS 1981a), Oxford (GB; DONCASTER et al. 1990), and Bristol (GB; SAUNDERS et al. 1993; BAKER et al. 2000). We therefore assume that a surplus supply of anthropogenic food is responsible for the high and still increasing fox population density in the city of Zurich. In order to test this hypothesis, the objectives of our study were (1) to analyse the composition of the diet of foxes inhabiting the city of Zurich with special reference to anthropogenic food, (2) to evaluate the availability of anthropogenic food supplied by households, in allotment gardens and public areas and (3) to estimate the potential population density supported by anthropogenic food.

Materials and method

Study areas

The study was conducted in Zurich, including its suburbs inhabited by about one million people. We defined two study areas in this project.
Study area A was used for the stomach analysis and consisted of the political community of Zurich. It covers 92 km^2, has a human population of 360000 and is made up of 53% built–over area, 24% forest, 17% agricultural area and 6% water (STAT. DEPARTMENT OF THE CITY OF ZURICH 1998). We divided this area into an urban zone, a border zone and a periurban zone. The urban zone refers to the built–over area, whereas the periurban zone consists of the surrounding forests and agricultural areas, the 500 m wide border zone separating one from the other.
Study area B was selected to study the availability of anthropogenic food. It is situated in the western part of study area A covering 6.8 km^2. It consists of the urban and border zones of 4 neighbouring municipal districts, which are known to have a high fox population (GLOOR 2002). Private properties cover 61% of the area, public areas 38% and allotment gardens 1%. 73% of the buildings are residential, 31% of them being detached houses. The population density is 9700 inhabitants/km^2.

Stomach analysis

Between January 1996 and March 1998, 402 foxes were collected by the 3 official game wardens of the city forest service and stored at –20°C. Age determination of foxes was done by measuring the relative width of the pulp cavity of a lower canine tooth by X–rays (KAPPELER 1991). Foxes were designated as juveniles when they were younger than 12 months, with the assumption that the cubs were born on April 1st (WANDELER 1976). We assigned the foxes to three seasons: spring (March–June), summer (July–October) and winter (November–February).
After removal and dissection of a stomach, its content was analysed as described by CAPT and STALDER (1988) and ROPER and LÜPS (1994). We defined 12 food categories, which we divided according to their origin into 5 natural, 5 anthropogenic and 2 intermediate food classes (Tab. 1). According to our definition, intermediate food has both natural and anthropogenic characteristics. Cultivated fruit and crops are on one hand part of the traditional fox diet in rural areas and on the other hand grown by humans, and the origin of an indefinable item could be natural as well as anthropogenic.
For each fox the relative proportion of each category of the total stomach content was estimated according to its volume with an accuracy of 5%. If a food category was found in traces only, its relative proportion was noted as 1%. Soil materials, grass and fox hairs were not taken into consideration. Many of the foxes shot by

game wardens were baited with meat. Therefore, meat was considered only if the fox died in an accident or for unknown reasons.

Birds and mammals were identified according to DAY (1966), NIETHAMMER and KRAPP (1982) and TEERINK (1991). For hair identification we (a) prepared prints of the medulla on transparent nail varnish that had been spread as a thin layer on a microscope slide, and (b) cut 10 μm cross-sections using a microtome.

To prevent underestimation of the presence of earthworms, we filtered the rinsing water in a sieve with mesh size 0.25 mm and transferred the filtrate portionwise in petridishes. Chaetae were counted under a binocular, x50 magnification. According to WROOT (1985) and REYNOLDS and AEBISCHER (1991), one chaeta of *Lumbricus terrestris* corresponds to an average of 1.9 mg fresh weight, which allowed estimating the proportion of earthworms on the total stomach content.

Anthropogenic food supply

To estimate the availability of anthropogenic food in private properties, we distributed questionnaires to 3000 randomly selected households in study area B in March 1999. Questions regarded the weekly volume of rubbish and the people’s habits of composting, feeding pets, birds and other wild animals and growing fruit and berries. Vegetables were not considered, as their energetic value and their presence in fox stomachs was negligible. In apartment buildings the questionnaire was given to one randomly selected household, which we supposed to be representative for all the other households of the building.

Berries grown in gardens were considered to be freely accessible to foxes, whereas fruit was considered to be accessible to foxes as windfall only. The calculation of the annual energy content based on the growers information about the number of plants, species, size, percentage of fruit picked, removing of windfall and energy content tables of FEUCHT (1982) and ELMADFA et al. (1987).

Concerning food offered to pets, birds and other animals, people had to specify the type, quantity and location of the food and if the food was left unattended and thus reachable for foxes. For birdseed we assumed that an average of 10% of the total amount of birdseed was accessible to foxes, even when located higher than 60 cm, as it would fall off bird tables and food nets.

Households either put their bin liners in solid skips, which are not accessible to foxes, or on the street border, where they get collected by municipal services once a week. The percentage of bin liners put out immediately before collection and therefore not accessible to foxes was estimated based on a sample of 470 bin liners.

In order to estimate the average energy content of rubbish and compost we analysed samples of compost that were collected by 17 households during 7 days, and 18 bin liners, randomly collected in February 1999. Edible components were weighed and their energy content calculated according to ELMADFA et al. (1987) and CASE et al. (1995). Considering all these evaluations, we estimated the energy content in megajoules per year (MJ/y) of the anthropogenic food supply from each household, which was accessible to foxes on the concerned private property. According to the statistics of the authorities responsible for garbage collection there are no obvious seasonal differences.

In addition, we handed out questionnaires to 500 randomly selected leaseholders of allotment gardens in study area B, since allotment gardens were the second most selected habitat category as revealed by a radio–tracking study in this area (GLOOR 2002). The questions were generally the same as with the households.

In order to evaluate the anthropogenic food supply in public areas, we randomly analysed streets, parks, cemeteries and play grounds using the transect method on 13 days from January to March 1999, collecting all the edible anthropogenic food. The searched area measured 67.5 ha and was representative for study area B, with respect to the proportions of these four habitat types. Contents of dustbins were considered if their upper edge was below 60 cm. Food items, which could be taken from bin liners without damaging them, were collected too.

To find out if foxes used bin liners as food source, we checked on 6 days of February and March 1999 a total of 1381 bin liners for animal damages. These bin liners had been accessible to foxes for at least one night.

Statistical analysis

Evaluating the proportional feeding on the 12 food categories, we had to consider the unit–sum constraint (AEBISCHER et al. 1993). The compositional analysis is a method testing seasonal and habitat effects on the intake of a food category, taking into account the utilisation of other food categories. We therefore transformed proportional values to log–ratios and substituted zero by 0.01% (AEBISCHER et al. 1993). Then we computed a multivariate analysis of variances ANOVA and Tamhane post–hoc tests.

To estimate the food supply of a whole apartment building, we multiplied the energy supply of rubbish and compost of the interviewed household with the number of flats. However, the energy supply of fruit and berries was kept as there was one garden per building only. The supply of animal food of the whole apartment building was calculated as follows: energy supply of the interviewed household + ($n_{households}$–1)*proportion(households in apartment buildings feeding animals)*median(energy supply of animal feeding households in apartment buildings).

To find out whether there were correlations between household size, the number of households in a building and the energy supply of households and buildings, we computed a multivariate analysis of variances ANOVA, followed by Scheffé post–hoc tests. Therefore, we defined 3 classes of household size (1–2, 3–4, 5 and more persons), 3 classes of building size (1–2, 3–8 and 9 and more households) and excluded extreme values, which were defined to be higher than 3.5 times the interquartile range above the median. In order to estimate the maximum number of foxes that could feed on anthropogenic food, we used median supplies distinguishing between detached/semi–detached houses and apartment buildings, because this was the most adequate obtainable land use information. According to SAUNDERS et al. (1993), we assumed a daily energy expenditure of 2.4 MJ per adult fox. 95% confidential intervals were calculated according to STAHEL (1995). All statistical tests were performed using SPSS 10.0 (NORUSIS 1986).

Table 1. Qualitative and quantitative analysis of 212 stomach contents of urban foxes from the city of Zurich, Switzerland.

Food categories	Frequency of occurrence (%)	Mean proportion of total stomach content (%±SE)	Mean volume when present (ml±SE)	Number of stomachs containing the concerned category exclusively	Number of stomachs mainly containing the concerned category
Natural food					
(1) Rodents	25.9	11 (±1.8)	20.5 (±3.8)	7	16
(2) Birds	23.6	4.8 (±1.1)	8.6 (±2.3)	0	10
(3) Other vertebrates	5.7	2.1 (±0.8)	17.1 (±9.8)	1	3
(4) Invertebrates	31.6	4.4 (±1)	7.1 (±2)	3	3
(5) Wild fruit	22.6	5.2 (±1.2)	4.4 (±0.6)	3	7
Total	68.9	27.5 (±2.4)	16.6 (±2.1)	18	37
Anthropogenic food					
(6) Scavenged meat	47.6	21.1 (±2.2)	24.3 (±4.3)	9	30
(7) Other scavenge	60.8	22.2 (±2.1)	17.8 (±2.7)	6	39
(8) Pets and domestic stock	10.4	4.5 (±1.3)	29.8 (±23.8)	4	5
(9) Petfood	6.1	2.2 (±0.7)	36.3 (±10.8)	0	5
(10) Birdseed	9.4	3.7 (±1)	8.4 (±1.8)	3	3
Total	83.5	53.6 (±2.7)	34.2 (±4.7)	39	78
Intermediate food					
(11) Cultivated fruit and crops	49.1	18.2 (±2)	25.1 (±3.4)	4	35
(12) Indefinable items	4.2	0.7 (±0.4)	4.7 (±2)	0	1
Total	50.9	18.9 (±2)	24.5 (±3.3)	4	31

Results

Stomach contents analysis

All in all, 190 (47%) of the 402 analysed stomachs were empty. Therefore, our analysis refers to a sample size of 212 stomachs with food content. The zonal and seasonal origin of the foxes as well as their age, sex and cause of death are presented in table 2. In spring, foxes were shot with special permission in the urban area only. This is why only 14% of the stomachs were collected in spring and originated of relatively fewer shot foxes.

The average proportions of the 12 food categories and their frequencies of occurrence showed a strong positive correlation (Spearman rang, r_s=0.93, $p<0.005$). In contrast, the mean proportion of a present component did not correlate with the other two parameters (Tab. 1).

Scavenged meat, other scavenge and cultivated fruit and crops were the staple diet, accounting for 61.5% of the mean stomach content (Fig. 1). Furthermore, these three categories were by far the most frequent main components, as 58% of all

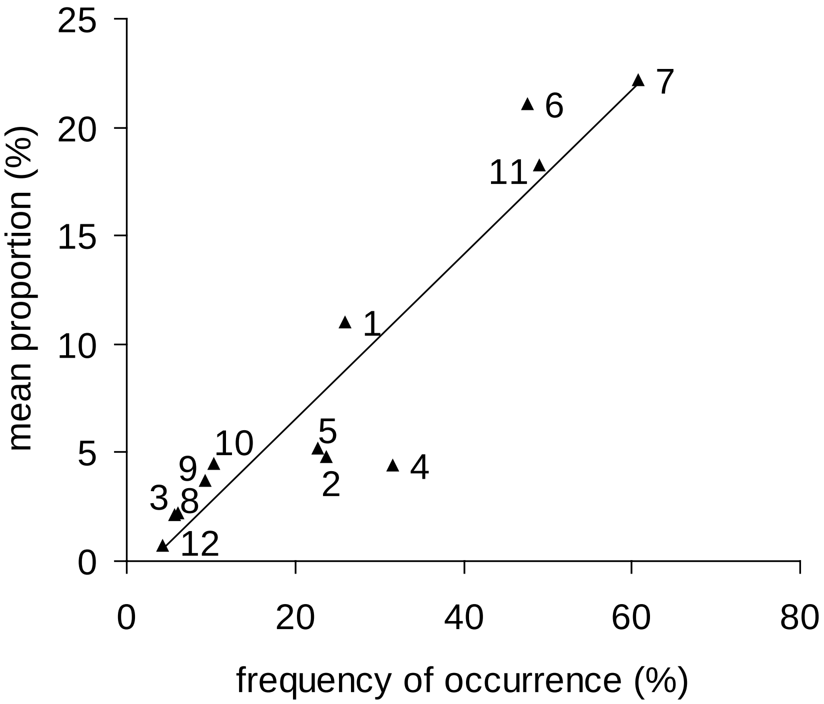


Fig. 1. Frequency of occurrence (%) and mean proportion of the total stomach content of 12 food categories. (1) rodents, (2) birds, (3) other wild vertebrates, (4) invertebrates, (5) wild fruit, (6) scavenged meat, (7) other scavenge, (8) pets and domestic stock, (9) petfood, (10) birdseed, (11) cultivated fruit and crops and (12) indefinable. Both variables refer to the 212 food containing fox stomachs collected in the city of Zurich, Switzerland. R^2=0.872.

stomachs mainly or exclusively contained one of these three categories (Tab. 1). Ranking the number of stomachs in which the food category in question was the only component, scavenged meat, other scavenge and rodents were dominant (Tab. 1).

The following details facilitate comparisons with other studies:
Rodents: we identified 12 northern water voles (*Arvicola terrestris*), 10 common voles (*Microtus arvalis*), six bank voles (*Clethrionomys glareolus*), six yellow–necked mice (*Apodemus flavicollis*), five *Apodemus spec.*, four house mice (*Mus domesticus*), three squirrels (*Sciurus vulgaris*), two wood mice (*Apodemus sylvaticus*), two field voles (*Microtus agrestis*) and one common rat (*Rattus norvegicus*). The genus of five rodents could not be determined.
Birds: 40 remains originated from Passeriformes, seven from *Columbiformes* and one from *Falconiformes*. Two feathers could not be assigned.
Other wild vertebrates: we found four small pieces of snakeskin, hair of two roe deer (*Capreolus capreolus*), skin and flesh of one hedgehog (*Erinaceus europaeus*), one blindworm (*Anguis fragilis*) and one unidentified fish.

Invertebrates: 17.5% of the stomachs contained imagines and larvae of insects. Only larvae of *Noctuidae* and *Syrphidae* had been eaten in bigger amounts. Earthworms were found in 20.9% of the stomachs, but they formed a mean proportion of only 2.6%.

Wild fruit: we identified yew (15x, *Taxus baccata*), hazelnut (13x, *Corylus avellana*), walnut (1x, *Juglans regia*) and rose hip (1x, *Rosa spec.*). 15 fragments could not be identified to species level.

Scavenged meat: this category including all kinds of cooked or processed meat and bones as well as butcher waste (signs of processing: cut parts, no fur, etc.), was found in 47% of all stomachs.

Other scavenge: 32.2% of the stomachs contained vegetable kitchen waste, 28.9% contained wrappers and other indigestible items and 27% contained remains of processed food like bread, pasta or cheese.

Pets and domestic stock: we identified remains of 12 hens (*Gallus gallus*), five cats (*Felis catus*), four rabbits (*Oryctolagus cuniculus*), two dogs (*Canis lupus f. familiaris*) and a cattle (*Bos primigenius f. taurus*). There are no wild populations of rabbits in the area. The flesh of rabbits and hens could originate from animals killed by the fox itself. Since predation on the other pet species is unlikely this flesh originated presumably from the remains of carcasses.

Petfood: commercial tinned or dried food for cats or dogs identified by its consistence and its smell had a low relative proportion, but its mean proportion when present was the highest of all food categories (Tab. 1).

Birdseed: typical mixtures of cereals or grains as sold in shops for bird feeding was found in stomachs from January, February and March only.

Cultivated fruit and crops included cultivated fruit, berries, vegetables and cereals, which a fox could have found on a field, in an orchard or garden, according to the season and the local cultivation attitudes. Remains not fulfilling these conditions, remains cooked or showing traces of cutting were allocated to other scavenge. Fruit occurred in 38.4% of the stomachs. The most frequently identified fruit species were apples (*Pyrus malus*), plums and cherries (*Prunus spec.*). Vegetables were found in 4.2% of the stomachs, namely carrots (*Daucus carota*), potatoes (*Solanum tuberosum*), sugar beets (*Beta vulgaris*) and beans (*Phaseolus spec.*) with a mean proportion of 1.2%. Cereals like wheat (*Triticum spec.*) and corn (*Zea mays*) occurred in 13.7% of the stomachs.

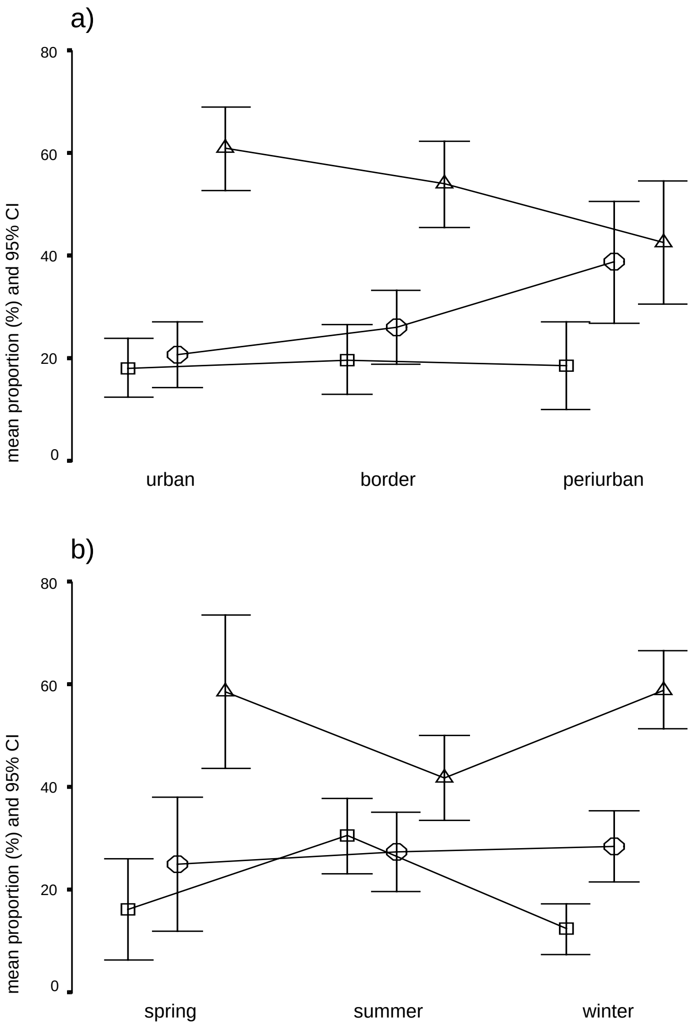


Fig. 2. Zonal (a) and seasonal variation (b) of the mean proportions of anthropogenic (triangles), natural (circles) and intermediate (squares) food in 212 fox stomachs from the city of Zurich, Switzerland. N(urban)=74, N(border)=86, N(periurban)=50. N(spring)=29, N(summer)=70, N(winter)=112. Anthropogenic food categories were: scavenged meat, other scavenge, pets and domestic stock, petfood and birdseed. Natural food categories were: rodents, birds, other vertebrates, invertebrates and wild fruit. Intermediate food categories were: cultivated fruit and crops and indefinable items. Differences are significant (for details see text).

Summarising, more than half of a mean stomach content was anthropogenic (Tab. 1). Furthermore, anthropogenic food was the only one with zonal variation ($F=11.7$, $df=2$, $p<0.001$), found in significantly higher mean proportions in urban than in periurban stomachs (Tamhane post–hoc test, $p<0.001$; Fig. 2a). A significant seasonal variation was observed for intermediate food ($F=10.5$, $df=2$, $p<0.001$), whose proportions were significantly higher in summer than in spring and winter (Tamhane, $p<0.003$ resp. $p<0.001$; Fig. 2b).

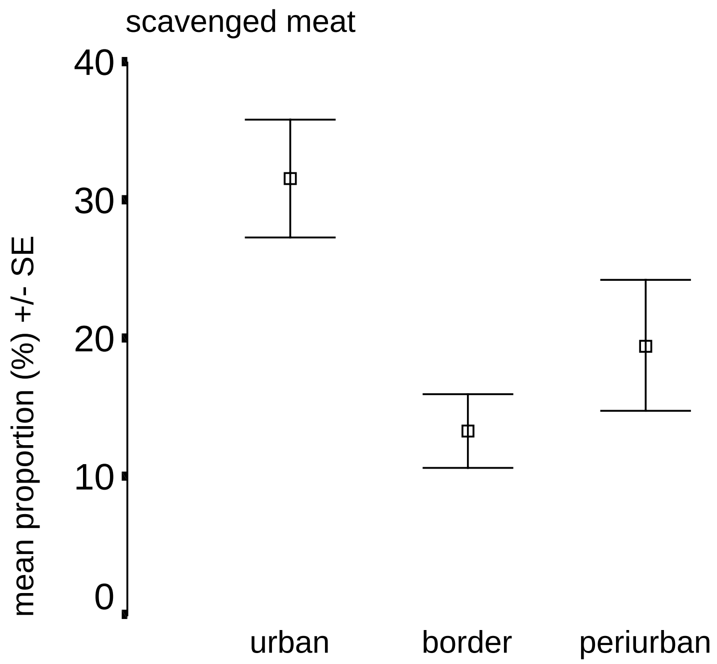


Fig. 3. Zonal variation of mean proportions (%) of scavenged meat in fox stomachs from the city of Zurich, Switzerland. N(urban)=74, N(border)=86, N(periurban)=50. Differences are significant (for details see text).

Tests of all 12 food categories showed that the zonal variation of anthropogenic food was caused by scavenged meat, which was consumed in significantly highest proportions in the urban zone ($F=71.3$, $df=2$, $p<0.001$; Tamhane $p<0.002$ resp $p<0.014$; Fig. 3). Seasonal differences of the proportion of intermediate food were determined by cultivated fruit and crops, which contributed 30% of the summer diet, and significantly less of spring or winter diet ($F=55.8$, $df=2$, $p<0.001$; Tamhane $p<0.004$ resp $p<0.001$; Fig. 4a).

Further seasonal differences were found for invertebrates ($F=33.8$ $df=2$, $p<0.001$) and birds ($F=12$, $df=2$, $p<0.018$). Proportions of invertebrates significantly decreased from summer to winter (Tamhane, $p<0.001$; Fig. 4b), corresponding to the proportions of birds (Tamhane, $p<0.008$; Fig. 4c).

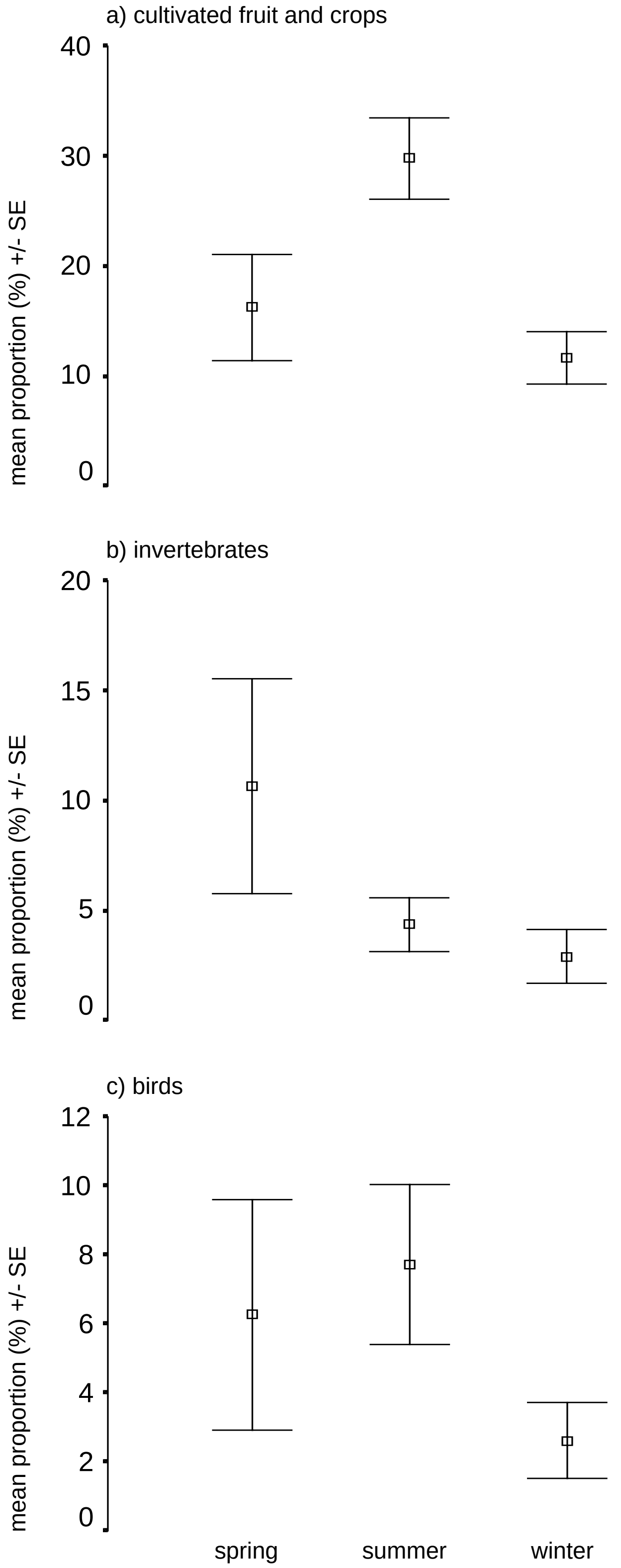


Fig. 4. Seasonal variation of mean proportions of a) cultivated fruit and crops, b) invertebrates and c) birds in fox stomachs from the city of Zurich, Switzerland. N(spring)=29, N(summer)=69, N(winter)=112. Differences are significant (for details see text).

Table 3. Average annual energy supply of anthropogenic food deriving from households, allotment gardens and public areas, which is accessible to foxes in the city of Zurich, Switzerland.

Food categories	Households (MJ/y*household±SE) N=554	Allotment gardens (MJ/y*garden±SE) N=147	Public areas (MJ/y*ha±SE) N=13
Rubbish	145.4 (±8.6)	-	79.1 (±20.2)
Compost	35.9 (±2.9)	11.9 (±2.6)	-
Berries	23.4 (±1.5)	67.6 (±3.4)	-
Windfall	18.3 (±2.1)	14.1 (±2.6)	-
Birdseed	6.7 (±0.9)	11.0 (±2.8)	8.9 (±4.5)
Petfood	1.5 (±0.5)	0.7(±0.4)	-
Food for wild animals	1.8 (±0.4)	0.4 (±0.4)	-
Mean	234.1 (±11.2)	106.8 (±5.7)	87.9 (±20.7)

Availability of anthropogenic food

Households

Of 3000 distributed questionnaires, 573 were returned, 19 were not complete and 554 were considered in our evaluation. Anthropogenic food was provided by 468 households (84.5%). The average annual food supply from a household consisted of 77% of digestible particles in bin liners and on compost heaps (Tab. 3). A further 18% consisted of windfall and berries. The proportion of food put out for birds, other wild animals and pets was 4%.

Bin liners were put on the street border by 248 households (44.8%). The average volume of a rubbish sack was about 35 l. The energy content of included edible items was 0.22±0.08 MJ per litre of rubbish. 78% of 470 bin liners were accessible to foxes during at least one night. In our sample of 1381 exposed bin liners, 1.3% had been damaged by foxes or other scavenging animals.

361 households (65.2%) habitually took compostable kitchen waste to a compost heap. Excluding the solidly covered ones as well as the compost heaps situated in public areas, this food source was available in 155 gardens only (28%). The daily average energy content of composted organic kitchen waste was 0.16±0.04 MJ per person.

Berries were cultivated in 291 private gardens (52.5%), most frequently redcurrants (*Ribes rubrum*), raspberries (*Rubus idaeus*) and blackberries (*Ribes nigrum*).

Table 4. Statistical comparison of the annual anthropogenic food supply of residential buildings, depending on the number of households, which is accessible to foxes in the city of Zurich, Switzerland.

Food categories	1-2 households N=277	3-8 households N=186	9 and more households, N=91	F	p
	(MJ/y±SE)	(MJ/y±SE)	(MJ/y±SE)		
Rubbish	196.2 (±15.3)	666 (±74.7)	788.3 (±156)	24.9	<0.001
Compost	59.4 (±5.7)	107.2 (±17.3)	71.4 (±27.9)	3.7	<0.025
Berries	35.7 (±2.3)	13.3 (±2.2)	10.7 (±3)	31.8	<0.001
Windfall	32.9 (±4.7)	25 (±7.2)	4.9 (±3.7)	4.1	<0.017
Bird seed	8.1 (±1.3)	21.4 (±10.9)	18.2 (±1.6)	1.4	n.s.
Petfood	5.5 (±3.9)	8.1 (±1.1)	17.2 (±1.3)	2.2	n.s.
Food for wild animals	4.8 (±1.4)	13.3 (±3.9)	22.8 (±1.7)	9.5	<0.001
Total supply per house	342.4 (±18.9)	854.3 (±78.6)	933.5 (±156.4)	22.5	<0.001

n.s.=not significant

Windfall was available on 175 private properties (31.6%). The most common fruit species were apples (*Pyrus malus*) and plums (*Prunus* spec.). A majority of householders estimated the proportion of windfall on the total yield to be less than 25%.

Birds were fed in the garden or on the balcony of 242 households (43.7%). Almost all householders restricted feeding birds to winter. Other wild animals were fed by 37 households (6.7%), 29 in the garden and eight elsewhere. The most regularly fed animals were hedgehogs (*Erinaceus europaeus*). Three householders (0.5%) fed foxes. Cats and dogs were fed outside by 46 households (8.3%).

The supply from households of the urban and the border zone did not significantly differ (df=1, F=0.09, p>0.92). However, the number of households per building had a significant influence on the food supply from the interviewed household (df=3, F=6.45, p<0.001), as well as on the summarised supply from the whole building (df=2, F=22.5, p<0.001; Tab. 4). The significantly reduced supply from buildings with one or two households (Scheffé post–hoc test, p<0.001) correlated with their reduced amount of rubbish (Scheffé, p<0.001). On the other hand, these buildings offered significantly more berries than buildings with three or more households (Scheffé, p<0.001) and more windfall than buildings with nine or more households (Scheffé, p<0.017; Tab. 4). Food for wild animals was provided by significantly more buildings with three or more households (Scheffé, p<0.04 resp. p<0.001; Tab. 4).

Allotment gardens

The returned questionnaires concerned 147 plots from 12 different allotment garden areas. Anthropogenic food was available in each plot. Bin liners were collected in skips and therefore not accessible to foxes at all. The mean anthropogenic food supply of allotment gardens was about half of the supply from a household (Tab. 3), and consisted of 63% berries, 13% fruit, 11% compost and 10% birdseed. Food for pets and wild animals was available occasionally only.

All gardeners, except one, cultivated berries. The most common species were the same as in the backgardens. Fruit trees were cultivated by 97 gardeners (66%), among them 10.2% who collected windfall daily and therefore did not supply any fruit, and 73% whose proportion of windfall was less than 25% of the total yield. The most popular fruit species were plums and cherries (*Prunus spec.*), apples (*Pyrus malus*) and apricots (*Prunus armeniaca*). There was a compost heap in almost all allotment gardens, but only 64 (43.5%) of them were accessible to foxes. 34% of the gardeners brought less than 25% of their kitchen waste, 27% between 25 and 75% and 41% more than 75%. Birds were fed in 70 gardens (47.6%). Due to better accessibility, the average annual supply of birdseeds in allotment gardens exceeded the supply from households by 61%. Birdseed was available in winter only. Petfood was accessible to foxes in two gardens. Two gardeners put out food for foxes. One of them fed regularly, with an annual supply of 53.3 MJ. The other person occasionally fed foxes with unspecified quantities.

Public areas

The anthropogenic food supply in public areas consisted of 90% food waste such as bread, apples, remains of fast food and pasta and 10% birdseed. As most of the findings were found on rather concealed places, where there was no daily cleaning, we assumed an average age of three days for these particles. This leads to an average annual food supply in public areas of 87.9±20.7 MJ/ha (Tab. 3).

Table 5. Mean anthropogenic food supply of households, allotment gardens and public areas, and the projection on study area B. This area is situated in the western part of the city of Zurich, Switzerland, and covers 6.8 km².The total includes rubbish in bin liners from households, whereas the conservative estimation excludes it.

		Mean		Study area B		
		Energy supply (MJ/y)	Number of supplied foxes	Number of unities	ΣMJ/y	Number of supplied foxes
Households	*including bin liners*					
	detached houses	272	0.31	1690	$4.6*10^5$	524.7
	buildings >1 household	306	0.35	3641	$11.1*10^5$	1271.9
	excluding bin liners					
	detached houses	87.5	0.09	1690	$1.5*10^5$	168.8
	buildings >1 household	9.1	0.01	3641	$0.3*10^5$	37.8
Allotment gardens		86.6	0.10	833	$0.7*10^5$	82.3
Public areas		81.2	0.09	254	$0.2*10^5$	23.5
Total					$16.7*10^5$	1902.4
Total, conservatively estimated					$2.7*10^5$	312.4

Total anthropogenic food supply in study area B

We estimated that the total annual anthropogenic food supply from all households in study area B could cover the potential demand of 1797±942 foxes, and 207±149 foxes respectively, when neglecting bin liners (Tab. 5).

Accordingly, the total annual food supply of all 833 allotment gardens in study area B could cover the potential demand of 82±13 foxes, and 24±7 foxes in the 254 ha of public areas (Tab. 5). Combining these projections, the annual anthropogenic food supply in study area B corresponded to the potential demand of 1902±942 adult foxes or 141–418 foxes/km². A conservative approach which excluded bin liners leads to a maximum of 312±149 foxes or 24–68 foxes/km².

Discussion

Anthropogenic food resources play an important part in the diet of foxes living in the city of Zurich. Scavenged meat and other scavenge were by far the most frequent food categories consumed in biggest proportions. This generally corresponds to the diet of urban foxes in Britain (HARRIS 1981a; DONCASTER et al. 1990;

SAUNDERS et al. 1993). In contrast to the results of LUCHERINI and CREMA (1994) and FERRARI and WEBER (1995) for mountainous habitats, we did not find an increase of foraging on scavenge in winter, but considerable proportions of scavenge throughout the year. Besides scavenge, cultivated fruit was widely provided in our area. Correspondingly, cultivated fruit and crops were the third staple component in the foxes' diet. According to the seasonal variation in abundance (DONCASTER et al. 1990; FERRARI and WEBER 1995), its exploitation by foxes was characterised by a high seasonality.

The large proportion of consumed anthropogenic food corresponds with its abundance and reflects the specific characteristics of anthropogenic food resources in human settlements, such as low seasonality, high predictability and a favourable cost–benefit ratio. Anthropogenic food, especially rubbish, is abundant throughout the year, and its ease of acquisition is constant, in contrast to many natural food categories, especially living prey (TSUKADA and NONAKA 1996). Due to the lack of limiting seasonal shortage, it should be completely exploitable.

Our results indicate that regular visits of places with anthropgenic food resources as compost heaps, fruit trees or feeding places are an efficient behaviour and can reduce time and energy that a fox has to exert in searching for food, as suggested by LOVARI et al. (1996) for vineyards. This allows a restriction of feeding activity to less disturbed times of day what might facilitates the colonisation of a habitat with high rates of disturbances, as it is the case for urban areas (Gloor 2002). Since foxes are an intensely prosecuted species the capability of avoiding humans has been a strong selective factor. For the exploitation of urban habitats, developing a certain tolerance towards disturbances would be advantageous. People offering food in their gardens for foxes frequently try to get in contact with the animals. Therefore feeding places can contribute to the tolerance of foxes towards humans and enhance behavioural, ontogenetic adaptation of young foxes to disturbances in urban areas.

So far, we have not observed that foxes exploit bin liners regularly or even systematically yet, concurring to BAKER et al. (2000). As an explanation for the foxes restraint towards bin liners lying along the pavements, where human disturbances are frequent, we suggest that the availability of less exposed food was so extensive that the behavioural adaptation, which is likely to be necessary for the exploitation of this probably most 'unnatural' food source, has not been a selective factor yet. This corresponds to TSUKADA and NONAKA (1996), who found that the feeding of foxes on food provisions of tourists did not depend on the availability of such anthropogenic food, but was negatively correlated with the availability of natural food.

In Zurich, many inhabitants are concerned about the high prevalence of the small tapeworm *Echinococcus multilocularis* in the fox population and the high contamination of public areas with its eggs (HOFER et al. 2000; STIEGER et al. 2003), because this parasite can cause human alveolar echinococcosis (ECKERT and DEPLAZES 1999). The awareness of this health risk has probably influenced the people's attitudes towards foxes (BONTADINA 2001). These concerns as well as the success of the official information campaign INFOX could explain, why in Zurich the total average amount of food deliberately supplied to foxes was nine times lower than in Bristol (BAKER et al. 2000). Corresponding to ADKINS and STOTT (1998), we expect that with increasing annoyance about damaged bin liners, new infrastructures for the waste disposal would reduce the accessibility of rubbish. Therefore, the estimation of maximum population density including the current availability of rubbish in bin liners is probably hypothetical.

Natural food still contributed 20% of the foxes diet even in the urban zone, and has therefore to be considered, too. The seasonal variation of invertebrates and birds probably correlated with their abundance, according to Doncaster et al. (1990) and TSUKADA (1997). The presence of areas of rural character, such as cemeteries and parks, has surely simplified the exploitation of city centres, as these rural–like habitats are generally preferred by urban foxes (GLOOR 2002).

Our finding of urban habitats being highly productive considering food resources is supported by many authors (e.g., DONCASTER et al. 1990; SAUNDERS et al. 1993). The abundant availability of food explains the high population density as well as the facts that urban home ranges are much smaller than rural home ranges, and that Zurich's fox families often consisted of more than two adults (GLOOR 2002). According to VON SCHANTZ (1984) and MACDONALD (1983), the breeding pair may share their territory with subordinate adults when food is abundant.

We suppose that the potential of anthropogenic food resources exceeds the needs of the current fox population by far, so that the adaptation to the use of secondary food resources has not been worthwhile yet.

Our most conservative estimation of a possible fox population density (26 adult foxes/km^2) is still far from being reached, as GLOOR (2002) estimated the current density in the area to be 11.5 adult foxes/km^2. However, we have to consider the competition of other animals exploiting anthropogenic food sources in urban habitats, such as cats (CALHOON and HASPEL 1989), stonemartens (TESTER 1986) and badgers (HARRIS 1984). On the other hand, we neglected the potential of natural food resources in our estimates. We expect a further increase of the urban fox population density, especially if further ontogenetic adaptations, learned improvements in handling efficiencies and increased tolerance allow an even more intensive exploitation.

Regarding the availability of anthropogenic food, we suggest that other resources like secure day–time rest sites and breeding places or social intolerance are more likely to have limiting effects on the density of urban fox populations. Concerning the management of fox populations in cities, only drastic changes in the availability of anthropogenic food resources can have regulative effects.

Acknowledgements

The authors would like to thank all collaborators involved in the Integrated Fox Project. We especially thank Christian Stauffer of the Green Department of the city of Zurich for his generous collaboration and for providing access to the data of the game sanctuary of Zurich. We also thank the game wardens Hermann Aerne, Stefan Dräyer, Erwin Nüesch and Bruno Zweifel for collecting the foxes and Sonja Hofer, Ulrich Müller, and Matthias Ulrich for assistance during necropsy at the Swiss rabies centre, Bern. We thank Francesca Cagnacci for introducing the first author in the methods of stomach analysis.

This investigation was carried out within the context of the Integrated Fox Project, a research and communication project on the dynamics of the fox population in Switzerland. The study was supported by the Swiss National Science Foundation (grant no. 31–47031.96), the Swiss Federal Office for Education and Science (EU FAIR Project CT97–3515 / BBW Nr. 97.0586) and the Students Foundation of the University of Zurich.

References

ADKINS, C. A.; STOTT, P. (1998): Home ranges, movements and habitat associations of red foxes *Vulpes vulpes* in suburban Toronto, Ontario, Canada. J. Zool. (London) 244, 335-346.

AEBISCHER, N. J.; ROBERTSON, P. A.; KENWOOD, R. E. (1993): Compositional analysis of habitat use from animal radio-tracking data. Ecology 74, 1313-1325.

BAKER, P. J.; FUNK, S. M.; HARRIS, S.; WHITE, P. C. L. (2000): Flexible spatial organisation of urban foxes, *Vulpes vulpes*, before and during an outbreak of sarcoptic mange. Anim. Behav. 59, 127-146.

BONTADINA, F.; CONTESSE, P.; GLOOR, S. (2001): Wie beeinflusst die persönliche Betroffenheit die Einstellung gegenüber Füchsen in der Stadt? For. Snow Landsc. Res. 76, 255-266.

BREITENMOSER, U; MÜLLER, U.; KAPPELER, A.; ZANONI, R. G. (2000): Die Endphase der Tollwut in der Schweiz. Schweiz. Arch. Tierheilk. 147, 447-453.

CALHOON, R. E.; HASPEL, C. (1989): Urban cat populations compared by season, subhabitat and supplemental feeding. J. Anim. Ecol. 58, 321-328.

CAPT, S.; STALDER, H. W. (1988): Untersuchung zur Habitatnutzung von Rotfüchsen (*Vulpes vulpes* L.) im Schweizerischen Alpenraum. Diss. thesis, University of Bern.

CASE, L. P.; CAREY, D. P.; HIRAKAWA, D. A. (1995): Canine and feline nutrition. A resource for companion animal professionals. St. Louis: Mosby.

CHAUTAN, M.; PONTIER, D.; ARTOIS, M. (2000): Role of rabies in recent demographic changes in Red fox (*Vulpes vulpes*) populations in Europe. Mammalia 64, 391-410.

DAY, M.G. (1966): Identification of hair and feather, remains in the gut and faeces of stoats and weasels. J. Zool. (London) 148, 201-217.

DONCASTER, C.P.; DICKMAN, C.R.; MACDONALD, D.W. (1990): Feeding ecology of red foxes (*Vulpes vulpes*) in the city of Oxford, England. J. Mammalogy 71, 188-194.

ECKERT, J.; DEPLAZES, P. (1999): Alveolar echinococcosis in humans: the current situation in Central Europe and the need for countermeasures. Parasitol. Today 15, 315-319.

ELMADFA, I.; FRITZSCHE, D.; CREMER, H.D. (1987): Die grosse GU Vitamin- und Mineralstofftabelle: Vitamine und Mineralstoffe unserer Lebensmittel; mit Angaben über die Nährstoffdichte; wichtige Sondertabellen für die Praxis. 3. Aufl. München: Gräfe und Unzer.

FERRARI, N.; WEBER, J.-M. (1995). Influence of the abundance of food resources on the feeding habits of the red fox, *Vulpes vulpes*, in western Switzerland. J. Zool. (London) 236, 117-129.

FEUCHT, W. (1982): Das Obstgehölz. Stuttgart: Eugen Ulmer.

GLOOR, S. (2002): The rise of urban foxes (*Vulpes vulpes*) in Switzerland and ecological and parasitological aspects of a population in the recently colonised city of Zurich. Diss. thesis, University of Zurich.

GLOOR, S.; BONTADINA, F.; HEGGLIN, D.; DEPLAZES P.; BREITENMOSER, U.

(2001): The rise of urban fox populations in Switzerland. Mamm. biol. 66, 155-164.

HARRIS, S. (1981a): The food of suburban foxes (*Vulpes vulpes*), with special reference to London. Mammal Rev. 11, 151-168.

HARRIS, S. (1981b): An estimation of the number of the foxes (*Vulpes vulpes*) in the city of Bristol, and some possible factors affecting their distribution. J. Appl. Ecol. 18, 455-465.

HARRIS, S. (1984): Ecology of urban badgers *Meles meles*: distribution in Britain and habitat selection, persecution, food and damage in the city of Bristol. Biol. Conserv. 28, 349-375.

HARRIS, S.; RAYNER, J. M. V. (1986): A discriminant analysis of the current distribution of urban foxes (*Vulpes vulpes*) in Britain. J. Anim. Ecol. 55, 605-611.

HOFER, S.; GLOOR, S.; MÜLLER, U.; MATHIS, A.; HEGGLIN, D.; DEPLAZES, P. (2000): High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zürich, Switzerland. Parasitology 120, 135-142.

KAPPELER, A. (1991): Die orale Immunisierung von Füchsen gegen Tollwut in der Schweiz [Diss. thesis]. University of Bern, Switzerland, 146pp.

LINDSTRÖM, E. (1989): Food limitation and social regulation in a red fox population. Holarct. Ecol. 12, 70-79.

LLOYD, H.G. (1980): The Red Fox. London: B.T. Batsford LTD.

LOVARI, S.; LUCHERINI, M.; CREMA, G. (1996): Individual variations in diet, activity and habitat use of red foxes in a mediterranean rural area. J. Wildl. Res. 1, 24-31.

LUCHERINI, M.; CREMA, G. (1994): Seasonal variation in diet and trophic niche of the Red fox in an Alpine habitat. Z. Säugetierkunde 59, 1-8.

MACDONALD, D. W. (1983): The ecology of carnivore social behaviour. Nature 301, 379-384.

MACDONALD, D. W.; NEWDICK, M. T. (1982): The distribution and ecology of foxes, *Vulpes vulpes* (L.), in urban areas. Urban ecology: Proceedings of the second European ecological symposium. Ed. by R. BORNKAMM and M. R. D. SEEWARD. Oxford: Blackwell Scientific Publications.

NIETHAMMER, J.; KRAPP, F. (1982): Handbuch der Säugetiere Europas. Vol. 1, Nagetiere I and 2/I, Nagetiere II. Wiesbaden: Akademische Verlagsgesellschaft.

NORUSIS, M.J. (1986): SPSS/PC+ advanced statistics. Chicago: SPSS Marketing Department.

REYNOLDS, J. C.; AEBISCHER, N.J. (1991): Comparison and quantification of carnivore diet by faecal analysis: a critique, with recommendations, based on a study of the Fox *Vulpes vulpes*. Mammal Rev. 21, 97-122.

ROPER, T. J.; LÜPS, P. (1994): Diet of badgers (*Meles meles*) in central Switzerland: an analysis of stomach contents. Z. Säugetierkunde 60, 9-19.

SAUNDERS, G.; WHITE, P. C. L.; HARRIS, S.; RAYNER, J. M. V. (1993): Urban foxes (*Vulpes vulpes*): food acquisition, time and energy budgeting of a generalized predator. Symp. Zool. Soc. Lond. 65, 215-234.

SCHOEFFEL, I.; SCHEIN, E. (1991): Zur Parasitenfauna des Rotfuchses in Berlin (West).

Berl. Münch.Tierärztl. Wschr. 104, 153-157.

STAHEL, W. A. (1995): Statistische Datenanalyse. Eine Einführung für Naturwissenschaftler. Braunschweig, Wiesbaden: Vieweg.

STATISTICAL DEPARTMENT OF THE CITY OF ZURICH (1998). Statistisches Jahrbuch der Stadt Zürich 1998.

STIEGER, C.; HEGGLIN, D.; SCHWARZENBACH, G.; MATHIS, A.; DEPLAZES, P. (2003). Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*. Parasitology TEERINK, B. J. (1991): West European Mammals Atlas and Identification Key. Cambridge: Cambridge University Press.

TESTER, U. (1986): Vergleichende Nahrungsuntersuchung beim Steinmarder *Martes foina* (Erxleben, 1777) in grossstädtischem und ländlichem Habitat. Säugetierkundl. Mitt. 33, 37-52.

TSUKADA, H. (1997): Acquisition of food begging behavior by red foxes in the Shiretoko National Park, Hokkaido, Japan. Mammal Study 22, 71-80.

TSUKADA, H.; NONAKA, N. (1996): Foraging behavior of red foxes *Vulpes vulpes schrencki* utilizing human food in the Shiretoko National Park, Hokkaido. Mammal Study 21, 137-151.

VON SCHANTZ, T. (1984): „Non-breeders" in the red fox *Vulpes vulpes*: a case of resource surplus. Oikos 42, 59-65.

WANDELER, A. I. (1976): Altersbestimmung bei Füchsen. Rev. Suisse Zool. 83, 956-963.

WROOT, A. J. (1985): A quantitative method for estimating the amount of earthworms (*Lumbricus terrestris*) in animal diets. Oikos 44, 239-242.

Manuskript C (Parasitology):
High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zurich, Switzerland

Sonja Hofer[1], Sandra Gloor[2,3], Uli Müller[4], Alexander Mathis[1] , Daniel Hegglin[1,2] and Peter Deplazes[1]

[1] Institute of Parasitology, University of Zürich, Winterthurerstrasse 266a, 8057 Zürich. Switzerl.
[2] Work Group Urban Ecology and Wildlife Research, Wuhrstrasse 12, 8003 Zürich, Switzerland.
[3] Zoological Museum, University of Zürich, Winterthurerstrasse 190, 8057 Zürich, Switzerland.
[4] Swiss Rabies Centre, University of Berne, Länggassstrasse 122, 3012 Bern, Switzerland.

Key words: Echinococcosis, Echinococcus multilocularis, Vulpes vulpes, Arvicola terrestris, urban, zoonosis.

Hofer S, Gloor S, Muller U, Mathis A, Hegglin D, Deplazes P. High prevalence of Echinococcus multilocularis in urban red foxes (Vulpes vulpes) and voles (Arvicola terrestris) in the city of Zurich, Switzerland. Parasitology 2000;120:135-142.

Summary

Over a period of 26 months from January 1996 to February 1998, 388 foxes were sampled from the city of Zurich, Switzerland, and examined for intestinal infections with *Echinococcus multilocularis* and other helminths. The prevalence of *E. multilocularis* in foxes sampled during winter increased significantly from 47% in the urban to 67% in the adjacent recreational area, whereas prevalence rates of other helminths were similar in both areas. Seasonal differences in the prevalence of *E. multilocularis* were only found in urban subadult male foxes which were significantly less frequently infected in summer than in winter. The distribution of the *Echinococcus* biomass, as expressed by worm numbers per fox was investigated in 133 infected foxes randomly sampled in winter. Ten of these foxes (8%) were infected with more than 10,000 specimens and carried 72% of the total biomass of *E. multilocularis* (398'653 worms). Prevalences did not differ significantly in these foxes in regard to age and sex but worm burdens were significantly higher in subadult foxes as compared with adult foxes. In voles (*Arvicola terrestris*) trapped in a city park of Zurich, *E. multilocularis*-metacestodes were identified by morphological examination and by PCR. The prevalence was 20% among 60 rodents in 1997 and 9% among 75 rodents in 1998. Protoscolices occurred in two of the cases from 1997. The possible risk for human infection is discussed with respect to the established urban *E. multilocularis* cycle.

Introduction

Human alveolar echinococcosis (AE), caused by larval stages of *Echinococcus multilocularis,* is one of the most lethal helminthic zoonoses (Amman & Eckert, 1995). In Europe, the natural cycle of *E. multilocularis* predominantly involves red foxes (*Vulpes vulpes*) as definitive hosts and several rodents species as intermediate hosts. Domestic dogs and cats have also been identified as definitive hosts, but their significance for zoonotic transmission needs further elucidation (Eckert & Deplazes, 1999).
In recent years, *E. multilocularis* prevalences in foxes of up to 60% have been reported from Central Europe, and this tapeworm was also reported from areas where it had not been described previously (Lucius & Bilger, 1995; Eckert & Deplazes, 1999). Furthermore, increasing fox densities were registered in several European countries (Chautan, Pontier & Artois, 1999) with this population increase being most noticeable in suburban and urban areas.
Although urban and suburban foxes had been a well known phenomenon in the UK since the 1940s (Macdonald & Newdick, 1982; Harris, 1977), it is only in approximately the last 15 years that high fox densities have been reported from cities also on the continent e.g. from Berlin (Schöffel *et al.*, 1991) and from Århus and Copenhagen (Møller Nielsen, 1990; Willingham *et al.*, 1996). In Switzerland, a considerable increase of the fox population was observed over the past ten years (Breitenmoser *et al.*, 1995), and foxes are now commonly seen in urban areas with cubs being bred in public parks and private gardens. The fox population in the city of Zürich is estimated to consist of 300-400 adult animals (Gloor, unpubl. data).
The most important intermediate host species of *E. multilocularis* in Europe are *Microtus arvalis* and *Arvicola terrestris*. Few data are available about parasite prevalences in rodents, but in general they are low (<1%–6%) as compared to those in foxes from the same area (20–60%). However, studies in France and Switzerland indicated that high-endemic areas of rodent *E. multilocularis* infections do exist focally where prevalences of up to 39% were observed (Eckert *et al.*, 2000a).
The epidemiological situation of alveolar echinococcosis in humans in Switzerland was stable over the last 36 years (Eckert & Deplazes, 1999). However, the invasion of urban areas by foxes raised new questions concerning the potential public health risks caused by them with regard to zoonotic parasitic infections. The city of Zurich is surrounded by an endemic area where *E. multilocularis* was detected in 40% of foxes (Ewald *et al.*, 1992). In order to investigate the potential contamination of public areas with *E. multilocularis* eggs and to assess whether an urban cycle of the parasite occurs, a survey of the intestinal helminths in foxes and metacestodes of *E. multilocularis* in voles was conducted in the city of Zurich.

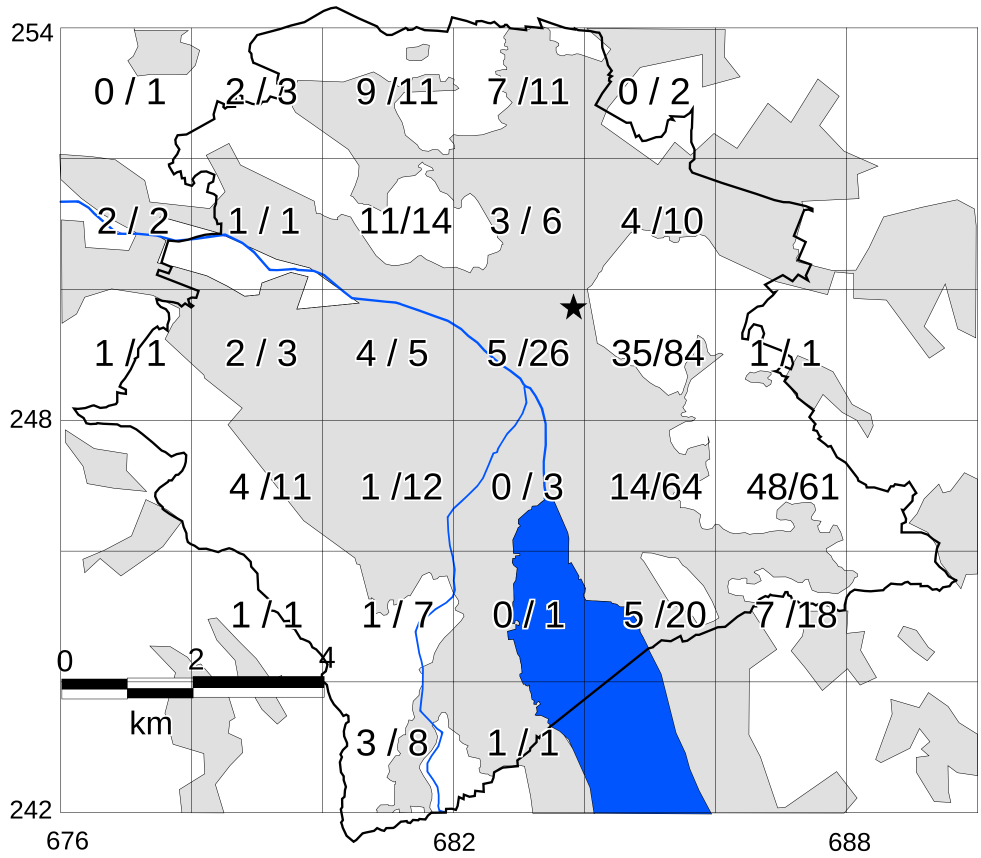


Fig. 1. Distribution of the 388 foxes investigated in the municipality of Zurich. Foxes originating from a grid of 4 km² were taken together (no. of foxes infected with *E. multilocularis* / no. of examined).White: rural area; light grey: urban area; dark grey : lake and rivers; black line: border of municipality; asterisk: Irchelpark (sampling site of *Arvicola terrestris*).

Materials and methods

Study area

The city of Zurich (92 km², 360 000 inhabitants) was divided into an urban and an adjacent rural area consisting mainly of wood, parks, farm land and allotment gardens. By our definition, the urban area extends 250 m from the built-up area into the rural zone (Fig. 1).

Foxes

Sampling. A total of 388 red foxes (*Vulpes vulpes*) were collected by 3 game wardens of the city forest service between January 1996 and February 1998. In 297 cases (76·5%) the foxes were shot in the course of the official local population control programme. Deaths of another 91 foxes (23·5%) resulted from road or rail traffic accidents or from unknown causes. Carcasses were wrapped up in plastic bags and stored at –20°C until necropsy. In winter (November to February) 123 foxes were sampled in the urban area and 129 foxes in the rural area. In the close season (spring, March 1st until June 15th) shooting of foxes was performed with special allowance in the urban area only. Therefore, 39 foxes (19 shot and 20 killed in accidents) were sampled in spring, all originating from the urban area. In summer (July to October) 93 urban and 4 rural foxes were collected.

Parasitological examination. Necropsy and examination of the intestines was carried out following strict safety precautions as described by Deplazes & Eckert (1996) and Eckert *et al.* (2000b) (e.g. separated laboratory, protective clothes, deep-freezing of intestines at –80°C for at least 4 days). Two techniques were performed. The intestinal scraping technique (IST) was done as described by Deplazes & Eckert (1996) using 15 deep mucosal scrapings which were taken from equally distributed sites of the small intestine. The intestinal sedimentation and counting technique (SCT) was performed as described by Rausch, Fay & Williamson (1990) with modifications. Briefly, the small intestine was incised longitudinally and cut into 5 pieces of approximately the same length. These pieces were transferred to a glass bottle containing 1 litre of 0.9% NaCl-solution. After shaking the bottle vigorously for a few seconds, the pieces of intestine were removed and the superficial mucosal layer stripped by means of pressure between thumb and forefinger to dislodge any attached helminths. After a sedimentation time of 15 min the supernatant was decanted and the bottle refilled with physiological saline solution. This procedure was repeated 2–6 times until the supernatant was clear. The sediment fraction was examined in small portions of about 5-10 ml in square Petri dishes (9 x 9 cm, Falcon®, Lincoln Park, NJ, USA) in transmission light under a stereomicroscope at a magnification of 120x. The whole sediment was checked if up to 100 worms were found; if higher numbers were present the total worm burden was calculated from the count of 1 subsample.
The SCT was performed with 310 intestines, of which 170 had previously been examined with the IST. Seventy-eight intestines were examined with the IST only.

Identification of helminths. *E. multilocularis* was identified based on typical morphological characteristics (Thompson, 1995). In cases where only juvenile stages were present, in particular scolices, *E. multilocularis* was confirmed by PCR (Bretagne *et al.*, 1993). The identification of *Taenia* spp. was based on length and shape of rostellar hooks (Verster, 1969). Specimens lacking hooks but with typical *Taenia* proglottids bearing taeniid eggs were recorded as *Taenia* sp.

Age determination of foxes. In line with the study of Wandeler (1976), cubs were assumed to be born on 1 April. Age determination of foxes collected after 1 July was done by measuring the relative width of the pulpar cavity of a lower canine tooth by X-rays (Kappeler, 1985), allowing to discriminate adults (older than 12 months) from subadults. In addition the age of 93 adult foxes randomly collected in winter was determined by counting annual incremental lines in tooth cementum (Grue & Jensen, 1979).

Rodents

From October to December 1997 and from July to October 1998, 60 and 75, respectively, Arvicola terrestris were trapped with tong traps in an urban public park („Irchelpark“) in the city of Zurich (Fig. 1). At necropsy, the liver in particular was examined for lesions. Metacestodes of *E. multilocularis* were identified directly on squashed metacestode material using the immunofluorescent labelled monoclonal antibody G 11 (Deplazes & Gottstein, 1991) and by histological identification of typical structures in HE-and PAS-stain. Specimens giving doubtful results were confirmed by PCR (Bretagne et al., 1993) after proteinase K digestion of the cut-up material. Species determination of metacestodes of other cestodes was evaluated by gross morphology and by comparing hook morphology and length.

Statistics

Calculation of 95% confidence intervals (CI) was performed as described by Lorenz (1988). Prevalence differences were compared by the χ^2 test and differences in infection intensity were compared by the Mann-Whitney U-test. Differences were considered significant at $P < 0{\cdot}05$.

Table 1. Small intestinal helminths discovered in 388 foxes collected from January 1996 to February 1998 in the city of Zurich (rural and urban area).

	No. of infected foxes	P (%)	CI (%)
Echinococcus multilocularis	172	44·3	39·3 – 49·4
Taenia spp.*	64	16·7	13·0 – 20·7
Mesocestoides sp.**	17	4·4	2·7 – 7·1
Dipylidium sp.**	2	0·5	0·1 – 2·1
Uncinaria stenocephala	259	66·8	61·8 – 71·4
Toxocara canis	184	47·4	42·4 – 52·5
Alaria sp.**	8	2·1	1·0 – 4·2

* *Taenia crassiceps*: 7·6%; *T. polyacantha*: 0·5%; *Taenia* sp.: 8·4%.

** No further species differentiation performed.

P, Prevalence; CI, Upper and lower 95% confidence interval.

Results

Helminths recovered

A total of 344 of the 388 foxes examined (88·7%) carried intestinal helminths (Table 1). The highest prevalence (66·8%) was recorded for Uncinaria stenocephala followed by Toxocara canis (47·4%) and *E. multilocularis* (44·3%). In 64 foxes (16·5%) infections with Taenia spp. were recorded but in approximately half of the cases the species could not be determined due to inappropriate conservation of the worms. T. crassiceps and T. polyacantha were found in 7·6% and 0·5% of the foxes, respectively.

E. multilocularis infections

Comparison of 2 parasitological methods. In 170 cases small intestines were investigated with both the intestinal scraping technique (IST) and the intestinal sedimentation and counting technique (SCT). *E. multilocularis* infections were detected in 87 cases (51·2%) with the SCT and in 68 cases (40·0%) with the IST. The sensitivity of the IST was 78% as compared with the results obtained with the SCT. None of the foxes diagnosed negative by the SCT turned out positive with the IST. In 12 of the 19 cases detected with the SCT only, less than 10 and in 5 cases 10-100 worms per fox were recovered. In 2 remaining cases, infections with juvenile

Table 2. Seasonal differences in the prevalences of *Echinococcus multilocularis* in urban and rural foxes collected from January 1996 to February 1998 in the city of Zurich.
(Statistical comparisons were done (a) between age and sex groups, (b) between rural and urban foxes in winter (c) between urban foxes in winter and summer. Statistically significant differences are indicated with a letter.)

Season	Foxes	Urban foxes No. investigated / No. infected*	Rural foxes No. investigated / No. infected*
Winter (Nov.–Feb.)	adult females	39 / 16 (41%)	34 / 21 (62%)
	subadult** females	22 / 8 (36%)	20 / 14 (70%)
	adult males	29 / 13 (45%)	33 / 19 (58%)
	subadult males	39 / 24 (62%)^{d}	36 / 28 (78%)
	Total	129 / 61 (47.3%)^{a}	123 / 82 (66.7%)^{b}
Summer (July–Oct.)	adult females	22 / 5 (23%)	1 / 1 (n.a.)
	subadult females	31 / 5 (16%)	1 / 1 (n.a.)
	adult males	12 / 4 (33%)	1 / 1 (n.a.)
	subadult males	28 / 5 (18%)^{e}	1 / 0 (n.a.)
	Total	93 / 19 (20.4%)^{c}	4 / 3 (n.a.)

* Chi-squared test: $^{a\,b}$ $P < 0{\cdot}01$; $^{a\,c}$ $P < 0{\cdot}0001$; $^{d\,e}$ $P < 0{\cdot}001$.
** Less than 12 months of age.
n.a.=not applicable

E. multilocularis stages were detected and confirmed by PCR (worm numbers of 432 and 11 640, respectively).
Prevalences in urban and rural foxes. Sampled foxes were not distributed homogeneously within the study area (Fig. 1). Statistical comparison of rural and urban foxes could be performed with animals originating from winter (November to February) only. The *E. multilocularis* prevalences in urban foxes (47·3%) and rural (66·7%) were significantly different as assessed by the χ^2 test (P < 0·01) (Table 2). On the other hand, the prevalences of infections with the other helminths investigated did not differ significantly among these 2 fox populations (P > 0·1, χ^2 test; data not shown).
Relation to fox sex and age. Within both areas investigated no significant differences in the prevalences of *E. multilocularis* were found related to sex or to the age groups „subadult“ and „adult“ (Table 2). Furthermore, no significant differences in the *E. multilocularis* prevalences were found between subadult and 93 adult foxes whose age was determined more precisely. Hence, the prevalence was 63% in 117

Table 3. Biomass of *Echinococcus multilocularis* (E. m.) expressed as percentage of the total worm numbers (398,653 worms) in 133 infected foxes collected in the city of Zurich in winter (November to February) in relation to sex and age.

	No. of infected foxes	E. m. biomass (%)	Median no. of E. m. specimens	∅ Worm number per fox	Worm number range	Mann-Whitney *U*-Test*
Female adult foxes	36	10%	60	1 050	1 – 19,344	n.s.
Female subadult foxes	20	22%	119.5	4 334	1 – 27,030	
Total female foxes	56	32%	56	2 223	1 – 27,030	
Male adult foxes	29	5%	120	730	1 – 5,720	n.s.
Male subadult foxes	48	63%	162.5	5 271	1 – 56,970	
Total male foxes	77	68%	150	3 561	1 – 56,970	
Total adult foxes	65	15%	63	907	1 – 19,344	$P<0.05$
Total subadult foxes	68	85%	147	4 995	1 – 56,970	
Total foxes	133	100%	108	2 997	1 – 56,970	

* Significance of differences in the worm numbers

n.s. not significant

subadult foxes, 58% in 62 foxes aged 12-35 months, and 48% in 31 animals aged 36-70 months (P > 0·1, χ^2 test; data not shown).

Annual and seasonal differences. Prevalences in rural and urban foxes sampled during 2 subsequent winters showed no significant differences within both habitats (P > 0·1, χ^2 test; data not shown). Seasonal variations in the prevalence of *E. multilocularis* were investigated in the urban area only. Urban foxes collected in winter were significantly more frequently infected (47·3%) than those from summer (20·4%) (P < 0·0001; χ^2 test) (Table 2). Interestingly, this significant difference was found in subadult male foxes only (P < 0·001; χ^2 test). Statistical analyses of 19 cubs (5% infected with *E. multilocularis*) and 20 adult foxes (30% infected with *E. multilocularis*) collected in spring revealed no significant differences considering age and sex (P > 0·05; χ^2 test; data not shown). This small group of animals was not used for further comparative analyses.

Distribution of the *E. multilocularis* biomass. The total Echinococcus biomass in 57 urban and 76 rural infected foxes randomly sampled during 2 winters was 398 653 *E. multilocularis* specimens. No significant difference in the worm burden was

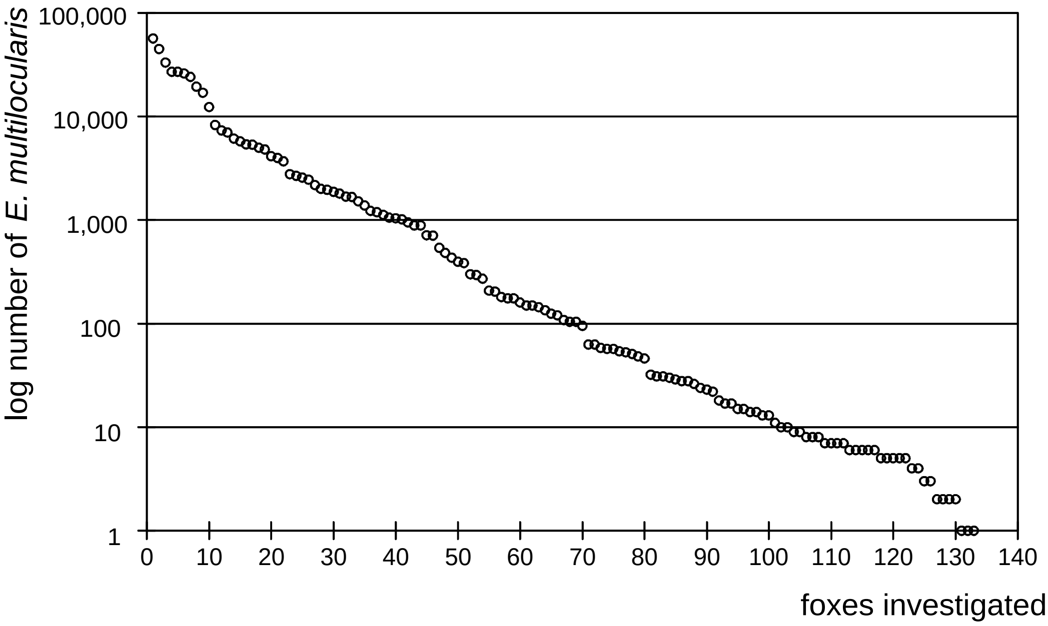


Fig. 2. Distribution of *Echinococcus multilocularis* biomass in 133 infected foxes (total worm burden 398,653) sampled in the city of Zurich (rural and urban area) in winter (November to February).

found between these urban foxes, carrying 42%, and rural foxes, carrying 58% of the total biomass, respectively (P > 0·1, Mann-Whitney U-test). Therefore, further quantitative evaluations of the worm burden in foxes of both areas were not independently analysed. Figure 2 shows the distribution of the biomass of *E. multilocularis* in the foxes investigated. In 92 (69%) of the foxes infections with less than 1000 *E. multilocularis* worms were found representing 3% of the total biomass. Infections with more than 1000 worms occurred in 41 foxes (31%) carrying 97% of the total biomass. As few as 10 foxes (8%) which were infected with more than 10 000 specimens harboured 72% of the total biomass of *E. multilocularis*. The two heaviest infections (56 970 and 45 020 worms; 26% of the biomass) were detected in 2 subadult male foxes collected in February in the urban area. The worm burden revealed no significant differences related to sex but subadult infected foxes carried significantly higher worm burdens than adults (Table 3). Furthermore, the median number of *E. multilocularis* worms was more than twice as high in subadult as compared with adult foxes.

Prevalence of metacestode infections in *Arvicola terrestris*

Metacestodes of *E. multilocularis* were found in 19 (14%) of 135 *A. terrestris* trapped in the Irchelpark in the city of Zurich (Fig. 1). The prevalence was 20% in

60 animals examined in 1997 and 9% in 75 animals examined in 1998. Protoscoleces occurred in 2 *A. terrestris* from 1997 only. In 27 animals (20%) an infection with the metacestodes of T. taeniaeformis (*Strobilocercus fasciolaris*) was found. Metacestodes of T. crassiceps were detected on 2 occasions in subcutaneous cysts and once in the pleural cavity.

Discussion

The prevalence of 67% in foxes from recreational areas in the city of Zurich is comparable to the prevalences found in a previous study from adjacent rural areas (Ewald et al., 1992). Also, a high percentage of the urban dwelling foxes in the city of Zürich was infected with *E. multilocularis* (prevalence 47%). This decline in the *E. multilocularis* prevalences from the recreational to the urban area is significant and may be caused by a lower predation on rodents by urban foxes. Indeed, stomach content analyses of 229 foxes investigated in this study revealed a lower number of rodent items in the stomachs of urban foxes as compared with those from rural areas (Gloor, unpublished data).
The prevalence of Taenia spp., however, which also are dependant on rodents as intermediate hosts did not differ significantly between these 2 fox populations most probably reflecting the higher biotic potential of Taeniid-species as compared with Echinococcus.
Schelling et al. (1991) found significantly higher prevalences of *E. multilocularis* in foxes (age not determined) collected in winter than in those collected in summer. This overall difference could also be observed in our study in urban foxes but closer examination revealed that only young urban male foxes contributed to this fact. This might be explained by the findings of Tackmann and colleagues (1998) that the diet of young foxes contains a lower proportion of rodents in June and July when they become less dependent on adults.
The influence of the foxes' age on the prevalence of *E. multilocularis*, however, is not yet fully understood. Juvenile foxes were found to be significantly more frequently infected than adults (Ewald, 1993; Vos & Schneider, 1994) whereas in other studies no significant age dependent differences were detected (for references see Tackmann et al., 1998). Interestingly, young foxes were significantly more frequently infected with *E. multilocularis* than adults under high-endemic conditions, whereas under low-endemic conditions adult foxes tended to be more frequently infected (Tackmann et al., 1998).
However, in our study which was conducted in a high-endemic area, the prevalence rates of subadult and adult foxes collected in winter did not differ significantly as determined with the highly sensitive intestinal sedimentation and counting technique which even allows detection with very low worm numbers. On the other

hand, subadult foxes carried significantly higher worm burdens than adult foxes. This might be an indication for the acquisition of a partial immunity after repeated infections as had been shown in dogs experimentally infected with E. granulosus (Gemmell, Lawson & Roberts, 1986). erlauben

The high variation in the worm burdens of the individual foxes indicates that the parameter “prevalence” might not be the most adequate one to characterize the epidemiological situation of *E. multilocularis*. A few highly infected foxes carrying thousands of fertile *E. multilocularis* worms can be responsible for most of the egg contamination in a distinct area. A similar distribution of parasites has been observed in dingoes infected with E. granulosus in south-eastern Australia (Jenkins & Morris, 1991). Furthermore, subadult male foxes which carried the major part of the *E. multilocularis* biomass in our study could have a special role for spreading the parasite in the environment because they usually migrate further away than the age-matched females (Storm, 1976).

The spectrum of the rodent fauna in the study area is not yet investigated. When analysing the stomachs of the foxes, the water vole Arvicola terrestris was the most frequently found potential intermediate host besides others that also were present (Microtus arvalis, Clethrionomys glareolus and Mus domesticus; Gloor, unpublished data). According to many authors (reviewed by Weber & Aubrey, 1993) predation of foxes on *A. terrestris* occurs, but is generally considered to be light. However, Weber & Aubrey (1993) found, that *A. terrestris*, when highly abundant, was the most frequent prey of foxes in a rural area of western Switzerland. Furthermore, in an endemic alveolar echinococcosis area in France, *A. terrestris* was the most abundant and the only infected rodent species (Laforge et al., 1992).

Low prevalences below 1% were found in geographically extensive studies (Eckert et al., 2000a) but *E. multilocularis* infections are not randomly distributed in *A. terrestris* populations in endemic areas. High-endemic foci were described with prevalences in *A. terrestris* up to 39% (Pétavy & Deblock, 1983; Gottstein et al., 1996). Furthermore, seasonal differences were observed in France where the highest prevalence of 17·6% was found in January (74 animals examined), while no infections were found in October (167 animals examined) (Pétavy & Deblock, 1983). Contrary to the previously mentioned study we found high prevalences in late summer and autumn when the vole density was high with the prevalence rates being highest in October 1997 (one third of the 30 animals examined infected). Therefore, we suspect that even higher prevalences could be higher in the park investigated at an earlier time of the year with more animals harbouring metacestodes that contain protoscolices.

The discovery of *E. multilocularis* infections in urban foxes and *A. terrestris* originating from a high-endemic focus in a public park provides evidence for the existence of a parasite cycle within the urban area. Furthermore, a synanthropic cycle including rodent-catching domestic carnivores, as described in a village in France (Pétavy, Deblock & Walbaum, 1991), seems to be possible in the area investigated. We detected urban *A. terrestris* that were infected with metacestodes of *T. taeniaeformis*, a cestode that is common in domestic cats, but was not found in our study in foxes. This indicates that an infection cycle between domestic cats and wild rodents indeed does exist. Although experimental studies with cats had shown that development of *E. multilocularis* was retarded and lower worm burden were found as compared to dogs which were highly susceptible (Thompson & Eckert, 1983), cat ownership was identified as a risk factor for alveolar echinococcosis (AE) in a recently published retrospective case-control study of patients in Austria (Kreidl *et al.*, 1998). Low prevalences of *E. multilocularis* of 0·3% and 0·4%, respectively, were found in Switzerland (Deplazes *et al.*, 1999) when investigating 660 randomly selected dogs and 263 cats, but higher prevalences of up to 12% have been reported in farm dogs with free access to rodents (Gottstein *et al.*, 1997). Considering the high number of domestic dogs and cats in Central Europe the urbanisation of the *E. multilocularis* cycle could increase the infection risk for domestic carnivores and consequently also for humans.

E. multilocularis-infected foxes in urban areas pose novel epidemiological and infectiological questions. Recreational areas (e.g. public parks and outdoor swimming pool areas) within or adjacent to the city are frequently and intensively used by city-dwellers. However, it is not proven that an increased infection pressure results in a higher number of AE cases in humans. At present we have no evidence of an increase in the incidence of human AE in the study area. A major difficulty to unravel such epidemiological relations is the long incubation period (5-15 years) of AE (Amman & Eckert, 1995).

Acknowledgements

The authors thank all collaborators involved in the Integrated Fox Project (IFP, an interdisciplinary study on the dynamics of the fox population in Switzerland), especially Fabio Bontadina, Urs Breitenmoser, Johannes Eckert, Therese Hotz and Christian Stauffer for their conceptual help or skilled technical assistance. We also thank the game wardens Hermann Aerne, Stefan Dräyer and Bruno Zweifel for collecting the foxes and Matthias Ulrich (Swiss Rabies Centre, Bern) for expert age determination of the foxes. This work was supported by the Swiss National Foundation for Scientific Research (grant no.: 31-47'031.96).

References

AMMAN, R. & ECKERT, J. (1995). Clinical diagnosis and treatment of echinococcosis in humans. In *Echinococcus and Hydatid Disease* (ed. Thompson, R. C. A. & Lymbery, A. J.), pp. 411-463. CAB International, Wallingford.

BREITENMOSER, U., KAPHEGYI, T., KAPPELER, A. & ZANONI, R. (1995). Significance of young foxes for the persistence of rabies in Northwestern Switzerland. In *Proceedings of the 3rd Congress of the European Society of Veterinary Virology : Immunbiology of viral infections, 1995* (ed. Schwyzer, M., Ackermann, M., Bertoni, G., Kocherhans, R., McCullough, K., Wittek, R. & Zanoni, R.), pp. 391-396.

BRETAGNE, S., GUILLOU, J. P., MORAND, M. & HOUIN, R. (1993). Detection of *Echinococcus multilocularis* DNA in fox faeces using DNA amplification. *Parasitology* 106, 193-199.

CHAUTAN, M., PONTIER, D. & ARTOIS, M. (2000). Role of rabies in a recent demographic chances in red fox (*Vulpes vulpes*) populations in western Europe. Mammalia, 64(4), 391-410.

DEPLAZES, P. & ECKERT, J. (1996). Diagnosis of the *Echinococcus multilocularis* infection in final hosts. *Applied Parasitology* 37, 245-252.

DEPLAZES, P. & GOTTSTEIN, B. (1991). A monoclonal antibody against *E. multilocularis* Em2-antigen. *Parasitology* 103. 41-49.

DEPLAZES, P., ALTHER, P., TANNER, I., THOMPSON, R. C. A. & ECKERT, J. (1999). *Echinococcus multilocularis* coproantigen detection by enzyme-linked immunosorbent assay in fox, dog and cat populations. *Journal of Parasitology* 85, 115-121.

ECKERT, J. & DEPLAZES, P. (1999). Alveolar echinococcosis in humans: the current situation in central Europe and need for countermeasures. *Parasitology Today (in press).*

ECKERT, J., RAUSCH, R. L., GEMMELL, M. A., GIRAUDOUX, P., KAMIYA, M., LIU, F. J., SCHANTZ, P. M. & ROMIG, T. (2000a). Epidemiology of *Echinococcus multilocularis*, *Echinococcus vogeli*, and *Echinococcus oligarthrus*. *WHO: Manual on Echinococcosis in humans and animals* (in press).

ECKERT, J., DEPLAZES, P., CRAIG, P. S., GEMMELL, M. A., GOTTSTEIN, B., HEATH, D., JENKINS, D. & KAMIYA, M. (2000b). Echinococcosis in animals: Clinical aspects, diagnosis and treatment. *WHO: Manual on Echinococcosis in humans and animals* (in press).

EWALD, D. (1993). Prävalenz von *Echinococcus multilocularis* bei Rotfüchsen (*Vulpes vulpes* L.) in der Nord-, Ost- und Südschweiz sowie im Fürstentum Liechtenstein. Ph.D. thesis, Universität Zürich.

EWALD, D., ECKERT, J., GOTTSTEIN, B., STRAUB, M. & NIGG, H. (1992). Parasitological and serological studies of *Echinococcus multilocularis* Leuckart, 1863 in red foxes (*Vulpes vulpes* Linnaeus, 1758) in Switzerland. *Revue Scientifique et Technique* 11, 1057-1061.

GEMMELL, M. A., LAWSON, J. R. & ROBERTS, M. G. (1986). Population dynamics in echinococcosis and cysticercosis, biological parameters of *Echinococcus granulosus* in dogs and sheep. *Parasitology* 92, 599-620.

GOTTSTEIN, B., SAUCY, F., WYSS, C., SIEGENTHALER, M., JACQUIER, P., SCHMITT, M., BROSSARD, M. & DEMIERRE, G. (1996). Investigations on a Swiss area highly endemic for *Echinococcus multilocularis. Applied Parasitology* 37, 129-136.

GOTTSTEIN, B., SAUCY, F., DEPLAZES, P., TEUSCHER, F., DEMIERRE, G. & DUCROT, H. (1997). Risk assessment of infection with *Echinococcus multilocularis* in a highly endemic focus of Switzerland. *Schweizerische Medizinische Wochenschrift* 39, 1629.

GRUE, J. & JENSEN, B. (1979). Review of the formation of incremental lines in tooth cementum of terrestrial mammals. Danish Review of Game Biology 11, 1-48.

HARRIS, S. (1977): Distribution, habitat utilization and age structure of a suburban fox (*Vulpes vulpes*) population. Mammal Rev., Vol. 7, No. 1, 25-39.

JENKINS, D. J. & MORRIS , B (1991). Unusually heavy infections of Echinococcus granulosus in wild dogs in south-eastern Australia. Australian Veterinary Journal 68, 36-37.

KAPPELER, A. (1985). Untersuchungen zur Altersbestimmung und zur Altersstruktur verschiedener Stichproben aus Rotfuchs-Populationen (*Vulpes vulpes* L.) in der Schweiz. Lizentiatsarbeit, Institute of Zoology, University of Berne.

KREIDL, P., ALLERBERGER, F., JUDMAIER, G., AUER, H., ASPÖCK, H. & HALL, A. J. (1998). Domestic pets as risk factors for Alveolar Hydatid disease in Austria. *American Journal of Epidemiology* 147, 978-981.

LAFORGE, M. L., GILOT, B., DOCHE, B., DEBLOCK, S. & PETAVY, A. F. (1992). Urbanisation et populations de microtides dans le foyer Haut-Savoyard d'echinococcose alvéolaire (Alpes françaises du Nord): l'exemple de La-Roche-sur-Foron. *Revue Suisse de Zoologie* 99, 377-394.

LORENZ, R. J. (1988). *Grundbegriffe der Biometrie.* 2nd edn. Gustav Fischer Verlag, Stuttgart.

LUCIUS, R. & BILGER, B. (1995). *Echinococcus multilocularis* in Germany: Increased awareness or spreading of a parasite? *Parasitology Today* 11, 430-434.

MACDONALD, D. W. & NEWDICK, M. T. (1982). The distribution and ecology of foxes, *Vulpes vulpes* (L.), in urban areas. In *Proceedings of the 2nd European ecological symposium* : *Urban Ecology*, *1982* (ed. Bornkamm, R., Lee, J. A. & Seeward, M. R.), pp. 123-135. Blackwell Scientific Publications, Oxford.

PÉTAVY, A. F. & DEBLOCK, S. (1983). Connaissance du foyer auvergnat d'échinococcose alvéolaire. *Annales de parasitologie humaine et comparée* 58, 439-453.

PÉTAVY, A. F., DEBLOCK, S. & WALBAUM, S. (1991). Life cycles of *Echinococcus multilocularis* in relation to human infection. *Journal of Parasitology* 77, 133-137.

RAUSCH, R. L., FAY, F. H. & WILLIAMSON, F. S. L. (1990). The ecology of *Echinococcus multilocularis* (Cestoda: Taeniidae) on St. Lawrence Island, Alaska. II. – Helminth populations in the definitive host. *Annales de parasitologie humaine et* *comparée* 65, 131-140.

SCHELLING, U., SCHÄFER, E., PFISTER, T. & FRANK, W. (1991). Zur Epidemiologie des *E. multilocularis* im nordöstlichen Baden-Württemberg. *Tierärtliche Umschau* 46, 673-676.

SCHÖFFEL, I., SCHEIN, E., WITTSTADT, U. & HENTSCHE, J. (1991). Zur Parasitenfauna des Rotfuchses in Berlin (West). *Berliner und Münchener Tierärztliche Wochenschrift* 104, 153-157.

STORM, G. L., ANDREWS, R. D., PHILIPS, R. A., SINIFF, D. B. & TESTER, J. R. (1976). Morphology, reproduction, dispersal and mortality of mid-western red fox populations. *Wildlife Monographs*, 49, 1-82.

TACKMANN, K., LÖSCHNER, U., MIX, H., STAUBACH, C., THULKE, H.-H. & CONRATHS, F. J. (1998). Spatial distribution patterns of *Echinococcus multilocularis* (Leuckart 1863) (Cestoda: Cyclophyllidea: Taeniidae) among red foxes in an endemic focus in Brandenburg, Germany. *Epidemiology and Infection* 120, 101-109.

THOMPSON, R. C. A. & ECKERT, J. (1983). Observations on *Echinococcus multilocularis* in the definitive host. *Zeitschrift für Parasitenkunde* 69, 335-345.

VERSTER, A. (1969). A taxonomic revision of the genus *Taenia* Linnaeus, 1758 *S. STR.*. *Onderstepoort Journal of Veterinary Research, Pretoria* 36, 3-58.

VOS, A. & SCHNEIDER, L. (1994). *E. multilocularis*-Befall beim Rotfuchs (*Vulpes vulpes*) im Landkreis Garmisch-Partenkirchen. *Tierärztliche Umschau* 4, 225-232.

WANDELER, A. I. (1976). Altersbestimmung bei Füchsen. *Revue Suisse de Zoologie* 83, 956-963.

WEBER, J.-M. & AUBRY, S. (1993). Predation by foxes, *Vulpes vulpes*, on the fossorial form of the water vole, *Arvicola terrestris scherman*, in western Switzerland. *Journal of Zoology (London)* 229, 553-559.

WILLINGHAM, A. L., OCKENS, N. W., KAPEL, C. M. O. & MONRAD, J. (1996). A helminthological survey of wild red foxes (*Vulpes vulpes*) from the metropolitan area of Copenhagen. *Journal of Helminthology* 70, 259-263.

Manuskript D (Parasitology):
Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*

Claudia Stieger[1], Daniel Hegglin[1,2], Gioia Schwarzenbach[2], Alexander Mathis[1] and Peter Deplazes[1]

[1] Institute of Parasitology, University of Zurich, Switzerland
[2] Zoological Museum, University of Zurich, Switzerland

Key words: *Echinococcus multilocularis*, diagnosis, fox, rodents, urban area, infection pressure.

Stieger C, Hegglin D, Schwarzenbach S, Mathis A, Deplazes P. Spatial and temporal aspects of urban transmission of Echinococcus multilocularis. Parasitology 2002;124:631-640.

Abstract

High prevalences of *Echinococcus multilocularis* have been reported from foxes of the city of Zurich, Switzerland. In order to characterise transmission in urban areas, a coproantigen ELISA was evaluated for diagnosing the infection in fox faecal samples collected in the environment. In addition, trapped rodents were investigated for the presence of metacestodes. Faecal samples could reliably be classified as being of fox origin by assessing physical properties as shown by the different parasite spectra of putative fox and dog faecal specimens. From the total of 604 tested putative fox faecal samples 156 (25.8%) were positive in the ELISA with a distinct increase in the proportion of positive samples from the urban to the periurban zone. Furthermore, samples collected in the border zone had significantly more coproantigen-positive results during winter. Prevalence of *E. multilocularis* in rodents was 9.1 % (81/889) for *Arvicola terrestris* (with 3.5% of the animals harbouring between 14 and 244400 protoscoleces) and 2.4% (2/83) for *Clethrionomys glareolus*. *E. multilocularis*-infected *A. terrestris* were found in 9 of 10 trapping sites in the border zone. The high infection pressure in the periphery of urban areas might pose a risk for infection with *E. multilocularis* for both domestic carnivores as well as for urban inhabitants. Interventions into the cycle aiming at reducing the infection pressure should therefore focus on these areas.

Introduction

Alveolar echinococcocosis (AE) in humans is caused by the metacestode stage of the fox tapeworm, *Echinococcus multilocularis*, which grows in a tumour–like manner, predominantly in the liver. This helminthic zoonosis of the northern hemisphere is mostly a lethal infection if left untreated (Amman & Eckert, 1996).

In central Europe the sylvatic cycle of *E. multilocularis* is perpetuated by red foxes (*Vulpes vulpes*) as definitive hosts and voles (particularly *Arvicolidae*) as intermediate hosts (Eckert *et al*., 2001a). In endemic areas, prevalences of *E. multilocularis* in fox populations may reach over 60 % (Eckert & Deplazes, 1999; Romig *et al*., 1999; Eckert *et al*., 2001a). Although foxes harbour the main parasite burden, domestic dogs and cats can be infected with intestinal stages but prevalences are generally low (Deplazes *et al*., 1999; Eckert & Deplazes, 1999). Relatively little is known about prevalences of *E. multilocularis* in *Arvicolidae*, the most suitable intermediate hosts, but they are low (1–6 %) compared with those of foxes (Houin *et al*., 1982; Pétavy & Deblock, 1983; Bonnin *et al*., 1986; Eckert *et al*., 2001a). However, high prevalences (10–39 %) have been found focally indicating the presence of so–called “hot spots” in rural (Gottstein *et al*., 2001) but also in urban environments (Hofer *et al*., 2000).

In spite of high prevalences of *E. multilocularis* in foxes in Europe, the annual incidence rates of human infections (0.02–1.4/100000 inhabitants) are low (Eckert & Deplazes, 1999; Romig *et al*., 1999). The significance of different ways of infection and infection risks still is unclear. It was suggested that there is a higher infection risk in rural areas, and a considerable part of patients with AE in Austria (50 %; Auer & Aspöck, 1991) and France (34 %; Vuitton *et al*., 1990) reported farming activities. In Switzerland, the incidence rates of human AE did not change greatly between 1956–1992 despite considerable fluctuations in the fox populations due to the occurrence of rabies and its control (Eckert & Deplazes, 1999). Whether domestic dogs and cats play a role in the transmission of *E. multilocularis* in central Europe needs further clarification (Deplazes & Eckert, 2001; Pétavy *et al*., 2000). Gottstein *et al*. (2001) recently reported that the prevalence of human AE in a Swiss rural area with extraordinary high prevalences, not only in foxes and voles but also in dogs and cats, was not higher than in the average national population.

Since the early 1990s a marked increase of fox densities was reported from several European countries (Artois, 1997). Coincidentally, suburban and urban areas were invaded by fox populations (Gloor *et al*., 2001) a phenomenon well known in Great Britain since the 1930s (Harris & Rayner, 1986). In Switzerland, fox breeding dens were reported in 20 of the 30 largest cities (Gloor *et al*., 2001). The urban fox population in the city of Zurich is currently estimated to consist of approximately 500 animals with densities of up to 10 adult foxes/km^2 (Deplazes *et al*., 2002). Only

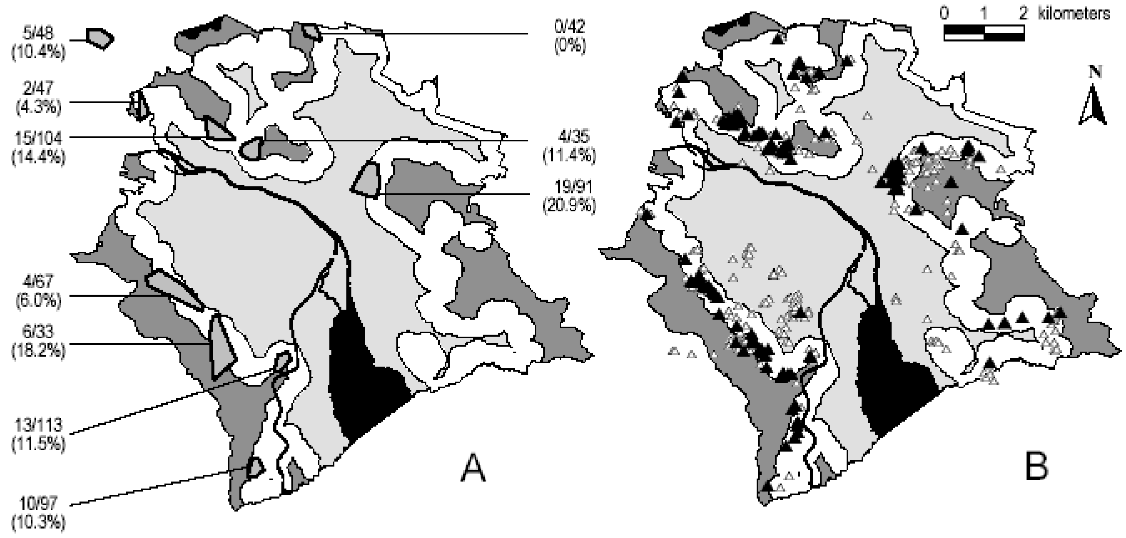


Fig. 1. Spatial distribution of trapped *Arvicola terrestris* and sampled fox faeces in the city of Zurich, Switzerland. (A) Polygons of trapping sites with more than 30 trapped *A. terrestris*, number of infected and number of trapped animals per trapping site (prevalence of *Echinococcus multilocularis* in parentheses); (B) 156 coproantigen positive fox faeces (black triangles) and 448 coproantigen negative fox faeces (white triangles). Black: lakes and rivers; light grey: urban zone (34 km^2); white: border zone (36 km^2); dark grey: periurban zone (17 km^2).

recently we have described the existence of an urban cycle of *E. multilocularis* in the city of Zurich (Hofer *et al.*, 2000). In that study the prevalence of *E. multilocularis* was found to be 44.3 % in urban foxes and up to 66.7 % in foxes from the outskirts of the city. Hence, the increasing fox densities in urban dwellings, and the high prevalence of *E. multilocularis* in foxes, raise the question whether a much larger human population may be exposed to a higher infection risk. The main issue of this study was to characterise spatial and temporal aspects of urban transmission of *E. multilocularis* by investigating fox faecal samples collected in the environment and different rodent species at necropsy.

Materials and methods

Study area

The survey was conducted in the municipality of Zurich, Switzerland, referred to in this study as “the city of Zurich” with a population of 390 000. The study area (87 km^2) was divided into an urban, a border and a periurban zone comprising 34, 36, and 17 km^2, respectively (Fig. 1). The urban zone is mainly a residential one with little green space. The periurban zone consists of forests, fields, pastures and meadows, which are intensively used for recreational activities. The border zone, which divides the urban and the periurban zone and which was defined as extending 250 m from the border of the built–up area into the residential area of the city and into the periurban surrounding, includes mostly residential areas, allotments, cemeteries, sports fields and public places.

Sampling and identification of fox faecal samples

Between December 1998 and October 2000, a total of 604 putative fox faecal samples were collected from the urban zone (203 specimens), the border zone (344 specimens) and the periurban zone (57 specimens).

The year was divided into 3 periods: spring (March – June, to coincide with fox birth and lactation; 146 faeces); summer/autumn (July – October, to coincide with growth and independence of cubs; 201 faeces); winter (November – February, to coincide with the dispersal period and mating; 257 faeces).

For safety precautions, all samples were stored at -80°C for at least 5 days before being further examined (Deplazes *et al.*, 1999). The samples were identified as being of fox origin by examining their size, shape, smell and the presence of food remnants such as hair, fruit and feathers. Parameters like relative age, intensity of typical fox smell and homogeneity of faeces were partially recorded in the field with 4 graduations for each parameter. Relative age was judged by shape, humidity (considering weather conditions) and signs of decomposition.

Because of a large dog population in the city, this classification strategy was evaluated by comparing the parasite spectra of 3 groups of faecal samples from a public park. Faecal samples were judged as being of dog (n=25) or fox (n=40) origin by the criteria mentioned above. Another 31 faecal samples were obtained from deposit boxes into which dog owners dispose their animals' faeces collected in plastic bags. Parasitological examination was performed with a combined sedimentation/flotation technique with zinc chloride solution (density 1.4) and microscopical identification of the helminth eggs.

Sampling of rodents

From August 1999 to November 2000, a total of 1155 rodents were caught. Tong traps were used to catch 889 *Arvicola terrestris* and 27 *Microtus sp.*, whereas 83 *Clethrionomys glareolus*, 154 *Apodemus sp.* and 2 *Microtus sp.* were trapped with live traps (Longworth traps, Penlon Ltd., Oxon, GB). Other accidentally trapped animals, e.g. shrews, moles and rats, were excluded from the study. Animals in live traps were anaesthetised with Metofane® (Pitman Moore, Mundelein, IL, USA) and subsequently killed by neck dislocation.

Most animals were trapped in the border and in the periurban zone. In order to estimate prevalences of *E. multilocularis* in different areas we regularly (1–3 months intervals) trapped *A. terrestris* at 10 trapping sites resulting in catching between 33 and 113 individuals per site throughout the investigation period. Rodents were stored at –20°C if immediate dissection was not possible.

Age determination of rodents

The rodents were classified as being adults or subadults/juveniles based on body weight, body length (as measured from the tip of the nose to the first vertebra of the tail) and development of sexual organs. From 521 female *A. terrestris*, 163 showed signs of reproduction (placental scars, lactating mamma or different stages of gravidity). The body weight of all these females exceeded, with one exception, 60 g (62.2 – 135 g; mean 89 g; median 88 g) and their body length ranged between 122 mm and 165 mm. Therefore, *A. terrestris* with body weights above 60 g and body length above 120 mm were classified as adults.

Diagnosis of *E. multilocularis* in faecal samples collected in the environment

Detection of *E. multilocularis* coproantigens with a validated sandwich–ELISA (EM–ELISA) was performed exactly as described by Deplazes *et al.* (1999). Results were expressed as corrected A_{405nm} (value of specific reaction minus value of control reaction). Samples with high absorbencies in both specific and control reactions were repeated after being diluted 1:2 with a negative control. Samples with persisting high values in both reactions were excluded from the study.
A cluster analysis (SYSTAT®, SPSS Science, Chicago, IL, USA) was carried out with the 604 samples identified as being of fox origin to determine an intrinsic cut–off value (Greiner *et al.*, 1994). After performing the cluster analysis 6 times (2–, 3–, 4–, 5–, 6–, 7–cluster separation) 27 clusters were obtained which were arbitrarily classified as 'high–' or 'low–responders'. Calculation of the mean value plus 3 standard deviations of all clusters classified as 'low–responders' yielded a cut–off value (A_{405nm}) of 0.21, which was slightly higher than that previously determined with fox intestinal contents (A_{405nm} 0.15; Deplazes *et al*., 1999).
Results from ELISAs were further evaluated by isolating *taeniid* eggs from 40 randomly selected faecal samples of foxes followed by *E. multilocularis*–specific PCR as described previously (Mathis, Deplazes & Eckert, 1996)

Detection of metacestodes in rodents

All dissected rodents were carefully examined macroscopically for lesions in livers and other organs. Morphological identification of metacestodes of *Taenia sp*. included analyses of hook number and morphology. *E. multilocularis* metacestode tissue was identified either morphologically or by detection of *E. multilocularis*

DNA using a modified PCR (Dinkel *et al.*, 1998) with a single primer pair (EM–H15 [5'–CCATATTACAACAATATTCCTATC–3']; EM–H17 [5'–GTGAGTGA-TTCTTGTTAGGGGAAG–3']).

Lesions exceeding 2 mm in diameter were investigated microscopically. *E. multilocularis* metacestodes containing protoscoleces were cut into small pieces, squashed, washed with PBS through a sieve (1 mm mesh size) and the number of protoscoleces in the whole flow–through fraction was counted with an inverted microscope if few protoscoleces (< 100) were present or their total number was calculated from the counting of 3 subsamples of 100 µl.

Statistics

Differences in the proportion of coproantigen-positive faeces and in prevalences of *E. multilocularis* in rodents were compared by χ^2 tests. If the minimum entry in the table of expectation was less than 5, P–values were calculated with the program Actus (Estabrook & Estabrook, 1989) which performs randomised contingency tables and gives probabilities for deviations from expected values. P–values less than 0.05 were considered significant if consistent with Bonferoni corrections. Confidence intervals (95%; CI) were calculated with GraphPad StatMate™ (GraphPad Software Inc., San Diego, CA, USA).

The degree of overdispersion of the protoscoleces burden in rodents was calculated using the maximum likelihood estimate of k, the parameter of the negative distribution which tends towards 0 as parasite aggregation increases (Wilson &-Grenfell, 1997).

Table 1. Helminthic infections determined by detection of *Echinococcus multilocularis*–specific coproantigens by ELISA and by microscopical identification of eggs in faecal samples collected in the field and classified as fox faeces (A), dog faeces (B) or dog faeces from deposit boxes (C) in a public park in Zurich, Switzerland

Sample type (n)	*E. multilocularis* coproantigen *	Taeniid eggs *	*Capillaria* eggs *	*Toxocara* eggs	*Trichuris* eggs
A (40)	18 (45 %)	16 (40 %)	22 (55 %)	8 (20 %)	3 (7.5 %)
B (25)	0	0	0	1 (4 %)	1 (4 %)
C (31)	0	0	1 (3.2 %)	1 (3.2 %)	0

*Significant differences between (A) and (B, C): P < 0.001 (Actus randomisation test).

Table 2. Detection of *Echinococcus multilocularis* coproantigens in 381 faecal samples collected in the field and classified as fox faeces in relation to increasing graduations of relative age (estimated by morphology and humidity), intensity of fox smell and homogeneity as judged in the field

	Increasing graduation			
	+	++	+++	++++
Parameters	No. of samples (% *E. multilocularis* coproantigen positive)			
Relative age1)	21 (28.6 %)	113 (33.6 %)	222 (33.3 %)	25 (32.0 %)
Smell intensity2)	131 (32.8 %)	113 (33.6 %)	107 (33.6 %)	30 (30.0 %)
Homogeneity3)	39 (35.9 %)	135 (39.3 %)	171 (28.6 %)	36 (27.8 %)

1)Estimated age: + less than 2 days; ++++: older than 1 week.

2) + No typical fox smell; ++++ intense fox smell.

3) + Most components macroscopically identifiable (fruit remnants, feathers, hair, etc.); ++++ homogenous faeces without identifiable components.

Results

Identification of faecal samples collected in the environment

The sampling strategy for faecal samples from the environment was tested by examining the parasite spectra of 2 groups considered to be of fox or dog origin and of dog samples derived from deposit boxes (Table 1). Parasitological examination revealed the presence of helminth eggs in 27 of the 40 (67.5 %) environmental faecal samples, which were presumed to be fox faeces, in 2 of the 25 samples judged as dog faeces and in 2 of the 31 dog samples from deposit boxes. The 40 presumed fox faeces contained significantly more often taeniid and *Capillaria* eggs, and in 45% of the samples coproantigens of *E. multilocularis* were detected by EM–ELISA (Table 1). Neither taeniid eggs nor specific coproantigens of

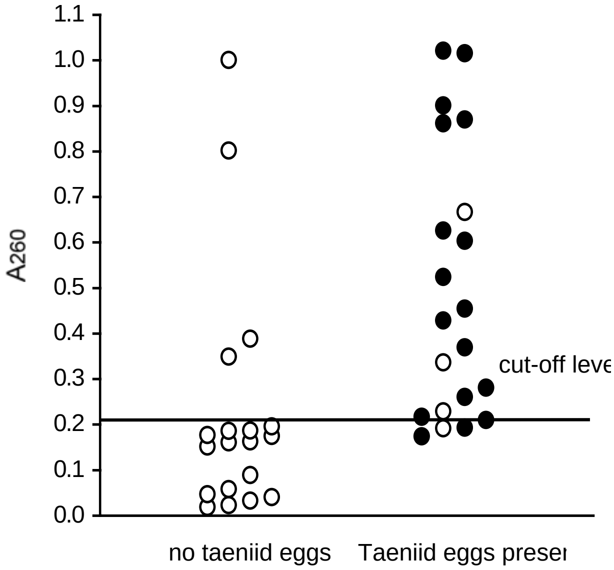


Fig. 2. Results of the *Echinococcus multilocularis* coproantigen ELISA (Deplazes et al., 1999), microscopical identification of Taeniid eggs and the *E. multilocularis*–specific PCR (Mathis et al., 1996) from 40 field samples classified as fox faeces in the city of Zurich, Switzerland. Open circles: PCR negative; filled circles: PCR positive. The cut–off value (A_{405nm}) for the ELISA was determined by a cluster analysis (Greiner et al., 1994) with 604 field faecal samples.

E. multilocularis could be detected in the 56 putative dog faeces (collected in the environment and from deposit boxes). No significant differences in the distribution of helminth eggs were found between these 2 groups of dog faeces.

Evaluation of the *E. multilocularis* coproantigen ELISA (EM–ELISA) with faecal samples collected in the environment

Comparison of *E. multilocularis* coproantigen detection, taeniid egg isolation and *E. multilocularis*–specific PCR with 40 randomly selected samples identified as fox faeces are shown in Fig. 2. Taeniid eggs were isolated from 21 (53 %) of the faecal samples of which 17 (43 %) were positive in the *E. multilocularis*–specific PCR. The sensitivity of the EM–ELISA for patent *E. multilocularis* infections, as determined by PCR, was 88 %. All 19 samples free of taeniid eggs were negative by PCR, but 4 of these samples were positive in the coproantigen ELISA.
With the aim to determine antigen stability, coproantigen results of 381 environmental faecal samples of putative fox origin were related to parameters recorded in the field such as relative age, intensity of fox smell and homogeneity. No significant differences in the distribution of coproantigen positive samples were found related to the graduations of these parameters (Table 2).

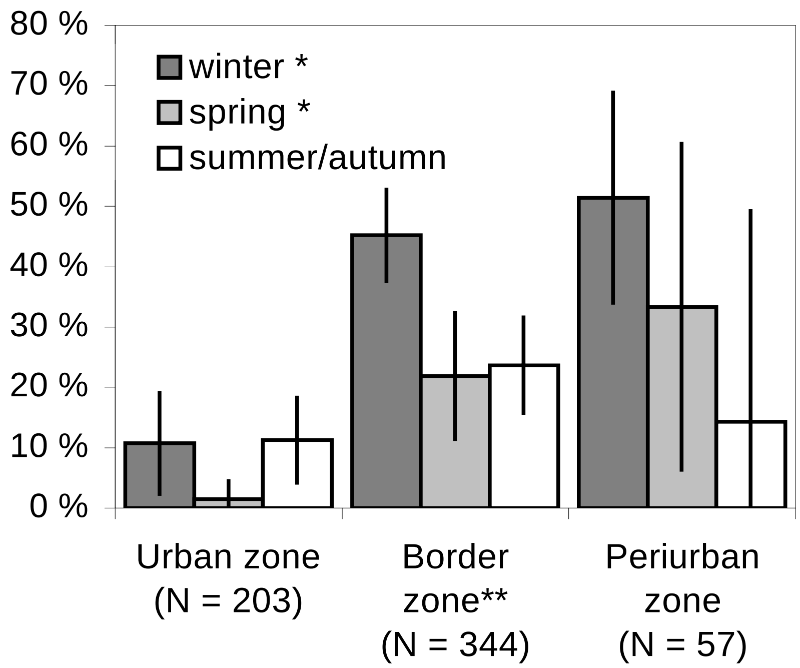


Fig. 3. Spatial and seasonal differences in the incidence of *Echinococcus multilocularis* coproantigens (Deplazes et al., 1999) in 604 field samples classified as fox faeces collected from December 1998 to October 2000 in 3 zones of the city of Zurich, Switzerland (% coproantigen positive samples and 95 % CI). Significant spatial (*) and seasonal (winter: November - February, spring: March – June; summer/autumn: July – October) (**) differences are marked with asterisks (P values after Bonferoni corrections: $P < 0.05$, χ^2 test).

Coproantigens in fox faecal samples collected in the environment

Spatial and seasonal differences. Of the 604 tested fox faecal samples 156 (25.8 %) were positive in the EM–ELISA. The proportion of coproantigen–positive faeces was higher in the border and periurban zone than in the urban zone. These spatial differences were highly significant for faeces sampled during winter and spring (Fig. 3). Samples from the border zone collected during the winter months (November to February) had significantly more coproantigen–positive results (45.2%) than samples of other seasons (21.9–23.7%). The same tendency was observed for the periurban zone. Coproantigen–positive faeces of the urban zone were mainly found in the periphery of this zone whereas in more central parts nearly no coproantigen–positve faeces could be found (Fig. 1B).

E. multilocularis **and Taenia spp. in rodents**

At necropsy, liver lesions were observed in 277 of 889 dissected *A. terrestris* and in 3 *C. glareolus,* 1 *Microtus sp*. and 1 *Apodemus sp*. (Table 3). Prevalence of

Table 3. Macroscopically visible liver lesions and detection of *Taenia taeniaeformis* and *Echinococcus multilocularis* metacestodes in 1155 rodents (*Arvicola terrestris*, *Clethrionomys glareolus*, *Microtus sp*. and *Apodemus sp*.) trapped in the city of Zurich, Switzerland
(Unidentifiable lesions were examined with an *E. multilocularis*–specific PCR.)

Rodent species (No. investigated)	No. liver lesions	*T. taeniaeformis* strobilocerci	*E. multilocularis* protoscoleces	lesions* investigated by EM–PCR	
				positive	negative
A. terrestris (889)	277**	108 (12.1%)	26 (2.9 %)	55 (6.2 %)	106
C. glareolus (83)	3	0	1 (1.2 %)	1 (1.2 %)	1
Microtus sp. (29)	1	0	0	0	1
Apodemus sp. (154)	1	0	0	0	1

* Morphologically unidentifiable lesions tested with EM–PCR modified according to Dinkel *et al*. (1998).
** 18 animals with 2 types of lesions.

E. multilocularis (protoscoleces and/or PCR positive) was 9.1% (81/889) for *A. terrestris*. The prevalence in 83 trapped *C. glareolus* was significantly lower (2.4%; $P<0.05$, χ^2 test) than in *A. terrestris*. Liver lesions of *Apodemus sp*. (1/154) and *Microtus sp*. (1/29) were negative in the *E. multilocularis*–specific PCR.
Metacestodes of *E. multilocularis* containing protoscoleces were found in 26 *A. terrestris* with numbers ranging between 14 and 244400 resulting in a total biomass of 926239 protoscoleces (Fig. 4). The maximum likelihood estimate of $k = 0.28$ indicates that the protoscoleces burden in *A. terrestris* is heavily overdispersed. Protoscoleces numbers below 1000 were found in 8 (31%) *A. terrestris* which harboured 0.2% (1779 protoscoleces) of the total biomass. Three animals (12%), with metacestodes containing more than 100 000 protoscoleces (120 000; 240 000; 244 400), carried 69 % of the total biomass. In 83 *C. glareolus* investigated, 1 animal harboured *E. multilocularis* metacestode tissue containing 108000 protoscoleces, whereas the small lesion in the second animal was identified by PCR only. All 27 lesions with protoscoleces showed clear positive PCR results.

Prevalence of Taenia spp.

The prevalence of *T. crassiceps* and *T. taeniaeformis* in *A. terrestris* was 2.0% (18/889) and 12.1% (108/889), respectively (Table 3). Metacestodes of *T. taeniaeformis* were found in liver tissue only, whereas *T. crassiceps* metacestodes were detected in pleural and peritoneal cavities and subcutaneous cysts. More than 1 metacestode species was found in 15 *A. terrestris* of which 8 carried

Table 4. Seasonal differences in the prevalence of *Taenia taeniaeformis*, *T. crassiceps* and *Echinococcus multilocularis* in 734 adult *Arvicola terrestris* trapped between August 1999 and November 2000

Period*	No. of animals	*T. taeniae-formis* positive	*T. crassi-ceps* positive	*E. multilocularis* positive	
				total	with protoscoleces
Winter	146	20.3 %	3.4 %	12.3 %	3.4 %
Spring	141	14.2 %	4.3 %	9.9 %	3.5 %
Summer/autumn	447	12.3 %	1.6 %	10.5 %	3.6 %

Winter: November - February; spring: March - June; summer/autumn: July - October

E. multilocularis and *T. taeniaeformis* metacestodes and 1 animal carried metacestodes of all 3 species.

Prevalence of E. multilocularis in A. terrestris in relation to sex and age.

In 734 adult *A. terrestris*, significantly higher prevalences of *E. multilocularis* (10.7%; CI [95%]: 8.6–13.2) and *T. taeniaeformis* (14%; CI [95%]: 11.6–16.7) were detected as compared to 155 subadults/juveniles (1.3% and 3.2%, respectively; χ^2 test: P<0.001 and P<0.0001). Differences in the prevalence of both cestodes related to sex were neither found in adult nor in subadult/juvenile *A. terrestris* (χ^2–test: P>0·05).

Prevalence of *E. multilocularis* in *A. terrestris*, spatial and seasonal differences.

E. multilocularis–infected *A. terrestris* were detected in 9 of 10 trapping sites with prevalences ranging from 4.3% up to 20.9% (Fig. 1). The Actus randomisation test revealed significant differences in the prevalence of *E. multilocularis* between the trapping sites (P=0.019). Animals harbouring *T. taeniaeformis* metacestodes were caught in all 10 areas (data not shown). The prevalence of *E. multilocularis* in 734 adult *A. terrestris* did not vary between the different seasons (Table 4). The same was observed for animals with protoscoleces. Prevalence of fully developed *T. taeniaeformis* strobilocerci was higher from November to February than in other months. However, due to Bonferoni corrections, this difference was not significant (P>0.05).

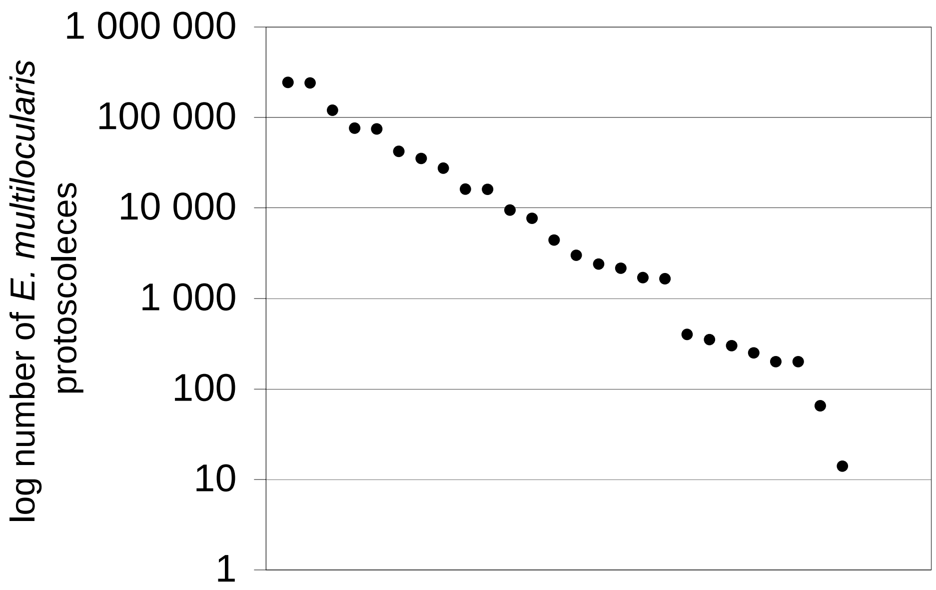


Fig. 4. Numbers *of Echinococcus multilocularis* protoscoleces (total number: 926 239) in 26 infected *Arvicola terrestris* trapped in the city of Zurich, Switzerland.

Discussion

The existence of an urban cycle of *E. multilocularis* in the city of Zurich has recently been described with a significantly lower prevalence of the parasite in foxes from urban areas as compared to those from the surrounding zone (Hofer *et al*., 2000). In the present study we observed a similar geographic distribution of the infection pressure as was obvious from the investigation of 604 faecal samples collected in the environment. Different factors may contribute to this difference of the parasite distribution. Preliminary results of radiotracking of foxes in our study area document small homerange sizes between 30 ha and 42 ha (Deplazes *et al*., 2002), which are in the range of those observed in urban areas in England (Harris & Rayner, 1986). Therefore, foxes living within the built–up area in a certain distance to the border zone do not roam these latter habitats, where good conditions for the development of vole populations exist. This assumption is supported by the fact that coproantigen–positive faeces from the urban zone were found mainly in the periphery of this area.

Significant seasonal differences in the detection of *E. multilocularis* in faecal samples were only found in the border zone of the city, where the percentage of positive faecal samples was higher during winter months. Correspondingly, foxes from the same study area had also higher prevalences in winter (Hofer *et al*., 2000). In contrast to this study, Morishima *et al*. (1999) did not find significant seasonal differences in the percentage of *E. multilocularis* coproantigen positive faeces. As red foxes are known to be opportunistic feeders, predation on rodents may differ seasonally. In suburban foxes in London (Great Britain), stomachs revealed higher percentages of mammals in autumn and winter (Harris, 1981).

Investigations on potential intermediate hosts of *E. multilocularis* are important to localise the cycle because voles are known to have small home ranges (Saucy & Schneiter, 1997). Therefore, infected voles represent a biological marker for the contamination of the ground in a distinct area. *A. terrestris* was the rodent species with the highest prevalence of *E. multilocularis* in our study. The only other infected species was *C. glareolus* with a significantly lower prevalence. *Apodemus spp*. have not yet been shown to be suitable intermediate hosts for *E. multilocularis* in central Europe (Rausch, 1995). This is confirmed by our results, as none of the 154 *Apodemus sp*., which were mostly trapped near sites with high prevalences of *E. multilocularis* in *A. terrestris,* were infected with the parasite. *Microtus spp*. are significantly involved in the transmission of *E. multilocularis* in Europe (Bonnin *et al*., 1986; Delattre, Giraudoux & Quere, 1990; Gottstein *et al.,* 2001). In our study area, however, none of our trapping sites revealed a high activity of *Microtus* species suggesting that *Microtus sp.* might not be as common as *A. terrestris* in the city of Zurich. However, the sample size (N=29) for this species was too small for definitive conclusions concerning the involvement of this species in the local cycle.

The high prevalence of *A. terrestris* suggests a major role in the perpetuation of the *E. multilocularis* cycle in the area investigated, which is supported by gut analysis of urban foxes (Gloor, unpublished data) revealing *A. terrestris* as the most frequent rodent in fox stomachs from Zurich. Furthermore, 47 fox faecal samples were discovered directly on vole ground systems of *A. terrestris* where signs of predation activities of carnivores were observed. Hence, the marking behaviour of red foxes seems to play an important role in the transmission of *E. multilocularis.*

The prevalences of *E. multilocularis* in *A. terrestris* varied significantly between the different trapping sites but were generally high (up to 20.9%) compared to other studies (Eckert *et al*., 2001a). *E. multilocularis* infected *A. terrestris* were found in 9 of 10 trapping sites in the border zone, which was highly contaminated with *E. multilocularis* coproantigen–positive faecal samples. We therefore assume that the transmission of *E. multilocularis* is not concentrated in so–called "hot–spots" but occurs in extended areas along the border of the built–up area of the city.

In this area, free-ranging dogs and cats are common which could acquire infections with *E. multilocularis*. The presence of *T. taeniaeformis* in *A. terrestris* populations in all trapping areas along the border zone, and the fact that *T. taeniaeformis* was not found in foxes in this area (Hofer *et al*., 2000), indicates a considerable predation pressure of domestic cats on *A. terrestris*.

There is only scarce information about seasonal variation in prevalence of *E. multilocularis* in intermediate hosts. In our study, no differences in adult rodents were observed which is in agreement with findings from France (Massif Central, Auvergne) for *A. terrestris* (Pétavy & Deblock, 1983).

Protoscoleces were found in 32% of the *E. multilocularis* infected *A. terrestris* resulting in an overall prevalence of 3.5%, which is within the range described in earlier surveys (0.2–8.3%; Gottstein *et al*., 1996; Hofer *et al*., 2000; Pétavy & Deblock, 1983). Again, no seasonal differences of prevalences of fertile cysts were observed (Table 4). To the best of our knowledge, no studies have so far been published on the numbers of protoscoleces of *E. multilocularis* in wild rodents. In the present study, there was a huge overdispersion of protoscoleces with a range from few (14) up to 244,400 per rodent host (Figure 4). From the 26 *Arvicola*, 69% harboured more than 1000 protoscoleces per animal.

Until recently, monitoring of the infection pressure of *E. multilocularis* in endemic areas was performed by parasite identification in definitive hosts at necropsy. However, data collection was strongly influenced by hunting regulations (e.g. close seasons, protected areas) and especially difficult in periurban and urban settings. As faecal samples of foxes can easily be collected in the environment, the identification of the presence of *E. multilocularis* in such samples by parasite–specific coproantigen detection (Craig, Rogan & Allan, 1996; Morishima *et al*., 1999; Eckert *et al.* 2001b) or copro–DNA (Mathis & Deplazes, 2002) opened up a new strategy for the direct assessment of the environmental contamination in a defined area.

Nevertheless, the strategy for collecting specifically fox faecal samples had to be scrutinised, as fox faeces may be confused, particularly with dog faeces, which are very frequent in urban areas. Our results clearly confirm that differentiation of dog and fox faeces can reliably be achieved.

The EM–ELISA used in this study was originally validated with intestinal contents of foxes (Deplazes *et al*., 1999). A cluster analysis (Greiner *et al*., 1994) of our fox environmental samples yielded an intrinsic cut–off value (A_{405nm}) slightly higher than in the former study. This might be due to different environmental influences on these faeces. The evaluation of this proceeding by isolating taeniid eggs followed by PCR identification (Mathis *et al*., 1996) in 40 of these samples resulted in a sensitivity of 88.2% for patent infections, which is comparable to the sensitivity of 83.6% determined with intestinal contents of 55 infected foxes (Deplazes *et al*., 1999). In 4 of 40 samples free of taeniid eggs DNA amplification by PCR was negative, but the EM-ELISA was positive due to either cross-reactions or the presence of prepatent infections that cannot be detected with our PCR strategy (Mathis *et al*., 1996). False negative results of the EM–ELISA can be explained with the high proportion of foxes infected with low worm burdens in the study area

(Hofer *et al*., 2000). Neither the relative age of samples nor the intake of different food affected the detection of *E. multilocularis* coproantigens. This is consistent with observations made with the same coproantigen test with environmental faecal samples from rural endemic areas in France (Raoul *et al.*, 2001). Stability of helminth coproantigens has been documented in 2 studies: *T. hydatigena* antigens were stable for at least 5 days at room temperature (Deplazes *et al.*, 1990), and the detection of *E. granulosus* coproantigens was not influenced by exposing the faeces during six days and nights to sun-exposed places in the Australian Capital Territory (Jenkins *et al.*, 2000).

Little is known about the correlation of the infection pressure of *E. multilocularis* on the incidence of human AE. Gottstein *et al*. (2001) found an increased seroprevalence in blood donors living in an *E. multilocularis* 'hot spot' area over a period of ten years without increase in clinical cases. There are no indications of a higher incidence of alveolar echinococcosis in urban dwellers in Switzerland (Renner–Schneiter *et al.*, 2000), but the recent invasion of foxes in urban habitats (Gloor *et al.*, 2001), and the considerable contamination of this area with *E. multilocularis*-infected fox faeces, could change the situation. Urban inhabitants use the border zone of the built–up area intensively for recreational activities, and this zone may therefore represent an area of increased risk for acquiring AE. Furthermore, the many free-roaming domestic cats and dogs in this area might prey on infected voles and hence could represent a potential source of infection for humans (Eckert & Deplazes, 1999). Based on the incubation time of 5–10 years in humans, changes in the epidemiology of AE would only be noticed in a long-term surveillance which could be achieved in the framework of a reporting system.

The cycle of *E. multilocularis* in urban settings seems to be determined by the small home ranges of foxes and the distribution of suitable intermediate hosts. Therefore, local interaction in the cycle reducing the infection pressure in defined areas (e.g. public parks, swimming pool areas, private gardens) should be feasible. Field studies in Zurich on the control of the *E. multilocularis* infection in urban areas, by distributing praziquantel-containing baits manually, are currently being carried out.

Acknowledgements

The authors thank all collaborators involved in the Integrated Fox Project. We especially thank Christian Stauffer and the game wardens of the city of Zurich for their assistance and for their generous collaboration. We thank Profs. J. Eckert and P. Ward for valuable comments on the manuscript. The study was supported by the Swiss Federal Veterinary Office (FVO Nr. 1.99.03) and the Swiss National Science Foundation (grant no. 31-47031.96). This work represents the dissertation of Claudia Stieger, veterinarian.

References

AMMAN, R. W. & ECKERT, J. (1996). Cestodes: *Echinococcus*. In *Parasitic Diseases of the Liver and Intestines* (ed. Weinstock, J.W.), pp. 655-689. Gastroenterology Clinics of North America, W.B. Saunders Company, Philadelphia.

ARTOIS, M. (1997). Managing problem wildlife in the 'Old World': a veterinary perspective. *Reproduction, Fertility, and Development* **9**, 17-25.

AUER H. & ASPÖCK, H. (1991). Incidence, prevalence and geographic distribution of human alveolar echinococcosis in Austria from 1854 to 1990. *Parasitology Research* **77**, 430-436.

BONNIN, J. L., DELATTRE, P., ARTOIS, M., PASCAL, M., AUBERT, M. F. & PETAVY, A. F. (1986). Contribution à la connaissance des hôtes intermédiaires d'*Echinococcus multilocularis* dans le nord-est de la France. Description des lésions trouvées chez 3 espèces de rongeurs naturellement infectés. *Annales de Parasitologie Humaine et Comparée* **61**, 235-243.

CRAIG, P. S., ROGAN, M. T., ALLAN, J. C. (1996). Detection, screening and community epidemiology of taeniid cestodes zoonoses: cystic echinococcosis, alveolar echinococcosis and neurocysticercosis. *Advances in Parasitology* **38**, 169-250.

DELATTRE, P., GIRAUDOUX, P. & QUERE, J.-P. (1990). Conséquences épidémiologiques de la réceptivité d'un nouvel hôte intermédiaire de Taenia multiloculaire (*Echinococcus multilocularis*) et de la localisation spatiotemporelle des rongeurs infestés. *Comptes rendues de l'académie des sciences serie III, Sciences de la vie* **310**, 399-344.

DEPLAZES, P. & ECKERT, J. (2001). Veterinary aspects of alveolar echinococcosis - a zoonosis of public health significance. *Veterinary Parasitology* **98**, 65-87.

DEPLAZES, P., GOTTSTEIN, B., STINGELIN, Y. & ECKERT, J. (1990). Detection of *Taenia hydatigena* copro-antigens by ELISA in dogs. *Veterinary Parasitology* **36**, 91-103.

DEPLAZES, P., ALTHER, P., TANNER, I., THOMPSON, R. C. & ECKERT, J. (1999). *Echinococcus multilocularis* coproantigen detection by enzyme-linked immunosorbent assay in fox, dog, and cat populations. *Journal of Parasitology* **85**, 115-121.

DEPLAZES, P., GLOOR, S., STIEGER, C., HEGGLIN, D. (2002). Urban transmission of *Echinococcus multilocularis*. In: Cestode zoonoses: echinococcosis and cysticercosis. An emergent and global problem (eds. Craig, P., Pawlowski, Z.S.). pp. 287-298. IOS press, Amsterdam.

DINKEL, A., VON NICKISCH-ROSENEGK, M., BILGER, B., MERLI, M., LUCIUS, R. & ROMIG, T. (1998). Detection of *Echinococcus multilocularis* in the definitive host: coprodiagnosis by PCR as an alternative to necropsy. *Journal of Clinical Microbiology* **36**, 1871-1876.

ECKERT, J. & DEPLAZES, P. (1999). Alveolar echinococcosis in humans: the current situation in central Europe and the need for countermeasures. *Parasitology Today* **15**, 315-319.

ECKERT, J., SCHANTZ, P.M., GASSER, R.B., TORGERSON, P.R., BESSONOV, A.S.,

MOVSESSIAN, S.O., THAKUR, A., GRIMM, F. and NIKOGOSSIAN, M.A. (2001a): Geographic distribution and prevalence. In *WHO/OIE Manual on Echinococcosis in Humans and Animals: a Public Health Problem of Global Concern* (eds. Eckert, J., Gemmell, M.A., Meslin, F.-X. & Pawlowski, Z.S.) pp. 100-142. World Organization for Animal Health, Paris.

ECKERT, J., DEPLAZES, P., CRAIG, P.S., GEMMELL, M.A., GOTTSTEIN, B., HEATH, D., JENKINS, D.J., KAMIYA, M. and LIGHTOWLERS, M. (2001b): Echinococcosis in animals: clinical aspects, diagnosis and treatment. In *WHO/OIE Manual on Echinococcosis in Humans and Animals: a Public Health Problem of Global Concern* (eds. Eckert, J., Gemmell, M.A., Meslin, F.-X. & Pawlowski, Z.S), pp. 72-99. World Organization for Animal Health, Paris.

ESTABROOK, C. B. & ESTABROOK, G. F. (1989). Actus: a solution to the problem of small samples in the analysis of two-way contingency tables. *Historical Methods* **82**, 5-8.

GLOOR, S., BONTADINA, F., HEGGLIN, D., DEPLAZES, P., BREITENMOSER, U. (2001). The rise of urban fox populations in Switzerland. *Mammal biology*, **66**, 155-164.

GOTTSTEIN, B., SAUCY, F., WYSS, C., SIEGENTHALER, M., JACQUIER, P., SCHMITT, M., BROSSARD, M. & DEMIERRE, G. (1996). Investigations on a Swiss area highly endemic for *Echinococcus multilocularis*. *Applied Parasitology* **37**, 129-136.

GOTTSTEIN, B., SAUCY, F., DEPLAZES, P., REICHEN, J., DEMIERRE, G., ZÜRCHER, CH., BUSATO, A., PUGIN, P. (2001). Is a high prevalence of *Echinococcus multilocularis* in wild and domestic animals associated with increased disease incidence in humans? *Emerging Infectious Diseases* **7,** 408-412.

GREINER, M., FRANKE, C. R., BÖHNING, D. & SCHLATTMANN, P. (1994). Construction of an intrinsic cut-off value for the sero-epidemiological study of *Trypanosoma evansi* infections in a canine population in Brazil: a new approach towards an unbiased estimation of prevalence. *Acta Tropica* **56**, 97-109.

HARRIS, S. (1981). The food of suburban foxes (*Vulpes vulpes*), with special reference to London. *Mammal Review* **11**, 151-168.

HARRIS, S. & RAYNER, J. M. V. (1986). Urban fox (*Vulpes vulpes*) population estimates and habitat requirements in several British cities. *Journal of Animal Ecology* **55**, 575-591.

HOFER, S., GLOOR, S., MÜLLER, U., MATHIS, A., HEGGLIN, D. & DEPLAZES, P. (2000). High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zurich, Switzerland. *Parasitology* **120**, 135-142.

HOUIN, R., DENIAU, M., LIANCE, M. & PUEL, F. (1982). *Arvicola terrestris* an intermediate host of *Echinococcus multilocularis* in France: epidemiological consequences. *International Journal for Parasitology* **12**, 593-600.

JENKINS, D. J., FRASER, A., BRADSHAW, H. & CRAIG, P. S. (2000). Detection of *Echinococcus granulosus* coproantigens in Australian canids with natural or experimental infection. *Journal of Parasitology* **86**, 140-145.

MATHIS, A. & DEPLAZES, P. (2002). The role of PCR-DNA detection of *Echinococcus multilocularis*. In: Cestode zoonoses: echinococcosis and cysticercosis. An emergent and global problem (eds. Craig, P., Pawlowski, Z.S.). pp. 195-204. IOS press, Amsterdam

MATHIS, A., DEPLAZES, P. & ECKERT, J. (1996). An improved test system for PCR-based specific detection of *Echinococcus multilocularis* eggs. *Journal of Helminthology* **70**, 219-222.

MORISHIMA, Y., TSUKADA, H., NONAKA, N., OKU, Y. & KAMIYA, M. (1999). Coproantigen survey for *Echinococcus multilocularis* prevalence of red foxes in Hokkaido, Japan. *Parasitology International* **48**, 121-134.

PÉTAVY, A. F. & DEBLOCK, S. (1983). Connaissance du foyer Auvergnat d'échinococcose alvéolaire. Recherche de l'hôte intermédiaire, description des lésions. *Annales de Parasitologie Humaine et Comparée* **58**, 439-453.

PÉTAVY, A. F., TENORA, F., DEBLOCK, S., SERGENT, V. (2000). *Echinococcus multilocularis* in domestic cats in France. A potential risk factor for alveolar hydatid disease contamination in humans. *Veterinary Parasitology* **87**, 151-156.

RAOUL, F., DEPLAZES, P., NONAKA, N., PIARROUX, R., VUITTON, D.A. & GIRADOUX, P. (2001). Assessment of the epidemiological status of *Echinococcus multilocularis* in foxes in France using ELISA coprotests on fox faeces collected in the field. *International Journal for Parasitology* **31**, 1579-1588.

RAUSCH, R. L. (1995). Life cycle patterns and geographic distribution of *Echinococcus* species. In *Echinococcus and Hydatid Disease* (ed. Thompson, R. C. A. & Lymbery, A. J.), pp. 89-134. CAB International, Wallingford, Oxon, UK.

RENNER-SCHNEITER, E. C., DEPLAZES, P., RENNER, E. L., AMMANN, R. W. (2000). Does the risk of *Echinococcus multilocularis* (EM) infection increase with increasing populations of infected foxes in Swiss cities? - A retrospective analysis of the cohort of the Swiss Echinococcosis Study Group (SESG) 1976-1999. *Schweizerische Medizinische Wochenschrift* **130**, 121.

ROMIG, T., KRATZER, W., KIMMIG, P., FROSCH, M., GAUS, W., FLEGEL, W. A., GOTTSTEIN, B., LUCIUC, R., BECKH, K., KERN, P. (1999). An epidemiologic survey of human alveolar echinococcosis in southwestern Germany. *American Journal of Tropical Medicine and Hygiene* **61**, 566-573.

SAUCY, F. & SCHNEITER, B. (1997). Juvenile dispersal in the vole *Arvicola terrestris* during rainy nights: a preliminary report. *Bulletin de la Société Vaudoise des Sciences Naturelles* **84**, 333-345.

VUITTON, D. A., BRESSSON-HADNI, S., LIANCE, M., MEYER, J. P., GIRAUDOUX, P., LENYS, D. (1990). L'échinococcose alvéolaire humaine. Hasard épidémiologique ou fatalité immunologique? *Gastroenterologie Clinique et Biologique* **14,** 124-130.

WILSON, K. & GRENFELL, B.T. (1997). Generalized linear modelling for parasitologists. *Parasitology Today* **13**, 33-38.

Manuskript E (book chapter):
Urban transmission of *Echinococcus multilocularis*

Peter Deplazes[1], Sandra Gloor,[2], Claudia Stieger[1], Daniel Hegglin[1]

[1] Institute of Parasitology, University of Zürich, Winterthurerstr. 266a , CH-8057 Zürich, Switzerland,
[2] Work Group Urban Ecology and Wildlife Research, Wuhrstr. 12, CH-8003 Zürich, Switzerland

Deplazes P, Gloor S, Stieger C, Hegglin D. Urban transmission of Echinococcus multilocularis. In: Craig P, Pawlowski Z, editors. Cestode Zoonoses: Echinococcosis and Cysticercosis; 2002: IOS Press, Amsterdam, Netherlands; 2002. p. 287-297.

Abstract

In several European countries a distinct increase of the red fox (*Vulpes vulpes*) population was observed in recent years, particularly in urban areas. The number of foxes shot or found dead in the city of Zürich increased 20 times between 1985 and 1997. Therefore, an interdisciplinary project was initiated to study ecological and parasitological aspects of the urban fox population.

Preliminary ecological results show that the population density of foxes in the urban area is high and the animals have small home ranges. Within the city border, the prevalence of *Echinococcus multilocularis* in foxes increased significantly from the urban (47%) to the adjacent recreational area (67%).

To estimate the contamination of city areas with eggs of *E. multilocularis*, faecal samples of foxes were collected and investigated by a coproantigen ELISA. The spatial distribution of coproantigen positive samples was in accordance with the different prevalences found in necropsied foxes. In rodents trapped in recreational areas of the city, *E. multilocularis* metacestodes were identified by morphological examination, by EmG11-antigen detection with ELISA and by PCR. The prevalence in 781 *Arvicola terrestris* was 9.2% with fully developed protoscolices (14-240,000) occurring in 24 *A. terrestris*. Thus, an urban parasite cycle is established and a potential infection risk exists not only for urban residents but also for domestic dogs and cats. This new epidemiological situation and the emerging public awareness concerning zoonoses justify the evaluation of local intervention in the cycle of *E. multilocularis*.

1. Introduction

Echinococcus multilocularis is typically perpetuated in a wild-life (= silvatic) cycle including foxes (genera *Vulpes* and *Alopex*) as definitive hosts and different rodent species, mainly *Arvicolidae*, as intermediate hosts [1]. In some endemic areas, other species of wild carnivores, such as coyote, wolf, and raccoon dog, are involved as definitive hosts. In addition, a synanthropic cycle exists in some rural communities with domestic dogs as definitive hosts, which acquire the infection from wild rodents [2, 3, 4].

In the central European endemic area, red foxes (*Vulpes vulpes*) are likely to be responsible for most of the environmental contamination with *E. multilocularis* eggs. This was concluded from a study in which the prevalences of *E. multilocularis* in foxes, dogs and cats were related to the estimated population sizes of these definitive hosts [1]. Recent studies have shown that *E. multilocularis* has a wider geographic range than previously anticipated but prevalences of *E. multilocularis* in red foxes differ widely within and between endemic areas from about 1% to over 60% [5, 6, 7, 8]. Furthermore, there are reports on increasing *E. multilocularis* prevalences in some regions [7].

From retrospective studies, there is no direct correlation between fox population densities and human alveolar echinococcosis (AE). In Switzerland, the country-wide average annual incidences of human AE did not vary (0.10–0.18) during 36 years (1956-1992) suggesting a stable epidemiological situation despite high variations of the fox densities during this time [1]. In Europe**,** there is now evidence for growing populations of red foxes in some areas, for an increasing invasion of cities by foxes in the last 15 years [chapter 2] and also for the establishment of the parasite cycle in urban areas [9]. However, a retrospective analysis (1975-1999) comparing cases of AE in humans living in urban and rural communities in Switzerland revealed no significant changes in the incidence rates [E.C. Renner-Schneiter and R.W. Ammann, personal communication]. Whether these data reflect a continuing stable and low infection risk in urban areas or whether the increased infection pressure in highly populated areas will lead to a delayed increase in the incidence of AE cases in the future, remains to be seen. In certain regions, e.g. China, ecological changes have been reported to have influenced the epidemiological situation of AE in the past [3, 4].

In this review, we focus on the *E. multilocularis* transmission in urban settings in respect of the changing fox ecology in such highly populated areas.

2. Ecological changes in urban areas: the urban fox phenomenon

2.1. Historical overview

Red foxes living in urban areas are known from Great Britain since the inter-war period in the 1930s [10]. In these years there was a boom of private house construction because of cheap land prices, resulting in large districts of middle-class suburbs with low-density housing and medium-sized gardens. This is the type of habitat which was found to be favoured by foxes [11]. Once established in these residential suburbs, foxes moved further into the city and also colonised less preferred habitats.
In the 1970s and 1980s, fox populations in British cities reached densities of up to five fox family groups per km2 (representing 12 adults on average, in some cases more than 30 adult foxes per km2), densities which had never been observed so far [12]. As these observations were unique world-wide, urban foxes were initially thought to be an isolated British phenomenon [13, 14].
On the European continent fox populations experienced in the 1970s and 1980s a heavy rabies epizootic, a zoonosis not present on the British Isles. Subsequently, fox populations decreased drastically on the continent. Rabies hit Switzerland in 1967 [15] and fox densities reached a low in 1984, as can be seen from the Swiss hunting bag [16]. However, fox populations recovered again from 1985 onwards (e.g. [17]) because of successful oral vaccination campaigns against rabies, which started in Switzerland in 1978 [18] and which were extended into the whole European epizootic area in the following years (e.g. [19]).
Apart from this development in rural areas, more and more foxes have been recorded from large Swiss conurbations and cities such as Zürich or Geneva. An inquiry of town officials and persons responsible for wildlife management revealed that foxes are present in 28 of the 30 largest Swiss cities [20]. Similar observations were recorded from other parts of the distribution area of the red fox, e.g. from Oslo, Norway [21], Arhus, Denmark [22], Stuttgart, Germany [7], Toronto, Canada [23] and Sapporo, Japan [24].
The presence of urban fox populations raises the question of the impact of human behaviour and attitudes towards these wild animals [25]. Food provided by humans represents a major part of the diet of urban foxes in Great Britain [26, 27]. Additionally, the presence of foxes in close neighbourhood of people influence the management of fox populations and prevention strategies of zoonoses (e.g. rabies and alveolar echinococcosis).

2.2. Ecological aspects of an increasing red fox population in the city of Zürich: preliminary results

The largest conurbation of Switzerland is the area of Zürich with some 1,000,000 inhabitants. However, only 360,000 of this population live in the political community of Zürich, which we refer to when we use the term “the city of Zürich”. The city (92km^2) consists of 53% urban area, 24% forest, 17% agricultural areas and 6% water surface [28]. Forest and agricultural areas surround the urban area and are referred to as the recreational area of the city in the following pages (Fig. 4). Correspondingly we distinguish between foxes found in urban area (urban foxes) and foxes found in adjacent recreational area (rural foxes).
As far as hunting is concerned, the city of Zürich is a game sanctuary. Official game wardens have maintained a constant hunting regime and a reporting system since 1926. Urban foxes have been present in the city of Zürich since the 1960s, but at low numbers until the mid 1980s (Fig. 1). From then onwards the number of foxes shot or found dead in the whole city increased drastically, i.e. 20 times between 1985 and 1997, notably in the urban area [20].

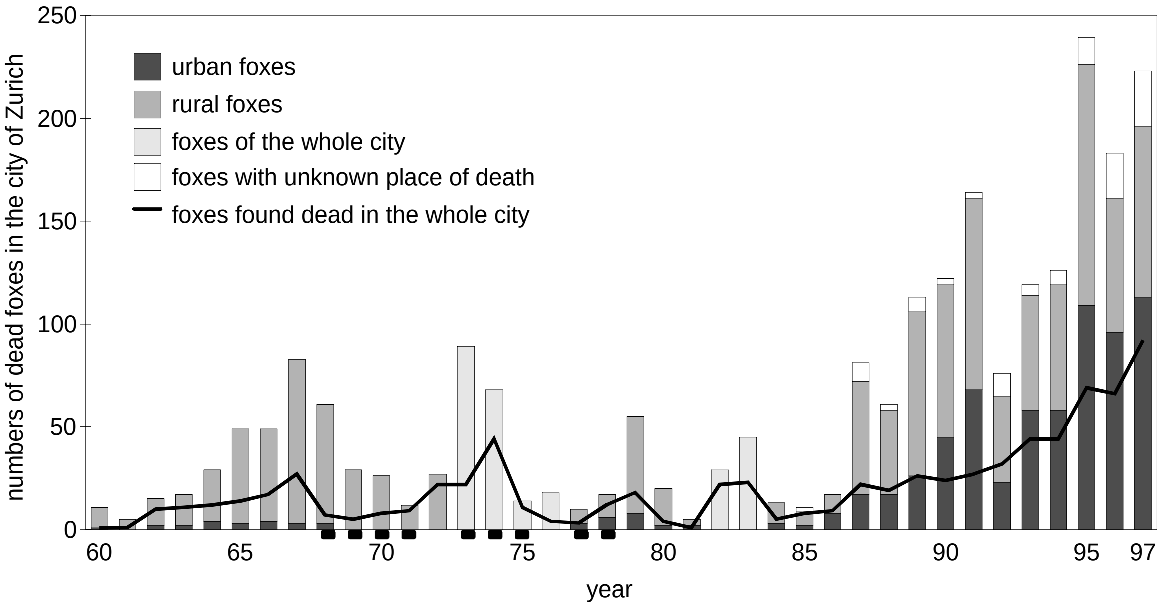


Fig. 1: Fox mortality (foxes shot or found dead) in urban and adjacent recrational areas in the city of Zürich (Switzerland) from 1960 to 1997. From the years 1973 – 1976 and 1982 - 1983 only total numbers of dead city foxes are available (white bars). The years with rabies cases within 5 km of the city centre are marked with small black bars (modified after [20]).

In order to study the spatial and habitat use of the urban fox population of Zürich, 20 adult foxes (12 females and 8 males) were observed by radiotracking [S. Gloor, unpublished data]. The study was carried out in a residential area of the city of about 11 km^2 between December 1996 and June 1999. The homeranges of the radiotracked foxes were analysed in three periods of the year (March to June; July to October; November to February). The home ranges of the vixens and of the resident male foxes were relatively small (Fig. 2) and comparable with those observed in British cities with high fox densities (e.g [29, 30]). According to preliminary home range analyses, the home ranges of vixens were 30.6 ha ± 15.9, and the home ranges of resident male foxes were 42.0 ha ± 23.9 (100% MCP). However, three male foxes had significantly larger home ranges of 144.1 ha ± 39.2 and did not seem to be resident in an own area. Overlapping home ranges of foxes of the same sex and observations of more than two adult foxes at breeding dens indicate the establishment of family groups. This is in agreement with preliminary results of reproductive data from dead foxes collected in the city of Zürich which revealed that not all of the adult vixens do reproduce.

In the area of the radiotracked resident foxes (6.7 km^2) 23 dens with cubs were known in 1999. Assuming two adult foxes per breeding den, the fox density in the area would be 6.9 adult foxes/km^2 or 10.3 adult foxes/km^2 with three adult foxes per den.

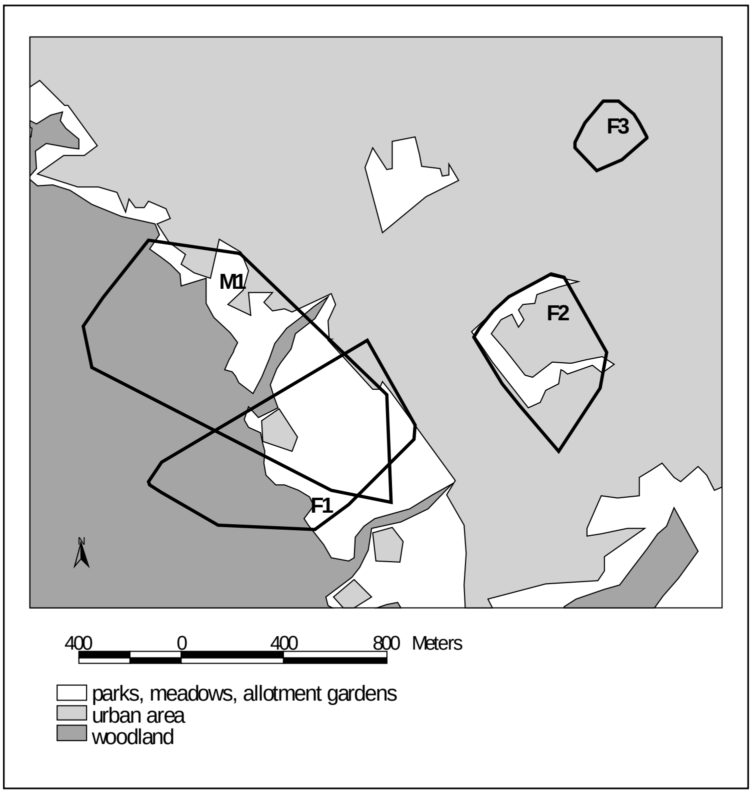


Fig. 2: Homeranges of three female foxes (F1, F2, F3) and one male fox (M1) from July to October 1998, in urban and adjacent recreational areas in the city of Zürich (Switzerland).

3. Epidemiology of *E. multilocularis* in urban settings

3.1. Infection pressure in urban areas

In recent years, the occurrence of *E. multilocularis* in urban foxes has been reported from several European cities, e.g. Copenhagen, Geneva, Munich, Stuttgart, Zürich [7, 9, 31] and from Sapporo (Japan) [24]. However, there is no detailed data available about the transmission ecology of *E. multilocularis* in the urban environment. A preliminary study on the epidemiological role of red foxes in the urban area of Sapporo was based on the detection of parasite coproantigen in faecal samples collected around active fox dens most of them being located in the urban fringe [24]. Thirty-three of the 155 samples (21%) which tested positive originated from the surroundings of 11 dens including one from the urban area. In this study, *E. multilocularis* was not detected in a small number of 23 rodents at necropsy. The authors pointed out that the life-cycle of *E. multilocularis* may not easily be maintained in the central urban area, whereas the outskirts of Sapporo offer a good habitat for the most suitable intermediate host *Clethrionomys spp*. [24].

3.2. Urban cycle of *E. multilocularis* in the city of Zürich (Switzerland)

Over a period of 26 months (1996-1998), 388 foxes from the city of Zürich were examined for intestinal infections with *E. multilocularis* and other helminths [9]. Seasonal differences in the prevalence of *E. multilocularis* were only found in urban subadult male foxes which were significantly less frequently infected in summer than in winter. The prevalence of *E. multilocularis* in 252 foxes sampled during winter increased significantly from 47% in the urban to 67% in the adjacent recreational area whereas a decrease of the *Mesocestoides* prevalence was observed (Table 1). The prevalence rates of other helminths were similar in both areas.
The distribution of the *Echinococcus* biomass, as expressed by worm numbers per fox, was overdispersed in 133 infected foxes randomly sampled in winter (Fig. 3) [9]. Therefore, a few highly infected foxes (carrying thousands of fertile worms) can be responsible for most of the environmental egg contamination. For example, 7.5% of the fox population (10/133) harboured more than 72% of the total worm number with a maximum individual worm burden of about 57,000. Prevalences did not differ significantly in these foxes in regard to age and sex, but worm burdens were significantly higher in subadult foxes as compared with adult foxes (Fig. 3). A total of 82.7% of the worm burden was detected in 68 subadult foxes, and 65 adult foxes harboured the remaining 17.3%. In the same study [9], metacestodes of *E. multilocularis* were found in 14% (19/135) of water voles (*Arvicola terrestris*) in a city park. This investigation provided evidence for the existence of an urban wildlife cycle of *E. multilocularis* in the city of Zürich. Therefore, a new project was

initiated in 1998 focusing on the assessment of the infection pressure with *E. multilocularis* eggs in urban environments by investigating faecal samples of foxes collected in the field and by further studies of rodents.

Table 1: Small intestinal helminths discovered in 252 foxes collected from January 1996 to February 1998 during winter (November to February) in the city of Zürich (Switzerland) [9]. Numbers, prevalences and confidence intervals are shown separately for foxes originating from the urban area (urban foxes) and from the adjacent recreational area (rural foxes).

	129 urban foxes			123 rural foxes			
	N	P (%)	CI(%)	N	P (%)	CI(%)	χ^2 test*
Echinococcus multilocularis	61	47.3	38.5 - 56.1	82	66.7	58.1 - 75.2	0.002
Taenia spp.	25	19.4	12.4 - 26.4	28	22.8	15.2 - 30.4	n.s.
Mesocestoides sp.	13	10.1	4.8 - 15.4	3	2.4	0.0 - 5.2	0.018
Dipylidium sp.	1	0.8	0.0 - 2.3	0	0.0	0.0 - 0.0	n.s.
Uncinaria stenocephala	92	71.3	63.3 - 79.4	89	72.4	64.3 - 80.5	n.s.
Toxocara canis	56	43.4	34.7 - 52.2	59	48.0	38.9 - 57.0	n.s.
Alaria sp.	2	1.6	0.0 - 3.7	6	4.9	1.0 - 8.8	n.s.

* Significance (two-tailed) of differences in prevalence of urban foxes and foxes from the adjacent recreational area (rural foxes).

Faecal samples were identified as of fox or dog origin by using the criteria, sample size, shape and smell. Since domestic dogs are numerous in urban areas, our sampling strategy was evaluated by comparing the parasite spectrum and the composition of the sample content of three types of samples, namely field samples identified as fox or dog faeces and samples taken from deposit boxes into which dog owners are advised to dispose their animals' faeces collected in plastic bags. Samples identified as fox field faeces contained significant more helminth eggs (68%) than dog field faeces (3%). Results from dog samples from the deposit boxes were comparable to those of the field samples judged as dog faeces. In fox samples fruit remnants and feathers were found frequently but not in samples of putative dog origin [C. Stieger and P. Deplazes, unpublished data].
The diagnostic strategy for the detection of *E. multilocularis* in the collected samples was performed as described by Mathis and Deplazes [32]. A coproantigen ELISA (EM-ELISA) [33] was used as a screening test and the results were confirmed by PCR [34] using 22 coproantigen positive and 18 negative samples [C. Stieger and P. Deplazes, unpublished data]. The sensitivity of the ELISA for patent infections, as determined by egg isolation and PCR, was 89% and comparable with

the sensitivity (84%) of the same test determined with samples obtained from killed animals [33]. These data confirm other results of *E. multilocularis* coproantigen studies applied in the field [35, 36].

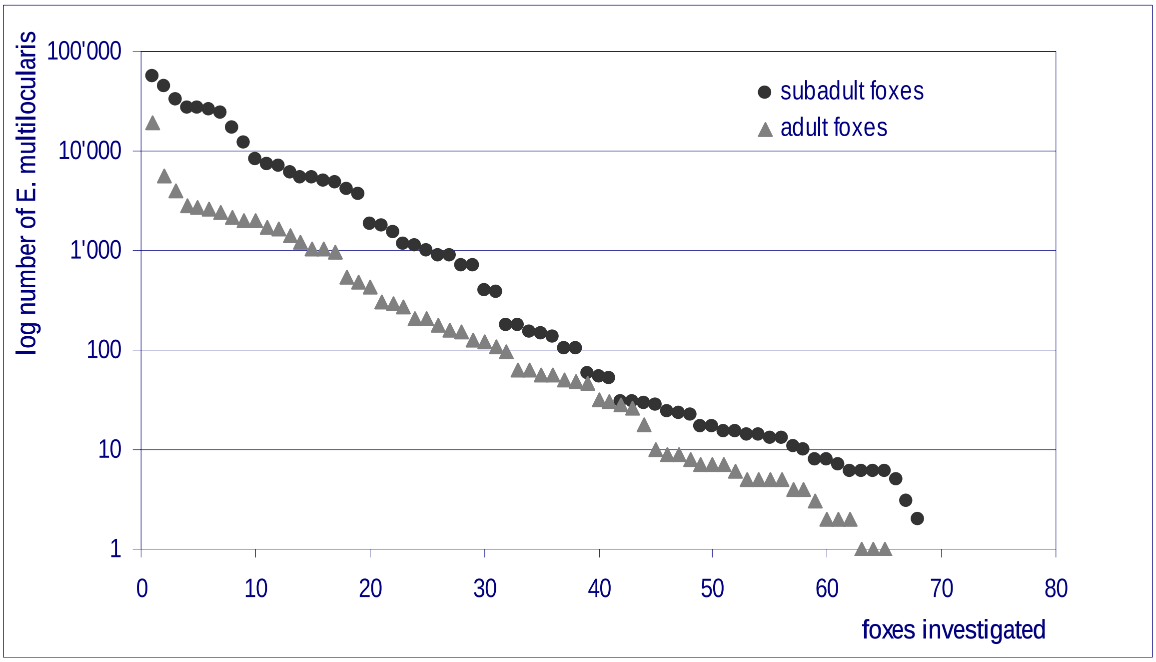


Fig. 3: Distribution of the *E. multilocularis* biomass in 65 adult foxes and 68 subadult foxes sampled in the city of Zürich (Switzerland) in winter (November- February).

The analyses of 647 fox faecal specimens collected within the city revealed copro-antigen-positive samples in 10% up to 60% in different areas. The spatial distribution of coproantigen positive samples (Fig. 4, A and B) was in accordance with the different prevalences found in necropsied foxes [9] and gave evidence for a high contamination with *E. multilocularis* in the recreational area. Furthermore, it is worth to note that 47 faecal samples were found directly on vole ground systems of *A. terrestris* where signs of predation activities of carnivores were observed. Metacestodes of *E. multilocularis* were identified morphologically, by PCR [32] and by an ELISA specific for *E. multilocularis* antigen [37]. In 72 (9.2%) of 781 *A. terrestris* trapped in the recreational area mainly at the city border *E. multilocularis* were detected (Fig. 4, C and D). Protoscolices (14-240,000) were seen in 24 animals. However, other important intermediate hosts, such as *Microtus* and *Clethrionomys* species need to be investigated to assess their role in this urban cycle.

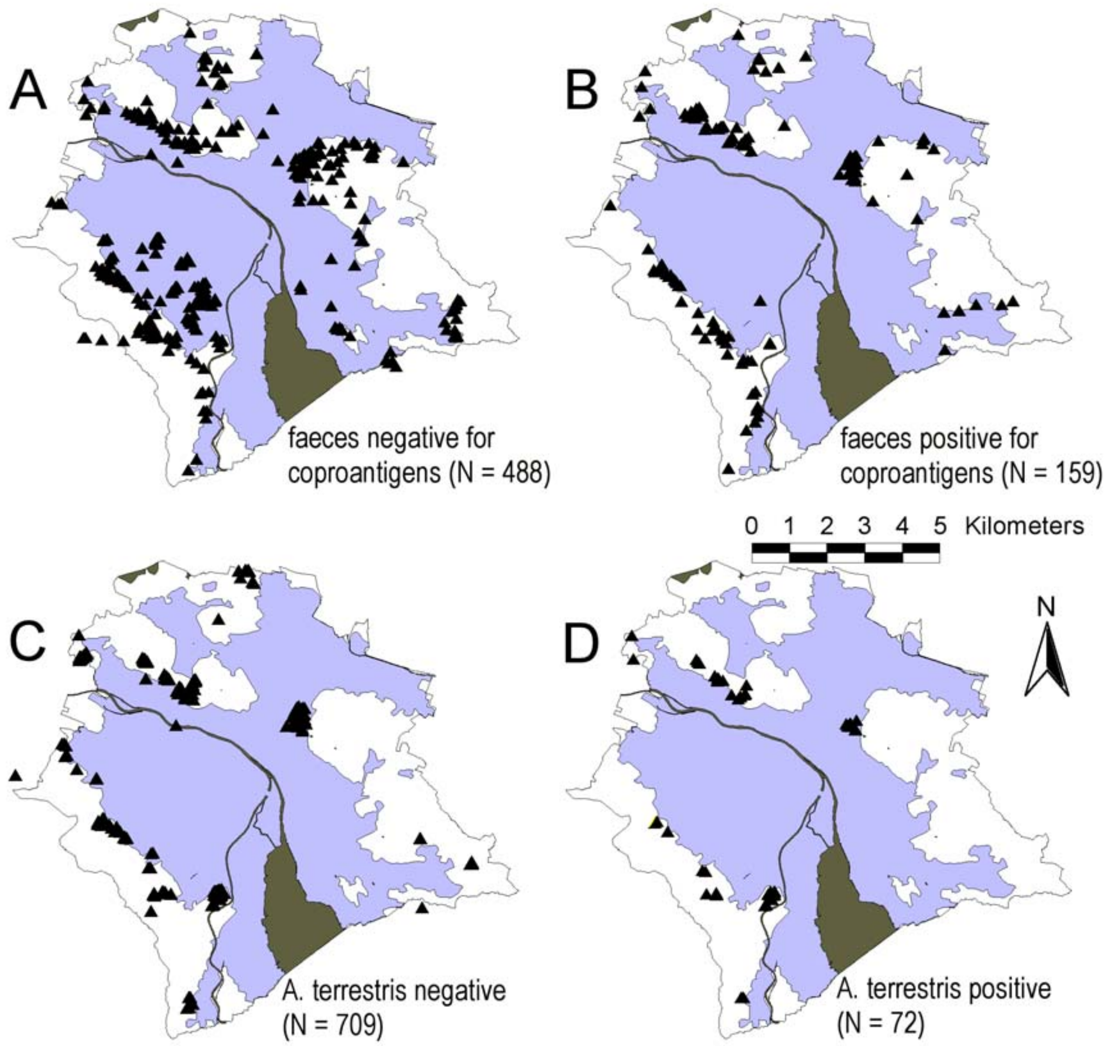


Fig. 4 (A-D): Distribution of coproantigen negative and positive faeces (A and B), and of *Arvicola terrestris* negative and positive for Echinococcus multilocularis (C and D) in the city of Zürich (Switzerland). Dark grey: rivers and lakes; bright grey: densely populated area; white: recreational area; black line: border of the city.

4. *E. multilocularis* infection in urban domestic carnivores

Our data show that an urban wild-life cycle of *E. multilocularis* in Zürich does exist and hence, a potential infection risk not only for urban residents, but also for domestic dogs and cats which may acquire the infection by preying on metacestode-infected rodents. In certain epidemiological situations in Alaska and China high prevalences of *E. multilocularis* have been found in domestic dogs (1-12%) which apparently were mainly responsible for the transmission of the infection to humans [3, 4]. In other endemic areas, e.g. Europe, USA, Japan, the epidemiological significance of domestic carnivores is uncertain. In France and Germany, studies performed on dogs and cats at necropsy revealed local *E. multilocularis* prevalences of

0.5% to 5.6% [38, 39]. Such necropsy studies have the disadvantage that the animals mostly represent a selected population and only low numbers of animals can be examined. Nowadays, modern techniques allow surveys of larger populations of living animals. Low *E. multilocularis* prevalences of 0.3% and 0.4%, respectively, were found in Switzerland in 660 randomly selected living domestic dogs and in 263 cats by detection of specific coproantigen and confirmation of positive results by PCR [33]. Higher infection rates of 7% in 86 dogs and of 3% in 33 cats were discovered in a rural area of western Switzerland with a high prevalence of *E. multilocularis* in fox and rodent populations [40].

The high prevalence of *Taenia taeniaeformis* (11.4%) in the *Arvicola terrestris* population in the city of Zürich, and the fact that *T. taeniaeformis* was not found in foxes in this area [9] indicate that domestic cats also could acquire *E. multilocularis* infections. However, the zoonotic significance of *E. multilocularis* infections in cats is probably low due to a retarded development and strongly reduced egg production of the worms [41].

Irrespective of the relative significance of dogs and cats for contaminating the environment with *E. multilocularis* eggs it should be stressed that all dogs and cats in endemic areas with access to rodents should be regarded as potential sources of human infection [42].

5. Future control of AE in urban areas

In view of the stable epidemiological situation of human AE in Switzerland [see introduction] there doesn't seem to be an urgent requirement for control measures against *E. multilocularis*. Nevertheless, the high prevalence of *E. multilocularis* in a growing urban fox population and the emerging public awareness concerning urban zoonosis might force officials to implement control strategies in the future. Therefore, active and thoroughly planned information campaigns about the presence of this zoonosis and its associated potential risks should be carried out [43] paralleled by further research on possible control strategies.

A reduction of the abundance of intermediate hosts is very difficult and ecologically questionable. The impact of fox culling is controversially discussed and is dependent on different parameters (e.g. [44]). A study on an urban fox population in London showed that hunting mainly affects the population structure and that a reduction in fox numbers can hardly be achieved with conventional control methods [13]. Culling could even have a counterproductive effect on zoonosis prevention [45], because recolonization of areas and spatial perturbation caused by culling could facilitate disease transmission.

A control strategy by repeated treatment of rural foxes with baits containing 50 mg praziquantel (20 baits per km2 distributed by aircraft) over large areas in Germany has shown that the prevalence of the parasite can be significantly reduced in the fox population. [7, 8]. However, the long-term effects and the cost-effectiveness remain to be determined. Fox baiting in urban areas has so far not been critically studied, not even for rabies control.

In a preliminary investigation we documented the uptake of baits in urban areas by means of camera traps. These results revealed that domestic cats and foxes were most frequently photographed at baiting places but neither cats nor the few observed stone martens and badgers did eat the baits [D. Hegglin, unpublished data]. Most of the 144 baits delivered in summer 1999 were taken up within three days by foxes (39 baits), followed by hedgehogs (14 baits) and domestic dogs (2 baits).

The cycle of *E. multilocularis* in urban settings seems to be determined by the small home ranges of foxes and the distribution of suitable intermediate hosts. Therefore, local interaction in the cycle reducing the infection pressure in defined areas (e.g. public parks, swimming pool areas, private gardens) should be feasible. Field studies in Zürich on the control of the *E. multilocularis* infection in urban areas by distributing praziquantel-containing baits manually are currently being carried out. Similarly, a baiting campaign is planned in Sapporo (Japan) [Y. Oku, personal communication].

Acknowledgements

We acknowledge the support of our research activities by the Swiss National Science Foundation (grant no. 31-47031.96), the Swiss Federal Office of Veterinary Medicine, Berne and the Swiss Federal Office for Education and Science (EU FAIR Projekt CT97-3515 / BBW Nr. 97.0586).

References

[1] J. Eckert and P. Deplazes. Alveolar echinococcosis in humans: The current situation in Central Europe and the need for countermeasures. *Parasitology Today* **15** (1999) 315-319.

[2] A.F. Pétavy, S. Deblock and S. Walbaum. Life cycles of *Echinococcus multilocularis* in relation to human infection. *Journal of Parasitology* **77** (1991) 133-137.

[3] P.M. Schantz, J. Chai, P.S. Craig, J. Eckert, D.J. Jenkins, C.N.L. Macpherson and A. Thakur.. Epidemiology and control of hydatid disease. In: R.C.A. Thompson and A.J. Lymbery (eds.), *Echinococcus* and Hydatid Disease. CAB International, Wallingford, Oxon, UK, 1995, pp. 233-331.

[4] P.S. Craig, P. Giraudoux, D. Shi, B. Bartholomot, G. Barnish, P. Delattre, J.P. Quere, S. Harraga, G. Bao, Y. Wang, F. Lu, A. Ito and D.A. Vuitton. An epidemiological and ecological study of human alveolar echinococcosis transmission in south Gansu, China. *Acta Tropica* **77** (2000) 167-177.

[5] R. Lucius and B. Bilger. *Echinococcus multilocularis* in Germany: Increased awareness or spreading of a parasite? *Parasitology Today* **11** (1995) 430-434.

[6] EurEchinoReg. European Network for Concerted Surveillance of Alveolar Echinococcosis: Final Report. (http://www.eurechinoreg.org). Community Program for Prevention of AIDS and some other Communicable Diseases. European Commission. Unité de Recherche SERF, Université de Franche-Comté, F-25030 Besançon, 1999.

[7] T. Romig, B. Bilger, A. Dinkel, M. Merli and U. Mackenstedt. *Echinococcus multilocularis* in animal hosts: new data from western Europe. *Helminthologia* **36** (1999) 185-191.

[8] J. Eckert, F.J. Conraths and K. Tackmann. Echinococcosis: an emerging or re-emerging zoonosis? *International Journal for Parasitology* **30** (2000) 1283-1294.

[9] S. Hofer, S. Gloor, U. Müller, A. Mathis, D. Hegglin and P. Deplazes. High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zürich, Switzerland. *Parasitology* **120** (2000) 135-142.

[10] S. Harris and J.M.V. Rayner. A discriminant analysis of the current distribution of urban foxes (*Vulpes vulpes*) in Britain. *Journal of Animal Ecology* **55** (1986) 605-611.

[11] S. Harris and J.M.V. Rayner. Models for predicting urban fox (*Vulpes vulpes*) numbers in British cities and their application for rabies control. *Journal of Animal Ecology* **55** (1986) 593-603.

[12] S. Harris and J.M.V. Rayner. Urban fox (*Vulpes vulpes*) population estimates and habitat requirements in several British cities. *Journal of Animal Ecology* **55** (1986) 575-591.

[13] S. Harris. Distribution, habitat utilization and age structure of a suburban fox (*Vulpes vulpes*) population. *Mammal Review* **7** (1977) 25-39.

[14] D.W. Macdonald and M. Newdick. The distribution and ecology of foxes, *Vulpes vulpes*, in urban areas. In: R. Bornkamm, J. A. Lee, and M. R. Seeward (eds.), Urban Ecology. Blackwell Scientific Publications, Oxford, 1982, pp. 123-135.

[15] U. Müller, A. Kappeler, R.G. Zanoni, and U. Breitenmoser. Der Verlauf der Tollwut in der Schweiz – Landschaft prägt die Ausbreitung einer Wildtierepidemie. *Schweizer Archiv für Tierheilkunde* **142** (2000) 431-438.

[16] U. Breitenmoser, U. Müller, A. Kappeler, R.G. Zanoni. Die Endphase der Tollwut in der Schweiz. *Schweizer Archiv für Tierheilkunde* **147** (2000) 447-453.

[17] A. Vos. Reproductive performance of the Red fox, *Vulpes vulpes*, in Garmisch-Partenkirchen, Germany, 1987-1992. *Zeitschrift für Säugetierkunde* **59** (1994) 326-331.

[18] A.I. Wandeler, S. Capt, A. Kappeler and R. Hauser. Oral immunization of wildlife against rabies: concept and first field experiments. *Review of Infectious Diseases* **10** (1988) 649-653.

[19] M. Artois, M. Langlais, and Ch. Suppo. Simulation of rabies control within an increasing fox population. *Ecology Models* **97** (1997) 23-34.

[20] S. Gloor, F. Bontadina, D. Hegglin, P. Deplazes and U. Breitenmoser. The rise of urban fox populations in Switzerland. *Mammalian Biology* (2001) in press.

[21] H. Christensen. Urban fox population in Oslo. *Revue d'ecologie la terre et la vie* **40** (1985) 185-186.

[22] S. Moller Nielsen. The food of rural and suburban woodland foxes, *Vulpes vulpes*, in Denmark. *Natura Jutlandica* **23** (1990) 25-32.

[23] C.A. Adkins and P. Stott. Home ranges, movements and habitat associations of red foxes, *Vulpes vulpes*, in suburban Toronto, Ontario, Canada. *Journal of Zoology* **244** (1998) 335-346.

[24] H. Tsukada, Y. Morishima, N. Nonaka, Y. Oku and M. Kamiya. Preliminary study of the role of red foxes in *Echinococcus multilocularis* transmission in the urban area of Sapporo, Japan. *Parasitology* **120** (2000) 423-428.

[25] F. Bontadina, P. Contesse and S. Gloor. Beeinflusst die persönliche Betroffenheit die Einstellung gegenüber Stadtfüchsen? - Aspekte zur Akzeptanz eines Wildtieres im Siedlungsgebiet. *Forest, Snow and Landscape Research* (2001) in press.

[26] S. Harris. An estimation of number of foxes (*Vulpes vulpes*) in the city of Bristol, and some possible factors affecting their distribution. *Journal of Applied Ecology* **18** (1981) 455-465.

[27] C.P. Doncaster, C.R. Dickman and D.W. Macdonald. Feeding ecology of red foxes (*Vulpes vulpes*) in the city of Oxford, England. *Journal of Mammalogy* **71** (1990) 188-194.

[28] Anonymous. Federal Office for Statistics. Statistik der Schweizer Städte. In: Statistisches Jahrbuch des Schweizerischen Städteverbandes. Bundesamt für Statistik, Bern, 1998.

[29] C.P. Doncaster and D.W. Macdonald. Drifting territoriality in the red fox, *Vulpes vulpes*. *Journal of Animal Ecology* **60** (1991) 423-439.

[30] W.J. Trewhella, S. Harris and F.E. McAllister. Dispersal distance, home-range size and population density in the red fox (*Vulpes vulpes*): a quantitative analysis. *Journal of Applied Ecology* **25** (1988) 423-434.

[31] C.M.O. Kapel and I. Saeed. *Echinococcus multilocularis* – en ny zoonotisk parasit i Danmark. *Dansk Veterinaertidsskrift* **83** (2000) 14-16.

[32] A. Mathis and P. Deplazes. Role of PCR-DNA detection of *Echinococcus multilocularis*. (2001) in this issue.

[33] P. Deplazes, P. Alther, I. Tanner, R.C.A. Thompson and J. Eckert. *Echinococcus multilocularis* coproantigen detection by enzyme-linked immunosorbent assay in fox, dog and cat populations. *Journal of Parasitology* **85** (1999) 115-121.

[34] A. Mathis, P. Deplazes and J. Eckert. An improved test system for PCR-based specific detection of *Echinococcus multilocularis* eggs. *Journal of Helminthology* **70** (1996) 219-222.

[35] N. Nonaka, H. Tsukada, N. Abe, Y. Oku, M. Kamiya. Monitoring of *Echinococcus multilocularis* in red foxes in Shiretoko, Japan, by coproantigen detection. *Parasitology* **117** (1998) 193-200.

[36] F. Raoul, P. Deplazes, N. Nonaka, D. Vuitton and P. Giraudoux. Can *Echinococcus multilocularis* coproantigen detection in fox faecal samples collected in the field be used to identify high and low endemicity areas? *Acta Parasitologica* **45** (2000) 238.

[37] P. Deplazes and B. Gottstein. A monoclonal antibody against *Echinococcus multilocularis* Em2 antigen. *Parasitology* **103** (1991) 41-49.

[38] A.F. Pétavy, F. Tenora, S. Deblock, V. Sergent. *Echinococcus multilocularis* in domestic cats in France: A potential risk factor for alveolar hydatid disease contamination in humans. *Veterinary Parasitology* **87** (2000) 151-156.

[39] WHO/OIE. Manual on Echinococcosis in Humans and Animals. Eckert, J., Gemmell, M.A., Meslin, F.-X., Pawlowski, Z. (eds.), Office International des Épizooties, Paris, 2001, in press.

[40] B. Gottstein, F. Saucy, P. Deplazes, J. Reichen, G. Demierre, Ch. Zürcher, A. Busato, P. Pugin. Is a high prevalence of *Echinococcus multilocularis* in wild and domestic animals associated with increased disease incidence in humans? *Emerging Infectious Diseases* (2001) in press.

[41] R.C.A. Thompson. Biology and systematicsof *Echinococcus.* In: R.C.A. Thompson and A.J. Lymbery (eds.), *Echinococcus* and Hydatid Disease. CAB International, Wallingford, Oxon, UK, 1995, pp. 1-50.

[42] P. Deplazes and J. Eckert. Veterninary aspects of alveolar echinococcosis – a zoonosis of public health significance. *Veterinary Parasitology* (2001) in press.

[43] F. Bontadina, S. Gloor, D. Hegglin, T. Hotz and Ch. Stauffer. INFOX – Kommunikation für ein konfliktarmes Zusammenleben von Menschen und Stadtfüchsen. *Forest, Snow and Landscape Research* (2001) in press.

[44] M.J. Heydon and J.C. Reynolds. Fox (*Vulpes vulpes*) management in three contrasting regions of Britain, in relation to agricultural and sporting interests. *Journal of Zoology* **251** (2000) 237-252.

[45] F.A.M. Tuyttens, R.J. Delahay, D.W. Macdonald, C.L. Cheeseman, B. Long and C.A. Donnelly. Spatial perturbation caused by a badger (Meles meles) culling operation: implications for the function of territoriality and the control of bovine tuberculosis (Mycobacterium bovis). Journal of Animal Ecology 69 (2000) 815-828.

Manuskript F (submitted):
Baiting red foxes in urban area: a camera trap study

Daniel Hegglin[1,2], Fabio Bontadina[3], Sandra Gloor[3], Uli Müller[4], Urs Breitenmoser[4] and Peter Deplazes[1]

[1] Institute of Parasitology of the University of Zürich, Switzerland.
[2] Zoological Museum of the University of Zürich, Switzerland.
[3] Urban Ecology and Wildlife Research, Zürich, Switzerland.
[4] Swiss Rabies Centre, Institute of Veterinary Virology, University of Bern, Switzerland.

Key words: bait competition, Echinococcus multilocularis, fox tapeworm, management strategy, photo trap, rabies, urban wildlife, Vulpes vulpes, zoonoses

submitted to Journal of Wildlife Mangement

Abstract

In recent years the increasing red fox population (*Vulpes vulpes*) of central and western Europe began invading urban habitats. As a result foxes live today in close vicinity to humans and their pets in many cities. As rabies is not yet extinct in Europe, and the small fox tapeworm *Echinococcus multilocularis* - a helminth that causes Alveolar Echinococcosis (AE), a severe human liver disease – is widespread in European fox populations, there is an increasing demand for effective fox baiting strategies in urban areas. In this study, bait uptake was evaluated using camera traps in Zurich, Switzerland. Baits with and without the anthelmintic Praziquantel were placed in several ways (exposed, covered and buried), at different locations (at dens, compost heaps and fox tracks) and in different seasons (early summer, summer, winter). In 756 trap nights, 91 of 252 surveyed baits (36%) disappeared within 3 days. Although the presence of camera traps significantly lowered the overall bait disappearance rate compared to the control sample without camera traps, most of the baits were consumed by foxes (44 baits). The other bait consuming species were hedgehogs (*Erinaceus europeus,* 17 baits), snails (9), dogs (8) and rodents (4). In 9 cases, identification of the bait consuming species was not possible. Domestic cats, stone martens (*Martes foina*) and badgers (*Meles meles*) never accepted the baits. Logistic regression revealed significant differences in bait uptake of foxes by location type, season, bait type and general activity of foxes at the different sites. Highest bait uptake by foxes was during summer, at compost heaps, for baits containing the anthelmintic agent Praziquantel and at places where a high general fox activity was detected. To achieve high fox specificity, baits in urban areas should be slightly buried. A short prebaiting period does not increase the uptake of baits, but the addition of the anthelmintic agent Praziquantel can minimise the competition with other species. Hence a combination of a rabies vaccine and Praziquantel in baits would not lower the efficiency of an oral vaccination campaign.

Introduction

On the European Continent, a heavy rabies epizootic caused an extreme decline of fox population densities in the 1960s and 1970s (Breitenmoser et al. 2000). Due to an oral vaccination campaign, using commercial vaccine baits with an attenuated virus (Virbac SAG2), fox populations in Switzerland recovered after 1984 and rabies came to an end in 1996 (Wandeler et al. 1988, Breitenmoser et al. 2000). Today, the population density of red fox, the only vector species of terrestrial rabies in Switzerland, is even higher than in different European countries before the rabies epizootic (Breitenmoser et al. 2000, Chautan et al. 2000). Apart from these population trends in rural areas, in the past 15 years foxes have started to colonize many European cities (Christensen 1985, Moller 1990, Gloor et al. 2001). Nowadays, the situation is similar to that in Great Britain (Gloor 2002), where urban foxes have been well known for over sixty years (Teagle 1967, Beames 1972, Harris 1977, Macdonald and Newdick 1982), and urban fox populations reach higher densities than in most rural areas (Harris 1981, Harris and Rainer 1986). It was speculated that the high number of foxes in cities and villages, in close contact with domestic pets and humans, could increase the risk of zoonoses, such as rabies and Alveolar Echinococcosis (AE) – a severe human liver disease caused by the small fox tapeworm *Echinococcus multilocularis* (Bacon and Macdonald 1981, Harris et al. 1991, Eckert and Deplazes 1999).

In Zurich, 47% of the urban foxes are infected with *E. multilocularis* (Hofer et al. 2000). Urban areas, intensively used by the public, such as public parks, allotment gardens or private gardens, are contaminated with fox feces containing *E. multilocularis* eggs, which are the source of infections for AE (Stieger et al. 2002). Studies in rural areas have already shown that the prevalence of this parasite in foxes, the main definitive host, can be reduced by distributing baits containing the anthelmintic Praziquantel (Schelling 1997, Tackmann and Conraths 2000). Because of the increasing urban fox populations and the existence of the parasite cycle within urban areas questions are raised about possible countermeasures against this parasite in densely populated areas (Deplazes et al. 2002).

Up to now, urban areas were considered as barriers in rabies control strategies on European Continent (Steck et al. 1980), but the invasion of urban areas by foxes changed this situation dramatically and new strategies have to be developed for the case of a possible new rabies outbreak (Harris et al. 1988, Saunders et al. 1997, Baker et al. 2001). In Great Britain, poisoned baits were planned to be delivered in urban areas in the event of a rabies outbreak (Harris et al. 1991). However, the effectiveness of this strategy has been questioned (Bacon and Macdonald 1980) and after the experience of the successful oral vaccination campaigns during the last rabies epizootic on the European Continent (Müller et al. 2000), the distribution of baits containing poison in urban areas would hardly find acceptance by the public. In our study we therefore focused on control strategies based on oral vaccination campaigns.

An effective baiting strategy is characterized by high bait acceptance of the target-species and low bait acceptance of non–target species (Guthery 1984). In urban area different factors can complicate the successful uptake of baits. Dogs, cats and different wild mammals (e. g. stone martens, raccoons) can reach very high population densities in cities and may strongly compete for distributed baits (Hadidian 1989, Andelt 1996). Different food supply for foxes can alter the relative attractiveness of baits and reduce bait acceptance in urban habitats (Wandeler 2000). However, the high population densities with more than 10 adult foxes per km^2 (Gloor 2002) demand a very effective baiting strategy to reduce the rabies susceptible population below the threshold density (Anderson 1986, Smith and Harris 1991, White et al. 1995). At the same time an urban baiting strategy should guarantee a low risk for contact by humans and domestic animals with the vaccine, especially if baits contain live attenuated rabies vaccine (Rosatte 92, Wandeler 2000).

The aim of this study was to provide basic data for an effective strategy to reach foxes with baits in urban areas. We evaluated the significance of other urban species, which can compete for baits, and identified factors affecting bait uptake by foxes and species specificity of bait delivery.

Methods

Study Area

The study was carried out in the city of Zurich, the largest urban area of Switzerland with some 1,000,000 inhabitants total and 352,000 inhabitants in the actual Community of Zurich. As far as hunting is concerned, Zurich is organized as a game sanctuary and covers an area of 92 km^2 consisting of 53% urban area, 24% forest, 17% agricultural area and 6% water (Statistical department of the city of Zurich 2000). The experiments were carried out in the urban area of the Zurich.

Urban Wildlife

Foxes have reached a high population density in the urban area with more than 10 adults per km^2 (Gloor 2002). They are mainly organized in family groups with three or more adults. Home ranges are generally small (100% MCP mean seasonal home range size: females 28.8 ± 22.7 ha, males 30.8 ± 11.0 ha) and have strong

Table 1. Estimated number of animals (No. estimated), number of animals found dead per year (No. dead) and number of animals shot per year (No. shot) in the community of Zurich (92 km^2), Switzerland.

species	No. estimated	No. dead	No. shot
red fox	600 [a]	127 [b]	100 [b]
domestic cat	20,000 [c]	n.i.	n.i.
domestic dog	6,500 [d]	n.i.	n.i.
hedgehog	2,000 – 5,000 [e]	n.i.	n.i.
stone marten	n.i.	11 [b]	17 [b]
badger	140 [b]	9 [b]	0 [b]
roe deer (*Capreolus capreolus*)	300 [b]	64 [b]	72 [b]
carrion crow (*Corvus corone*)	n.i.	n.i.	287 [b]

n.i.: no information available
[a]Estimation according to Gloor et al. (Gloor 2002)
[b]Game sanctuary report of the city of Zurich 99/00
[c]Estimation according to information from a Swiss pet food producer (EFFEMS, personal communication)
[d]Dog tax of Zurich (data 2000)
[e]Report of department for public areas of the city of Zurich (green department of the city of Zurich 1992)

overlapping with the home ranges of other members of a family group (Gloor 2002).

Different species of domestic and wild animals that potentially compete for the baits also occur in high numbers in the city (Table 1). Population densities of hedgehogs, domestic cats and dogs by far exceed the population density of foxes. According to the information of the local animal welfare organization (S. Gloor, Zürcher Tierschutz, personal communication) only a few stray cats and stray dogs live in Zurich. People usually walk their dogs on a leash.

Baits

The commercially available baits weighed 13.5 g (Impfstoffwerk Dessau Tornau GmbH, Germany) and their matrix consisted of Altrofox 91, which is the same matrix as in the widely used rabies vaccine bait Rabifox® (Impfstoffwerk Dessau Tornau GmbH, Germany). Half of the baits contained 50 mg of the anthelmintic Praziquantel (Droncit® Bayer AG, Germany).

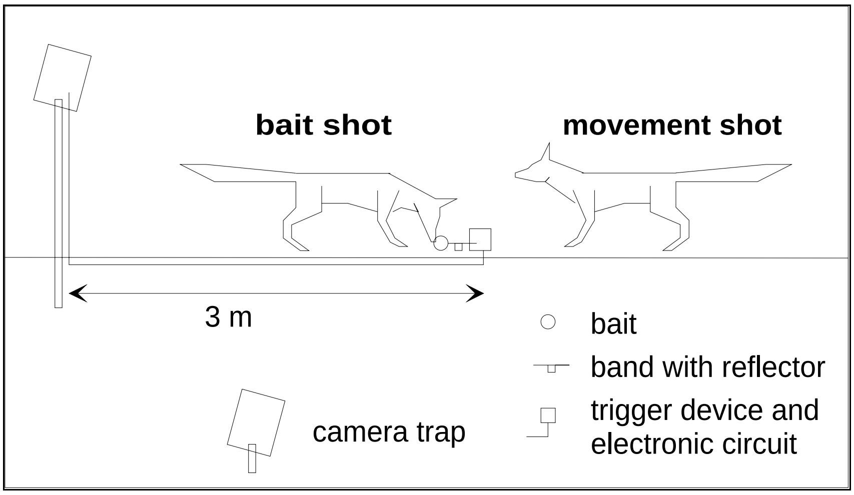


Fig. 1. Arrangement of camera trap, trigger device and bait (bold: type of picture) in Zurich, Switzerland, 1999–2000.

Camera Traps and Different Types of Pictures

The camera traps were built by the mechanical institute of the Theodor Kocher Institute (University of Bern). They were composed of a compact camera (BRAUN Trend DX AF 3 and AF–C, 35mm, auto–focus), two passive–infrared movement sensors, an electronic control and a solid waterproof plastic box. The camera trap recorded date and time of each exposure (data back). A BASIC–Stamp (Parallax, Inc., California, USA) allowed the coding of complex control programs (PBASIC interpreter).

Each bait was placed at a distance of about three meters from the camera trap. Baits were linked with a short (10 cm), loosely fixed plastic band with the camera trigger device. A small piece of reflector foil was attached to the plastic band which reflected in the case of the photo flash. We were therefore able to assess the bait presence on each picture (Fig. 1). The program for the camera traps allowed for pictures of the following types:

1. *Bait shot*. The off–take of a bait closed an electric circuit and triggered the camera trap three times with an intermission of eight seconds. To ensure the identification of the bait consumer, three additional pictures were taken if the movement sensors were activated. The first picture that allowed the identification of the bait consumer was defined as the *bait shot* (Fig. 1). The other pictures were excluded from analyses.
2. *Movement shot*. The activation of both movement sensors triggered the camera trap. The resulting pictures are defined as *movement shots*. After one *movement shot*, the camera was blocked for 15 minutes from taking further *movement shots* (but not *bait shots*). The number of *movement shots* was limited to eight pictures per 24 hours to save footage (Fig. 1).

3. *Opportunity shot*. For every picture it was considered whether a photographed animal had access to the bait. Accordingly all *movement shots* that were taken before the bait was removed and all *bait shots* were additionally classified as *opportunity shots*.

We defined *bait acceptance* as the number of removed baits divided by the number of *opportunity shots* expressed in percentages.

Experimental Design

We selected 24 different sites in the urban area (private gardens, allotments, industrial areas, cemeteries), where we installed two camera traps at a distance of 10 to 20 m from each other. A bait containing Praziquantel was placed in front of one camera and a bait without this agent in front of the other to assess the influence of Praziquantel on the attractiveness of the baits. Since prebaiting can improve bait acceptance of some species (e. g. Tietjen 1982, Sughihara 1995), after three days new baits were placed to all baiting sites. This procedure was repeated twice and after nine days the traps were removed. Every time a bait was replaced, the method of placement was changed (exposed, covered or buried). The order was balanced according to selected location type (fox den, compost heap, fox track). Both baits at one site (with/without Praziquantel) were always placed in the same manner.

We selected six fox dens with cubs for a first experiment. This experiment was conducted during the early summer of 1999 (from June 6, 1999 to July 30, 1999). For the main experiment we selected another six fox dens with cubs and additionally, six compost heaps and six fox tracks. The selection of these camera trapping sites was based on the results of a telemetry study on urban foxes carried out in the same area (Gloor 2002). We selected the trap sites in a way that members of one family group did not have access to different sites of one location type. Baits were delivered to these 18 camera trap sites in summer 1999 (July 20 to August 27, 1999) and in winter 2000 (January 25 to March 3, 2000).

Control

The camera traps were previously tested in a different project during 1997 (August 26, 1997 to September 18 1997). In this study we set the camera traps in the same area, but without the use of bait. With this data, we tested whether the number of *activity shots* is mainly a result of an attractive effect of the baits or whether it gives a general impression of the presence of different species around the baiting place. We compared the data from 1997 (20 camera trap sites, 167 trap nights) with the data from summer 1999 (18 camera trap sites, 324 trap nights).

We also tested the effect of the camera traps on the disappearance rate of the delivered baits. In the summer of 2000 we therefore delivered baits in exactly the same way at the same places as in summer 1999, but without the use of a camera trap and trigger device.

Statistical Analyses

Statistical analyses were performed with SPSS–PC Version 10.0. A stepwise forward logistic regression was used to control for the influence of the following variables on bait uptake by foxes (dependent variable "uptake by fox": [1] bait not taken by fox, [2] bait taken by fox): "location" ([1] fox den, [2] compost heap, [3] fox track); "season" ([1] early summer, [2] summer, [3] winter); "method of placing" ([1] exposed, [2] covered with surrounding material [3] slightly buried in the soil); "type of bait" ([1] with Praziquantel, [2] without Praziquantel); "bait number" ([1] first bait at one location, [2] second bait, [3] third bait); "fox activity" (mean number of *movement shots* of foxes during three days).
We compared differences in *bait acceptance* and bait uptake among different species by χ^2 tests. If the minimum entry in the table of expectation was less than 5, P–values were calculated with the program Actus (Estabrook and Estabrook 1989) that performs randomized contingency tables and gives probabilities for deviations from expected values. Further univariate statistical analyses were performed with Mann–Whitney U–test and Kruskal–Wallis test. All P values were Bonferroni corrected (Rice 1989).

Results

Control

Comparison of baited versus non–baited sites revealed that the baits had no particular attracting effect on foxes. The mean number of *activity shots* per trapping night was 0.54 ± 0.11 SE in 1997 and 0.48 ± 0.12 SE in 1999. Additionally for dogs, badgers and martens we recorded no significant difference between camera traps with and without baits. Hedgehogs were photographed 0.038 ± 0.019 SE times per night when baits were absent and 0.238 ± 0.010 SE times per night when baits were present. Due to Bonferroni correction this difference was not significant. The only species significantly attracted by the presence of baits were domestic cats. Without baits 0.25 ± 0.08 SE pictures and with baits 0.90 ± 0.16 SE pictures per night were recorded (Mann–Whitney U–test: $Z = -3.62$, $P < 0.01$).
We also compared the disappearance of 108 baits with camera traps (summer 1999) and 108 baits without camera traps (summer 2000) within three days. Overall we found a significant lower disappearance rate for baits with camera traps (46%) than for baits without camera traps (75%; $\chi^2 = 18.6$, $P < 0.001$).

For experiment and control we looked at the influence of the variables “location”, “method of placing”, “type of bait” and “bait number” on the disappearance rate with a stepwise forward logistic regression. In both analyses “method of placing” was the only variable that had a significant effect on bait disappearance and entered the model (experiment: $\chi^2 = 17.9$, $P < 0.001$, $n = 36$; control: $\chi^2 = 10.8$, $P < 0.01$, $n = 36$). In both the experiment and the control, exposed and covered baits disappeared more often than the buried baits (experiment: 63.9% of exposed baits, 58.3% of covered baits and 16.7% of buried baits; control: 88.9% of exposed baits, 80.6% of covered baits and 55.6% of buried baits). Nevertheless, the camera traps did not lower the bait disappearance in general, but according to the selected location type: In the experiment more baits disappeared at compost heaps (61.1%) than at fox dens (38.9%) and fox tracks (38.9%), whereas in the control it was just the reverse with comparable disappearance rate for compost heaps (63.9%) but more disappeared baits at fox dens (83.3%) and fox tracks (77.8%).

Table 2. Number of *activity shots*, *opportunity shots*, removed baits (number of *bait shots* and number of removed baits with evidence for a certain species); percentage of removed baits and derived *bait acceptance* in Zurich, Switzerland, 1999–2000.

	activity	*opportunity*	removed baits[a]				*bait*
	shots	*shots*	*bait shots*	evidence	total	% total	*acceptance*
fox	373	258	44	0	44	48.4%	17.1%
domestic cat	525	431	0	0	0	0.0%	0.0%
domestic dog	71	46	8	0	8	8.8%	17.4%
hedgehog	79	46	14	3[b]	17	18.7%	37.0%
stone marten	32	27	0	0	0	0.0%	0.0%
badger	18	12	0	0	0	0.0%	0.0%
carrion crow	1	1	0	0	0	0.0%	0.0%
other birds	277	277	0	0	0	0.0%	0.0%
snail	n.r.	n.r.	n.r.	9[c]	9	9.9%	n.r.
rodent	n.r.	n.r.	n.r.	4[d]	4	4.4%	n.r.
not identified	n.r.	n.r.	2	7	9	9.9%	n.r.
Total	1376	1098	68	22	91	100.0%	n.r.

n.r.: not recorded

[a]22 baits disappeared although the trigger was not removed. Species were identified according to *activity shots* and traces.

[b]several *opportunity shots* of hedgehogs with contact to the bait

[c]a lot of snail mucus and no indication of other species

[d]several *opportunity shots* with rodents just near the bait

Bait Acceptance

We observed 252 baits with camera traps each for three days and nights and collected 1376 pictures. The main activity at the baiting sites was by cats, foxes and various birds (Table 2). In total, 91 baits (36.1 %) disappeared within three days. About half of the baits were removed by foxes (Table 2). The other baits were consumed by hedgehogs, dogs, mice and snails. We were not able to identify the species in three times due to technical problems. 22 baits disappeared although the trigger was not removed from the trigger device. This is only possible if the bait is treated cautiously and eaten piece by piece without being removed. Viewing the *activity shot* and looking at evidence at the baiting site indicated that most of these baits were consumed by snails, mice and hedgehogs (Table 2).

The 278 pictures of birds included a carrion crow (1 x *Corvus corone*), domestic chickens (17 x *Gallus gallus*), blackbirds (267 x *Turdus merula*) and various other songbirds (n = 9). There was no picture showing a bird manipulating the bait and it seems that the presence of birds was not associated with the presence of bait. In contrast, cats apparently were interested in the baits and often sniffed at them, as did stone martens and badgers. In 11 out of 27 pictures of martens and in 4 out of 12 of

Table 3. Results of the stepwise forward logistic regression with “uptake by fox” as dependent and “location”, “season“, “type of bait”, “fox activity”, “method of placing” and “bait number” as independent variables. “method of placing” and “bait number” did not enter the model. In italic the values for the dummy variables.

variabel	label	B	S.E.	Wald	df	P	Exp(B)
”location”				9.93	2	0.007	
location (1)	*den*	*-0.62*	*0.80*	*0.61*	*1*	*0.437*	*0.54*
location (2)	*compost*	*1.32*	*0.59*	*5.03*	*1*	*0.025*	*3.76*
”season“	*summer*	1.25	0.57	4.81	1	0.028	3.49
”type of bait”		-1.09	0.53	4.23	1	0.040	0.34
”fox activity”		0.38	0.10	14.16	1	0.000	1.46
constant		-3.52	0.67	27.30	1	0.000	0.03

badgers, the animals were oriented to the bait, and the distance between snout and bait was estimated to be less than 50 cm. Nevertheless, these species never took the bait (Table 2). On the other hand *bait acceptance* (number of removed baits / number of *opportunity shots*) by dogs was the same as by foxes (17.4% and 17.1%; χ^2 =0.003, P > 0.1) and *bait acceptance* by hedgehogs was significantly higher than the *bait acceptance* by foxes (37.0% and 17.1%; χ^2 = 4.53, P < 0.05).
For foxes, *bait acceptance* was highest at the fox dens tested during early summer (28.4%, 67 *opportunity shots*), and significantly less at fox dens tested in summer and winter (5.6%, 54 *opportunity shots*; χ^2 = 10.45, P < 0.002). A comparison of the *bait acceptance* of foxes at fox dens, compost heaps and fox tracks revealed no significant differences between summer and winter data (P < 0.05, Actus randomization test). Therefore we compared the pooled summer and winter data to investigate differences in *bait acceptance* at different location types. Foxes accepted the bait significantly more often at compost heaps (21.3%, 75 *opportunity shots*) than at fox dens (5.6%, 54 *opportunity shots*) and fox tracks (9.7%, 62 *opportunity shots*; χ^2 = 7.81, P < 0.05).

Factors Affecting Bait Uptake by Foxes

Factors possibly affecting bait uptake by foxes were tested by means of a stepwise forward logistic regression. To compute the model we counted baits consumed by species other than fox as baits not taken by fox. Since the observed acceptance at fox dens in early summer was not the same as for fox dens observed in summer and winter, we analyzed this data separately.
Only one variable entered the logistic regression model for the fox dens tested in early summer (model χ^2 10.4, P = 0.001): the number of fox *activity shots* ($R_{coef.}$

Table 4. Number of baits distributed (No. bait), number of baits consumed by foxes (No. fox) and mean fox activity (activ. $\bar{x}$) at the different location types during early summer (es), summer (su) and winter (wi) in Zurich, Switzerland, 1999–2000. Baits with Praziquantel and without Praziquantel are shown separately.

location (season)	without Praziquantel			with Praziquantel			total		
	No. bait	No. fox	activ. $\bar{x}$	No. bait	No. fox	activ. $\bar{x}$	No. bait	No. fox	activ. $\bar{x}$
fox den (es)	18	11	4.00	18	8	4.47	36	19	4.24
fox den (su)	18	0	1.17	18	2	0.56	36	2	0.86
compost heap (su)	18	6	2.44	18	7	1.78	36	13	2.11
fox track (su)	18	1	0.50	18	4	2.22	36	5	1.36
total summer	54	7	1.37	54	13	1.52	108	20	1.44
fox den (wi)	18	0	0.11	18	1	1.17	36	1	0.64
compost heap (wi)	18	0	0.33	18	3	0.78	36	3	0.56
fox track (wi)	18	1	1.28	18	0	0.39	36	1	0.83
total winter	54	1	0.57	54	4	0.78	108	5	0.68

0.41, ± 0.17 SE, Wald = 5.7, $P = 0.017$, Exp(B) = 1.51). At baiting sites with more *activity shots*, the chance that bait was taken by a fox increased. The variables “bait number”, “type of bait” and “method of placing” had no significant influence on bait uptake by foxes.

For the main experiment we additionally tested the variables “location” and “season“. The final model (Table 3) included the four predictors “location”, “season“, “type of bait” and “fox activity” (model $\chi^2 = 42.5$, $P < 0.001$) and had predictive values of 24.0% for the events “bait removed by fox“ and 96.9% for the events “bait not removed by fox“ (overall predictive value 88.7%). The variables “method of placing” and “bait number” did not enter the model. Overall most baits were consumed at fox dens in early summer and at compost heaps (Table 4). In general foxes took many fewer baits in winter. If there were generally a large number of foxes at a baiting site (*activity shots*) more baits were taken by foxes. In the main experiment, more Praziquantel–containing baits were taken by foxes than baits without this agent (Table 4). On the other hand all 4 baits consumed by mice and all 6 baits disappearing without the trigger device being activated (indicating a small animal consumed the bait piece by piece without removing it) did not contain Praziquantel.

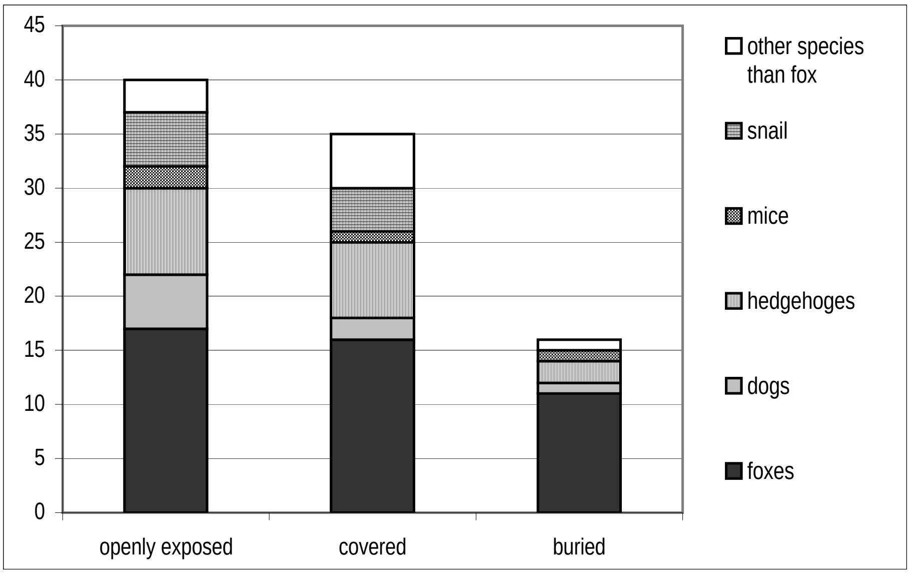


Fig. 2. Number of exposed, covered and buried baits that disappeared by different species in Zurich, Switzerland, 1999–2000. Number of delivered baits: n (openly exposed) = 84, n (covered) = 84, n (buried) = 84.

Baits tended to be more accepted by foxes if they were offered exposed or covered, but not buried. This difference was not significant. Burying baits prevented to some extent the uptake of baits by other species (Fig. 2): 23 exposed (27.4%) and 19 covered baits (22.6%), but only 5 buried baits (6.0%) were taken by animals other than foxes ($\chi^2 = 13.8$, $P = 0.001$). Furthermore, buried baits never melted as was the case for six exposed and two covered baits that were placed at sites with little shadow during early summer and summer.

Baits not Removed

Of the 252 baits monitored with camera traps, 162 baits (64.3%) did not disappear within three days. Many of the remaining baits showed a reduction in mass. In this cases snails and, to a much lower extent, other invertebrates (e. g. ants, isopods) were found directly on the baits and / or mucus of snails and signs of rodent teeth were visible on them indicating that the loss of mass can mainly be attributed to snails and rodents.
In early summer and summer significantly fewer baits were still present after three days (69 of 144 baits, 47.9%,) than in winter (93 of 108 baits, 86.1%, $\chi^2 = 39.21$, $P < 0.001$). Furthermore, the mean mass reduction of the remaining baits was significantly more pronounced in this period (early summer and summer: 20.1% ± 3.6% SE mass reduction, n = 69 vs. winter: 2.1% ± 0.7% SE mass reduction n = 93; Mann–Whitney U–test: Z = -3.28, $P < 0.001$).

The method of bait placement significantly influenced the extent of mass reduction. Burying the baits, especially in summer, when the mean mass loss was higher, prevented bait consumption by small animals (mean loss of bait mass: 6.4% ± 3.1% SE, n = 35) compared to covered baits (mean loss of bait mass: 25.0% ± 7.1% SE, n = 19) and exposed baits that experienced a huge loss of bait mass (mean loss of bait mass: 46.0% ± 8.9% SE, n = 15; Kruskal–Wallis test: $\chi^2 = 19.62$, $P < 0.001$). In summer the amount of snail mucus around exposed and covered baits was often very high, indicating intense foraging activity whereas in winter there was generally only a small amount of snail mucus around the remaining baits.

Discussion

Evaluation of Method

Field evaluations of bait uptake have usually been done by checking individually marked baits for disappearance, or by searching for a biomarker that was added to the baits in target and non-target animals (Linhart et. al., 1997). Checking baiting sites is an efficient evaluation method and, under specific conditions, it can give valuable information about species specificity (e. g. Guthery 84). In urban areas with a high amount of sealed ground and a high general activity of many animal species, this method can, however, give only vague information about possible and real bait consumers. A biomarker can ideally give a direct measure of the portion of animals reached in a target population (e.g. Kappeler 92, Olson 2000). But in practice, this method is very labor intensive because it depends on a large study area to minimize border effects and requires a large sample size of target and non-target animals. In contrast, the evaluation of bait uptake using camera traps is a non-invasive control method that yields detailed data regarding bait competition between different species under different conditions.
The comparison of camera trap sites with and without baits revealed that the activity of foxes around baiting sites is not significantly affected by the presence of bait. Therefore we can conclude that the number of *activity shots* is a valid measurement for the general activity of foxes at different baiting sites. Nevertheless, in contrast to Gürtler et al. (1982), our control experiment without camera traps provides evidence that the installation of camera traps lowered the bait disappearance rate (46% with camera traps, 75% without camera traps). This difference could also be explained by simple annual variations, but an ongoing study on the effect of distributing Praziquantel–containing baits gives evidence that bait disappearance is generally higher if baits are not monitored with a camera trap. Presumably the installation of the traps and/or the slight fixation of the bait to the trigger device increased the

wariness of potential bait consumers. We assume that this is especially true at fox dens and fox tracks where human activity is typically much less common, and therefore foxes are more cautious than at compost heaps, and therefore show lower *bait acceptance*. Accordingly we recommend placing camera traps and trigger devices several days before the baits are placed in future studies. Nevertheless, results such as the influence of the method of placing baits, are consistent with the simple monitoring of bait disappearance and indicate that camera traps provide a valid and powerful tool to evaluate baiting techniques, helping to improve existing baiting strategies.

Bait Uptake by Different Species

In rural areas of Italy, Belgium, Luxembourg and Germany the disappearance rate of similar types of baits was considerably lower than in our control experiment (baits without camera traps) and ranged between 18% and 42% (Linhart et al. 1997). Our study revealed that about half of the removed baits in an urban area were actually taken by foxes. The most important competitors for baits in urban habitats were dogs and, surprisingly, rodents, snails and hedgehogs, which can reach considerably higher population densities in urban compared to rural areas (Bontadina et al. 1993, Zingg 1994).

In Brooklyn, New York, Calhoon and Haspel (1989) recorded densities of free–ranging domestic cats of up to 4.9 individuals per ha, exceeding the highest registered population densities for urban foxes (Harris and Rayner 1986, Baker et al. 2000). The large number of *activity shots* of domestic cats (38% of all *activity shots*) indicates the abundance of free ranging cats in Zurich. Nevertheless, they never removed the baits. This points to the importance of selecting bait types that are not attractive to possible bait competitors.

The anthelmintic Praziquantel is a very bitter substance. Hence – according to the experience of veterinarians – the application of this agent is difficult for some species (e.g. domestic cats). The fact that Praziquantel-containing baits were more often consumed by foxes could at least partly be caused by the avoidance of these baits by other species. Consequently, the application of Praziquantel to urban foxes is feasible and it would be worthwhile investigating the effect of this antihelmintic on an urban cycle of *E. multilocularis*.

We assume that the lower disappearance rate at baiting sites with camera traps is mainly caused by reduced bait acceptance by foxes. According to hunters experience, game species like foxes, badgers and stone martens, can be very cautious and often do not accept baits if there was too much manipulation at a baiting site, unlike dogs, cats and hedgehogs. Based on the interest in the baits that martens and badgers exhibited in some photographs, we cannot rule out that these species may also accept baits occasionally. Nevertheless, Kappeler (1992) found a considerably lower proportion of badgers and stone martens positive for tetracyclin compared to foxes in areas where vaccine containing chicken heads have been distributed. Furthermore, these two species were photographed for fewer times than foxes (Table 2), and it is unlikely that they could be strong bait competitors due to their low relative population densities (Table 1).

Even if there is a lack of controlled rabies management experiments (Schubert 1998) there is overwhelming evidence that rabies vaccination is a very effective strategy to stop a rabies epizootic (e. g. Müller 2000). There is a general consensus that the density of foxes susceptible to the disease has to be lowered under a specific threshold value to stop the transmission of rabies (Anderson 1986). It was estimated that from 94% up to 98% (Anderson 1986) or around 75% (Smith and Harris 1991) of an urban fox population should be reached with baits. In reality these modeled values can hardly be achieved. In the urban area of Bristol (UK) baits with a blood marker were delivered to simulate a poisoning campaign. The study revealed that the baits reached an insufficient amount of 17–35% of the urban fox population (Trewhella et al. 1991). In Switzerland, culling did not have a significant effect on the rabies epizootic in the rural areas during the 1970s, when culling even during close season and the gassing of fox dens was carried out extensively (Zanoni et al. 2000).

In contrast to culling, the vaccination of foxes has the advantage that living, but immune foxes can act as barriers to the movement of infected individuals (Bacon and Macdonald 1980). Therefore lower numbers of foxes may have to be reached to prevent effectively the spread of rabies. However, a strategy of rabies control in urban areas is dependent on very effective baiting methods, which additionally could be combined with other measures to restrict urban fox population densities.

Management implications

Our results indicate urban foxes readily accepted the delivered baits and that most bait consumption was by this species. However, hedgehogs, dogs, snails and rodents were important competitors for baits in this study. For an efficient and selective baiting strategy for urban foxes the following recommendations are given:

1. Baits should be slightly buried in order to achieve a high species specificity and to prevent hedgehogs, rodents and snails from feeding on them.
2. Baiting places should be selected where domestic dogs have no or restricted access.
3. Selecting particular location types and baiting periods (e. g. fox dens during early summer) can increase the uptake rate of baits.

4. Baiting sites should be chosen not only at attractive places for foxes but especially where foxes show a high activity.
5. A short prebaiting period does not increase the uptake of baits by foxes (compare variable “bait number”).
6. Praziquantel does not reduce the uptake of baits by foxes. As other bait consumers seem to prefer baits without Praziquantel, this agent can even improve uptake. Hence a combination of a rabies vaccine and Praziquantel in one bait should not lower the efficiency of an oral vaccination campaign against rabies.

As many baits will not be consumed by foxes, it might be advisable for safety reasons to mark vaccine containing baits in urban areas and to recollect them, if they have not disappeared within several days. However, an anthelmintic treatment would not have to fulfil the same safety requirements as an oral vaccination campaign, because in contrast to rabies vaccine, the anthelmintic Praziquantel represents no risk for urban wildlife or urban inhabitants (Sweet 1987). Correspondingly the species specificity is of reduced importance and there is no need to bury Praziquantel–containing baits.

Regarding the high population densities of urban foxes and the inherent problems with the resulting demand to reach an extremely high proportion of the population with the rabies vaccine, rabies control in urban areas must also focus on other measures to lower the risk of a rabies epizootic. Reducing resources for foxes such as food supply or sheltered dens for reproduction could play an important rule in such a strategy to keep the population density at a limited level.

Acknowledgments

The authors thank all collaborators involved in the Integrated Fox Project. We especially thank J. Romer, R. Wyss, A. Klingenböck, J. Laas for their assistance in field work and their technical support. The Swiss Rabies Center of the University of Bern, Switzerland, provided the camera traps. P. Ward and D. Hosken gave valuable comments on an earlier draft of the manuscript. This investigation was carried out within the context of the Integrated Fox Project, a research and communication project on the dynamics of the fox population in Switzerland. The study was supported by the Swiss Federal Office of Veterinary Medicine, Berne and the Swiss Federal Office for Education and Science (EU FAIR Projekt CT97-3515 / BBW Nr. 97.0586).

References

Andelt, W. F., and T. P. Woolley. 1996. Responses of urban mammals to odor attractans and a bait-dispensing device. Wildlife Society Bulletin 24:111-118.

Anderson, R. M. 1986. Vaccination of Wildlife reservoirs. Nature, 322:304–305.

Bacon, P. J. and D. W. Macdonald. 1980. To control rabies: vaccinate foxes. New Scientist 87:640–645.

_____, and _____. 1981. Habitat and spread of rabies. Nature, 289:634–635.

Baker, P.J., S. M. Funk., S. Harris, and P. C. White. 2000. Flexible spatial organization of urban foxes, *Vulpes vulpes*, before and during an outbreak of sarcoptic mange. Animal Behaviour 59:127–146.

_____, P. J., S. Harris, C. P. Robertson, G. Saunders, and P. C. White. 2001. Differences in the capture rate of cage-trapped red foxes *Vulpes vulpes* and an evaluation of rabies control measures in Britain. Journal of Applied Ecology 38:823–835.

Beames, I. 1972. The spread of the fox in the London area. Ecologist 2:25-26.

Bontadina, F., S. Gloor, and T. Hotz. 1993. Igel *Erinaceus europaeus* in der Stadt Zürich. Revue Suisse de Zoologie 100:797.

Breitenmoser, U., U. Müller, A. Kappeler, and R. G. Zanoni. 2000. Die Endphase der Tollwut in der Schweiz. Schweizer Archiv für Tierheilkunde 147:447–453.

Calhoon, R. E., and C. Haspel. 1989. Urban cat populations compared by season, subhabitat and supplemental feeding. Journal of Animal Ecology 58:321–328.

Chautan, M., D. Pontier, and M. Artois. 2000. Role of rabies in recent demographic changes in red fox (*Vulpes vulpes*) populations in Europe. Mammalia 64:391-410.

Christensen, H. 1985. Urban fox population in Oslo. Revue d'Ecologie (la Terre et la Vie) 40:185-186.

Deplazes, P., S. Gloor, C. Stieger, and D. Hegglin. 2002. Urban transmission of Echinococcus multilocularis. Pages 287-297 *in* P. Craig and Z. Pawlowski, editors. Cestode Zoonoses: Echinococcosis and Cysticercosis. IOS Press, Amsterdam, Netherlands.

Eckert, J., and P. Deplazes. 1999. Alveolar echinococcosis in humans: The current situation in Central Europe and the need for countermeasures. Parasitology Today 15:315–319.

Gloor, S., F. Bontadina, D. Hegglin, P. Deplazes, U. Breitenmoser. 2001. The rise of urban fox populations in Switzerland – Die Entstehung urbaner Fuchspopulationen in der Schweiz. Mammalian Biology, 66:155–164.

_____. 2002. The rise of urban foxes (*Vulpes vulpes*) in Switzerland and ecological and parasitological aspects of a fox population in the recently colonised city of Zurich. Dissertation, University of Zurich, Zurich, Switzerland.

Gürtler, W. D., and E. Zimen. 1982. The use of baits to estimate fox numbers. Comparative Immunology, Microbiology and Infectious Diseases 5:277–283.

Guthery, F. S., and W. P. Meinzer. 1984. Evaluation of placed baits for reducing coyote damage in Texas. Journal of Wildlife Management 48:621–626.

Hadidian, J., S. R. Jenkins, D. H. Johnston, J. Savarie, V. F. Nettles, D. Manski, and G. M.

Baer.1989. Acceptance of simulated oral rabies vaccine baits by urban raccoons. Journal of Wildlife Diseases 25:1–9.

Harris, S. 1977. Distribution, habitat utilization and age structure of a suburban fox (*Vulpes vulpes*) population. Mammal Review 7:25-39.

_____. 1981. An estimation of number of foxes (*Vulpes vulpes*) in the city of Bristol, and some possible factors affecting their distribution. Journal of Applied Ecology 18:455-465.

_____, C. L. Cheeseman, G. C. Smith, and W. J. Trewhella. 1991. Rabies contingency planning in Britain. Pages 11:63–78 in P. O'Brien and G. Berry, editors. Wildlife rabies contingency planning in Australia. Bureau of Rural Resources Planning Proceedings. Australian Government Publishing Service, Canberra, Australia.

_____, and J. M. Rayner. 1986. Urban fox (*Vulpes vulpes*) population estimates and habitat requirements in several British cities. Journal of Animal Ecology 55:575-591.

_____, G. C. Smith, and W. J. Trewhella. 1988. Rabies in Urban Foxes (*Vulpes vulpes*) – Developing a Control Strategy. State Veterinary Journal 42:149–161.

Hofer, S., S. Gloor, U. Müller, A. Mathis, D. Hegglin, and P. Deplazes. 2000. High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zürich, Switzerland. Parasitology 120:135–142.

Kappeler, A. 1992. Die orale Immunisierung von Füchsen gegen Tollwut in der Schweiz. Dissertation, University of Bern, Bern, Switzerland.

Linhart, S. B., K. Kappeler, and L. A. Winderg. 1997. A Review of Baits and Bait Delivery Systems for Free–Ranging Carnivores and Ungulates. Contraception in Wildlife. Animal and Plant Health Inspection Service, United States Department of Agriculture, USA. Technical Bulletin 1853:69–132.

Macdonald, D. W., and M. Newdick. 1982. The distribution and ecology of foxes, *Vulpes vulpes* in urban areas. Pages 123-125 *in* R. Bornkamm, J. A. Lee, and M. R. Seeward, editors. Urban ecology. Blackwell Scientific Publications, Oxford, U.K.

Moller, N. S. 1990. The food of rural and suburban woodland foxes *Vulpes vulpes* in Denmark. Natura Jutlandica 23:25-32.

Müller U., A. Kappeler, R. G. Zanoni, U. Breitenmoser. 2000. Der Verlauf der Tollwut in der Schweiz – Landschaft prägt die Ausbreitung einer Wildtierepidemie. Schweizer Archiv für Tierheilkunde 142:431–438.

Olson, C. A., K. D. Mitchell, and P. A. Werner. 2000. Bait ingestion by free-ranging racoons and nontarget species in an oral rabies vaccine field trial in Florida. Journal of Wildlife Diseases 36:734–743.

Rice, W.R. 1989. Analyzing tables of statistical tests. Evolution 43: 223-225.

Rosatte, C. R., M. J. Power, C. D. MacInnes, and J. B. Campbell. 1992. Trap-vaccinate-release and oral vaccination for rabies control in urban skunks, racoons and foxes. Journal of Wildlife Diseases 28:562–571.

Saunders, G., P. C. White, and S. Harris. 1997. Habitat utilisation by urban foxes (*Vulpes vulpes*) and the implications for rabies control. Mammalia 61:497–510.

Schelling, U., W. Frank, R. Will, T. Romig, and R. Lucius. 1997. Chemotherapy with praziquantel has the potential to reduce the prevalence of *Echinococcus multilocularis* in wild foxes (*Vulpes vulpes*). Annals of Tropical Medicine and Parasitology 91:179–186.

Schubert, C. A., R. C. Rosatte, C. D. MacInnes, and T. D. Nudds. 1998. Rabies control: An adaptive management approach. Journal of Wildlife Management 62:622–629.

Smith, G. C., and S. Harris. 1991. Rabies in urban foxes (Vulpes vulpes) in Britain: The use of a spatial stochastic simulation model to examine the pattern of spread and evaluate the efficacy of different control regimes. Royal Society of London. Philosophical Transactions. Biological Sciences 334:459–479.

Steck, F., A. Wandeler, B. Nydegger, C. Manigley, and M. Weiss. 1980. Die Tollwut in der Schweiz 1967-1978. Schweizer Archiv für Tierheilkunde 122:605-636.

Stieger, C., D. Hegglin, G. Schwarzenbach, A. Mathis, and P. Deplazes. 2002. Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*. Parasitology 124:631–640.

Statistical department of the city of Zurich (2000). Statistisches Jahrbuch der Stadt Zürich 2000. Statistical department of the city of Zurich, Zurich, Switzerland.

Sugihara, R. T., M. E. Tobin, and A. E. Koehler.1995. Zinc phosphide baits and prebaiting for controlling rats in Hawaiian sugarcane. Journal of Wildlife Management 594:882–888.

Sweet, D. V. 1987. Registry of toxic effects of chemical substances. User's guide. 1985-86 Edition. U.S. Government Printing Office, Washington, USA.

Tackmann, K., and F. J. Conraths. 2000. Bekaempfung des "Kleinen Fuchsbandwurmes" *Echinococcus multilocularis* in Mitteleuropa - Moeglichkeiten und Grenzen. Berliner und Muenchener Tieraerztliche Wochenschrift, 113:139-143.

Teagle, W. G. 1967. The fox in the London suburbs. The London Naturalist 46:44-68.

Tietjen, H. P. and G. H. Matschke. 1982. Aerial prebaiting for management of prairie dogs with zinc phosphide. Journal of Wildlife Management 46:1108–1112.

Trewhella, W. A., S. Harris, G. C. Smith, and A. K. Nadian. 1991. A field trial evaluating bait uptake by an urban fox (*Vulpes vulpes*) population. Journal of Applied Ecology 28:454–466.

Wandeler, A. I. 2000. Oral immunization against rabies: afterthoughts and foresight. Schweizer Archiv für Tierheilkunde 142:455-462.

_____, S. Capt, A. Kappeler, and R. Hauser. 1988. Oral immunization of wildlife against rabies: concept and first field experiments. Reviews of Infectious Diseases 10, 649-653.

White, P. C. L., S. Harris, and G. C. Smith. 1995. Fox contact behaviour and rabies spread: a model for the estimation of contact probabilities between urban foxes at different population densities and its implications for rabies control in Britain. Journal of Applied Ecology 32:693–706.

Zanoni, R. G., A. Kappeler, U. M. Müller, C. Müller, A. I. Wandeler, and U. Breitenmoser. 2000. Tollwutfreiheit der Schweiz nach 30 Jahren Fuchstollwut. Schweizer Archiv für Tierheilkunde 142:423–429.

Zingg, R. 1994. Aktivität sowie Habitat– und Raumnutzung von Igeln (*Erinaceus europeus*) in einem ländlichen Siedlungsgebiet. Dissertation, University of Zurich, Zurich, Switzerland.

Manuskript G (for submission): Small scale anthelmintic baiting of foxes reduces urban *Echinococcus multilocularis* egg contamination

Daniel Hegglin[1], Paul I. Ward[2] and Peter Deplazes[1]

[1] Institute of Parasitology, University of Zurich, Winterthurerstr. 266a , CH-8057 Zurich, Switzerland
[2] Zoological Museum, University of Zurich, Winterthurerstr. 190, Zurich, Switzerland

Key words: anthelmintic baiting, *Arvicola terrestris*, intervention strategy, praziquantel, urban foxes, urbanization, *Vulpes vulpes*, zoonoses

for submission to Emerging Infectious Diseases

Abstract

In recent years a rise of urban fox populations has been observed in many countries of the northern hemisphere. As a result *Echinococcus multilocularis* has invaded the urban environment. Because of a possible increased risk for alveolar echinococcosis there is a need to evaluate intervention strategies. In Zurich city, Switzerland, 50 praziquantel-containing baits per km^2 were distributed monthly in six 1-km^2 bait areas and one 6-km^2 bait area between April 2000 and October 2001. The proportion of *E. multilocularis* coproantigenpositive fox feces collected in six control areas remained unchanged, but decreased significantly in the 1-km^2 bait areas from 38.6% to 5.5%, and in the 6-km^2 bait area from 66.7% to 1.8%. *E. multilocularis* prevalence in the intermediate host *Arvicola terrestris* also decreased significantly in baited areas. This controlled baiting study shows that a pronounced reduction of *E. multilocularis* egg contamination in urban high endemic areas is feasible.

Introduction

The zoonotic tapeworm *Echinococcus multilocularis* is typically perpetuated in a wild-life cycle including foxes (genera *Vulpes* and *Alopex*) as definitive hosts and various rodent species as intermediate hosts (1). Accidentally, eggs are also ingested by humans and the invasion mainly of the liver by the metacestode can cause alveolar echinococcosis (AE), a severe and even fatal disease if left untreated (2, 3).
Studies on the epidemiology of AE are scarce. Risk factors for AE may be associated with occupational and behavioral factors. However, hunters, trappers and people working with fur were not at increased risk for AE in South Dakota, USA (4). Older data from central Europe have indicated that persons working in agriculture were at increased risk of infection (5). Contamination of the rural environment with *E. multilocularis* connected with farmers activities was indirectly demonstrated by high prevalences of AE in sows kept indoors but fed with grass (6). Areas with high water vole densities (*Arvicola terrestris*) yielded a 10-fold higher risk for human AE compared to areas with low densities of this important intermediate host (7). In a high endemic rural area up to 39% of *A. terrestris* and up to 7% of dogs with free access to rodents were infected with *E. multilocularis* (8), and it was shown that people who have kept dogs around dwellings were at higher risk from AE, on St. Lawrence Island, Alaska (9).
Red foxes (*Vulpes vulpes*) are likely to be the most important final host in many regions (10). In the past two decades foxes have started to colonize cities in many countries around the world (11-13) and evidence for the establishment of the parasite cycle in urban areas is increasing (12, 14, 15). In the city of Zurich, Switzerland, 47% of the urban fox population were found to be infected with *E. multilocularis* (16).
It has been proposed that the high number of infected foxes in cities and villages, in close contact with domestic pets and humans, could increase the risk of AE (15). Whether the actual incidence rate of AE does reflect a continuing stable and low infection risk or whether the increased infection pressure in highly populated areas will lead to a delayed increase in the incidence of AE cases in the future is unclear, since the disease has a long incubation period of 5-15 years (3). However, there is evidence that ecological changes resulted in a very high AE prevalence of 4.0% in a high endemic area of China (17). The high prevalence of *E. multilocularis* in densely populated areas and the spread of foxes living in close vicinity to humans strongly suggest it would be prudent to evaluate possible intervention strategies.
There are only few field studies focussing on anthelmintic treatment of definitive hosts. Rausch et al. (9) demonstrated in a village of a hyperendemic area (St. Lawrence Island, Alaska) that continuous treatment of dogs with praziquantel reduces infection pressure of *E. multilocularis* resulting in lower prevalence in

locally trapped voles. In extended rural areas of Germany and Japan the distribution of praziquantel baits in the field was successful in lowering the prevalence of *E. multilocularis* in foxes (18-20). But these results can not be transferred to the condition of agglomerations and urban areas, where up to present no attempt has been made to evaluate an intervention strategy for foxes.

The urban cycle of *E. multilocularis* was studied intensively in the city of Zürich, Switzerland (15, 16, 21). Fox stomach analyses revealed that *Arvicola terrestris* was the most frequently consumed intermediate host (22), and an extraordinary high prevalence of *E. multilocularis* (mean 9.1%, maximum 20.9%) could be found in this vole species living predominantly along the city border (21). Accordingly, the prevalence in foxes was significantly higher in the urban periphery then in more central areas (16), and the infection risk for AE might therefore be concentrated mainly in delimited areas in the urban periphery (15). Since urban inhabitants frequently use exactly these zones of highest contamination for recreational activities and their domestic cats and dogs have access to infected voles, the urban periphery may represent a risk for AE.

In this controlled experimental field study we investigated the effect of anthelmintic baiting in defined, high endemic urban area and tested 1) if a significant reduction of *E. multilocularis* egg contamination and, 2) as an expected consequence, a lower prevalence in urban intermediate hosts can be achieved.

Methods

Study area

The study was conducted in the political community of Zurich and its near surroundings. Zurich covers 92 km^2 and has a human population of 360,000. It consists of 53% built-over area, 24% forest, 17% agricultural area and 6% water (23). We divided this area into an urban, a border and a periurban zone. The urban zone is mainly residential with little green space. The periurban zone consists of forests, fields, pastures and meadows. The border zone, which divides the urban and the periurban zone, was defined as extending 250 m from the border of the built-up area into the residential area of the city and 250 m into the periurban surroundings. It includes mostly residential areas, allotments, cemeteries, sports fields, public places and pastures. The border zone and the periurban zone are intensively used by the public for recreational activities.

As far as hunting is concerned, the city of Zurich is organized as a game sanctuary and, compared to the high population density of more than 10 adult foxes per km^2 (24) , the hunting bag (foxes shot by game wardens) was relatively low during the course of this study (1.0 shot foxes per km^2 and year).

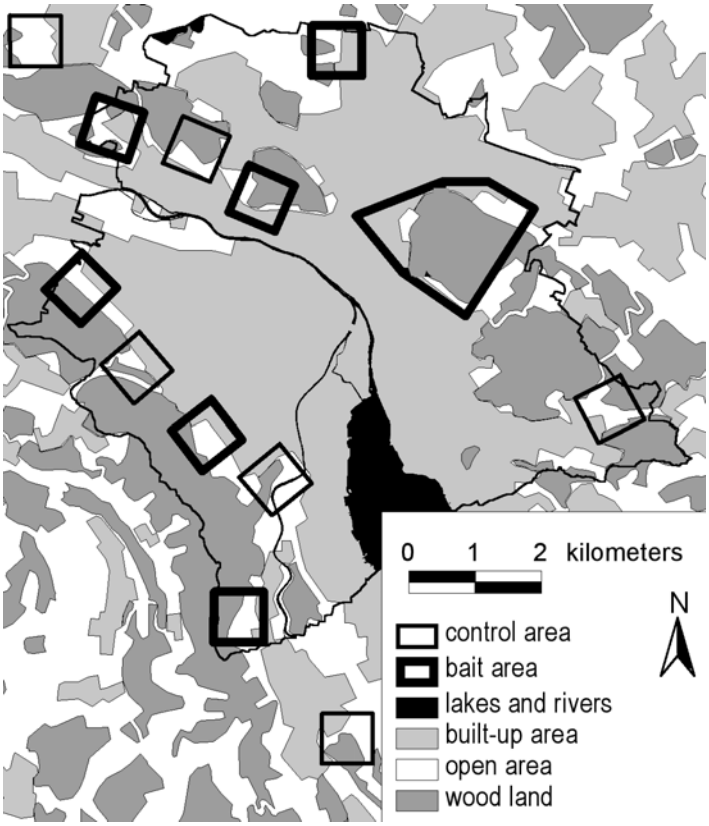


Figure 1. Study area of the controlled anthelmintic baiting experiment in the conurbation of the city of Zurich. 50 Praziquantel-containing baits per km^2 were delivered monthly in six 1-km^2 bait areas and one 6-km^2 bait area, that alternated along the urban fringe with six control areas. The border of the community of Zurich is drawn with a black line.

Baits

Commercial baits were used in the study (Impfstoffwerk Dessau Tornau GmbH, Germany). Each weighed 13.5 g and the matrix consisted of Altrofox 91. This is the same matrix as in the widely used rabies vaccine bait Rabifox® (Impfstoffwerk Dessau Tornau GmbH, Germany). The baits contained 50 mg of the anthelmintic praziquantel (Droncit® Bayer AG, Germany) a highly efficient drug against adult cestodes.

Experimental design

Along the urban periphery we selected 6 bait and 6 control areas of 1-km^2 each and an additional bait area of 6-km^2. Bait and control areas were separated by at least 600 m in order to minimize the chance of individual foxes using two areas (Figure 1). All areas included a similar amount of built-up area, open area (public parks, cemeteries, allotment gardens, meadows etc.) and woodland in a pattern typical for the urban fringe (Figure 1). In baited areas, 50 praziquantel containing baits per km^2

were distributed monthly (intervals of 25 to 35 days) during 19 months between April 2000 and October 2001. Baits were distributed manually at places that were judged to be frequented by foxes (e.g. fox tracks, fox dens, compost heaps) but not by dogs. To avoid olfactory contamination baits were always handled with rubber gloves. Baits were covered with surrounding material to protect from sun at exposed sites.

Sampling and analyses of fox feces

Fox feces were collected at least once per month in bait and control areas and their immediate vicinity during the following periods: winter 99/00 (November 1999 to February 2000), spring 00 (April to June 2000), summer/autumn 00 (July to October 2000), winter 00/01 (November 2000 to February 2001) and summer/autumn 01 (July to October 2001). Several criteria such as size, shape, homogeneity and smell of the droppings were used to distinguish fox feces from other feces (21). For each of the 1,537 collected fecal samples we recorded the exact position to an accuracy of 20 m.

E. multilocularis coproantigen detection was performed by a sandwich-ELISA (EM-ELISA) (25), which was recently validated for field fecal samples in eastern France (26) and in our study area (21). Coproantigen-positive feces, collected in bait and control areas during 2001 were further evaluated to check whether infected foxes in bait areas have predominantly fresh, prepatent infections and do not excrete *E. multilocularis* eggs. Therefore, we isolated taeniid eggs out of the fecal samples followed by *E. multilocularis* specific PCR as described previously (27).

Sampling and analyses of *A. terrestris*

In Zurich city we found the highest prevalence in the intermediate host *A. terrestris* (21). Therefore, we focused on this species to evaluate the effect of bait distribution on intermediate host populations. *A. terrestris* were trapped with unbaited tong traps (Hauptner Instrumente GmbH, Dietlikon, CH) and Topcat traps (TOPCAT GmbH, Wintersingen, CH). Traps were set in intervals of one to two months in each bait and control area from April to November 2000 and from July to October 2001. Additionally, in the 6-km^2 bait area, traps were regularly set from July 1999 to February 2000. All 1,229 dissected rodents were carefully examined macroscopically for lesions in their livers and other organs. Lesions $\geq$ 2 mm in diameter were investigated for *E. multilocularis* metacestode tissue either morphologically or by DNA detection using modified PCR (28).

Statistical analysis

Statistical analyses were performed with SPSS-PC Version 10.0. Stepwise backward logistic regression was used to test the effect of baiting on the proportion of coproantigen-positive feces and on the prevalence in *A. terrestris*. The influence of baiting was represented by the interaction between the two factors “area type” (baited versus non-baited areas) and “period” (temporal progress of the experiment). The two variables “area type” and “period” were added as blocking variables to the initial model. In addition, the two variables “season” (spring: March to June, summer/autumn: July to October, winter: November to February) and “urban area” (urban zone, border zone and periurban zone) were included in the initial model since these factors were known to affect prevalence of *E. multilocularis* (16).

Deviations from expected frequencies were tested by χ^2 tests. P-values are given two-tailed if not otherwise stated. If the minimum entry in the table of expectation was less than 5, P-values were calculated with the program Actus that performs randomized contingency tables and gives probabilities for deviations from expected values (29). Critical significance levels were Bonferroni corrected according to Rice taking into account multiple tests on the same data (30). We calculated exact binomial 95% confidence intervals for means of binomial variables according to Clopper and Pearson (31).

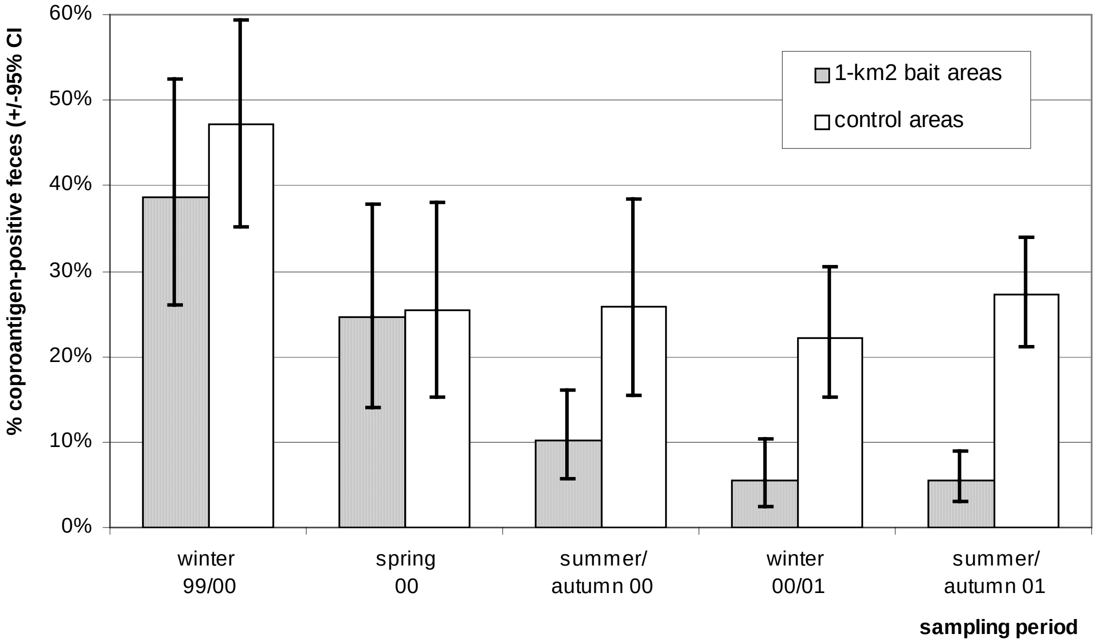


Figure 2. Proportions of *E. multilocularis* coproantigen-positive fox feces and 95% exact binomial confidence intervals in the six 1-km^2 bait areas, baited monthly with 50 praziquantel-containing baits per km^2, and the six unbaited control areas during the experiment.

Results

Baiting effect on environmental contamination

To evaluate the effect of the experimental baiting we analyzed 682 fox feces collected in the six 1-km^2 bait areas and 523 feces from the six control areas. The stepwise logistic regression revealed a significant final model (model χ^2 = 139.4, df 11, p <0.001) with a highly significant influence of anthelmintic baiting, expressed by the interaction between the two factors “area type” and “period” on the proportion of coproantigen-positive feces (Wald Statistics 20.5, df 4, p <0.001). The proportion of coproantigen-positive feces in bait areas decreased from 38.6% (95%-CI: 26.0%-52.4%) during winter 1999 to 5.5% (95%-CI: 3.1%-8.9%) in summer/autumn 2001. In the control areas the initial proportion of coproantigen-positive feces was 47.1% (95%-CI: 35.1%-59.4%) in winter 1999 and decreased to 25.4% (95%-CI: 15.3%-37.9%) in the initial phase of baiting (spring 2000), but thereafter remained stable during the baiting experiment (Figure 2). The two blocking factors “period” (Wald Statistics = 60.9, df 4, p <0.001) (Figure 2) and “urban area”(Wald Statistics = 6.0, df 2, p =0.05) also entered the final model. In the urban zone only 1 of 33 feces was coproantigen-positive (mean: 3.0%; 95%-CI: 0.0%-15.8%), whereas within the border zone and in the periurban zone the

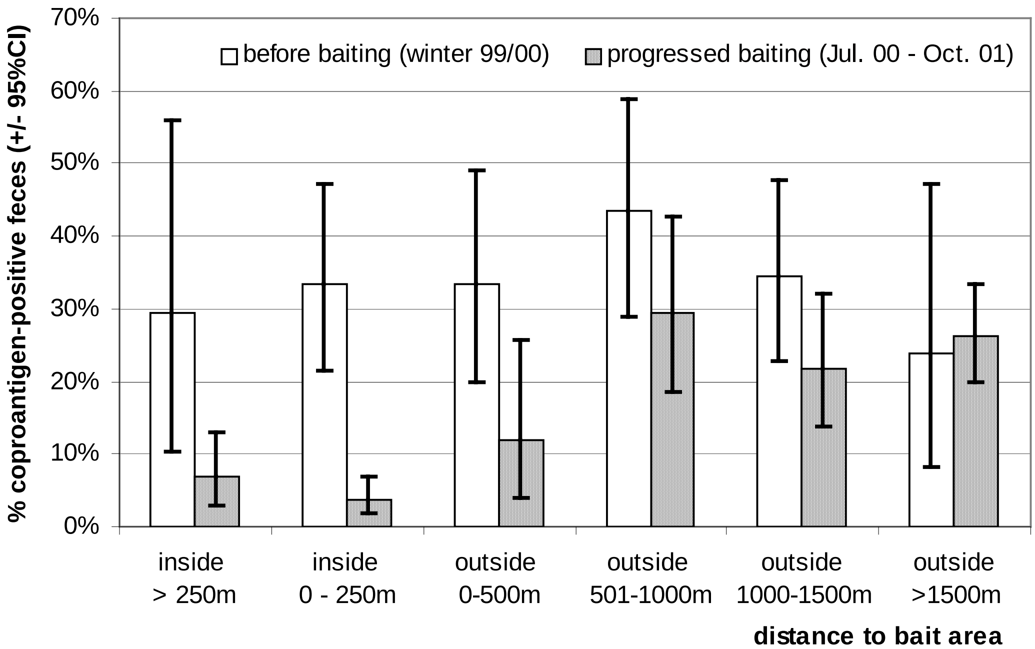


Figure 3. Proportions of *E. multilocularis* coproantigen-positive fox feces and 95% exact binomial confidence intervals sampled in different distances to the border of the 1-km^2 bait areas, baited monthly with 50 praziquantel-containing baits per km^2, before baiting started (November 1999 to March 2000) and after baiting has started for three months (July 2000 to October 2001).

proportion of coproantigen-positive feces was significantly higher with similar percentages of 19.1% (95%-CI: 16.3%-22.0%) and 18.5% (95%-CI: 14.8%-22.6%). A strong decrease in the proportion of coproantigen-positive feces was also recorded in the 332 fecal samples collected in the 6-km^2 bait area. Before baiting started in winter 99/00 the proportion of coproantigen-positive feces was significantly higher than in the 1-km^2 bait areas (mean: 66.7%; 95%-CI: 46.0%-83.5%; χ^2 test: $p < 0.05$). It decreased significantly to 9.2% (95%-CI: 3.8%-18.1%) during summer/autumn 2000, and to 1.8% (95%-CI: 0.0%-6.5%) during summer/autumn 2001 (Actus randomization test, $p < 0.001$). This final proportion of coproantigen-positive feces did not differ significantly from the final proportion of positive feces found in the 1-km^2 bait areas.

The spatial persistence of the baiting effect was investigated by comparing the prevalence depending on distance to the baiting area. In both the bait area center (more than 250 m inside the bait area) and in the bait area periphery (250 m inside to the border of the bait area) the effect of baiting was very pronounced (Figure 3). For feces collected at a distance of 0 to 500 m to the next bait area the effect of baiting was less clear and in a distance of 500 or more meters no significant effect could be registered any more.

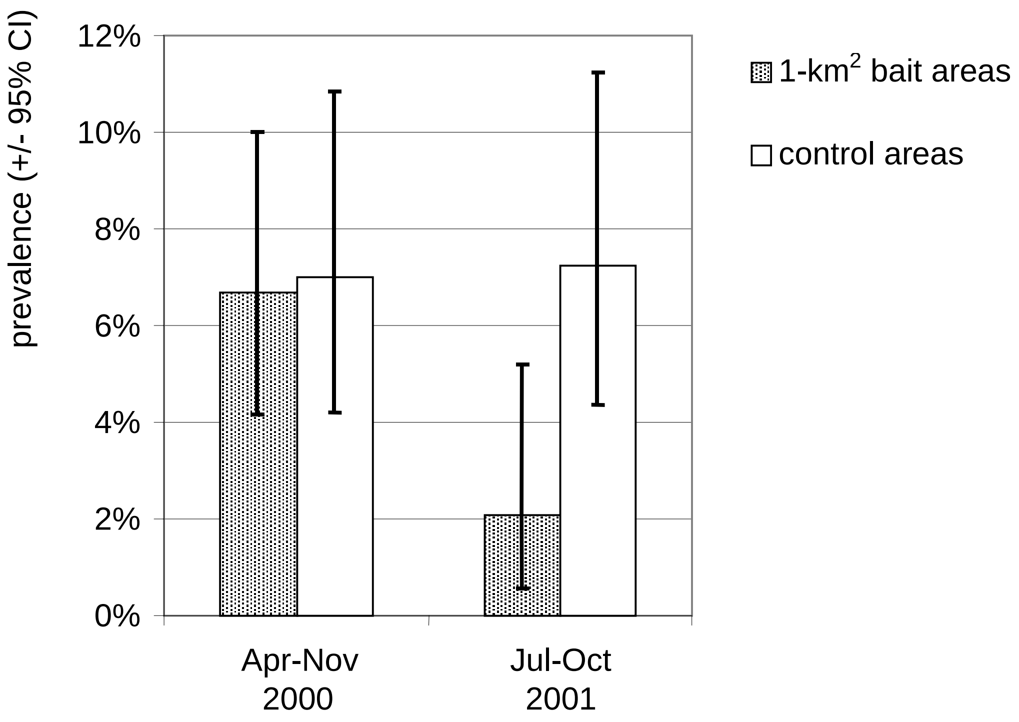


Figure 4. Prevalences of *E. multilocularis* in *A. terrestris* and 95% exact binomial confidence intervals in the six 1-km^2 bait areas, baited monthly with 50 Praziquantel-containing baits per km^2, and the six unbaited control areas during the experiment.

A total of 16 coproantigen-positive feces from bait areas and 55 coproantigen-positive feces from control areas, all sampled between July 2001 and October 2001, were investigated for the presence of *E. multilocularis* eggs. PCR analyses revealed significantly less feces positive for *E. multilocularis* eggs (mean: 25.0%; 95%-CI: 7.3%-52.4%) in bait areas than in control areas (mean: 52.7%; 95%-CI: 38.8%-66.3%; χ^2 test (one-tailed): $P < 0.05$).

Effect on prevalence in intermediate hosts

Of 1,014 *Arvicola terrestris*, 509 individuals originated from 1-km^2 bait areas and 505 from control areas. The stepwise backward logistic regression revealed a significant final model (model $\chi2 = 8.4$, df 3, $p < 0.05$) with a significant influence of anthelmintic baiting, expressed by the interaction between the two factors “area type” and “period”, on the prevalence of *E. multilocularis* in *A. terrestris* (Wald Statistics 3.7, df 1, p (1-tailed) <0.05). During the first year of baiting the prevalence in control and baited areas was similar (Figure 4), but during autumn 2001 the prevalence in baited areas was significantly lower (mean: 2.1%; 95%-CI: 0.6%-5.2%) than in control areas (mean: 7.3%; 95%-CI: 4.4%-11.2%). Independently from their interaction effect, the two blocking variables “period” and

"area type" also entered the final model, but not the variables "urban area" and "season".
The results for the 1-km^2 bait areas could be confirmed in the 6-km^2 bait area. The prevalence of *E. multilocularis* in 215 *A. terrestris* was highest from July 1999 to February 2000 before baits were delivered (mean: 21.6%; 95%-CI: 11.3%-35.3%) and decreased significantly afterwards ($\chi^2 = 4.54$, df 2, p (1-tailed) =0.05). The prevalence was lower from April to November 2000 (mean: 14.3%; 95%-CI: 6.4%-26.2%) and lowest from July to October 2001 (mean: 9.3%; 95%-CI: 4.5%-16.4%).

Discussion

Baiting strategy and bait density

The high bait density of 50 baits per km^2 combined with a manual bait distribution at sites attractive for foxes was highly effective. In oral rabies vaccination campaigns up to 20 baits were usually delivered per km^2 (32). Also, in the anthelmintic bait studies of Germany bait densities from 15 to 20 baits per km^2 were successfully used (18, 19). In contrast to rural habitats in urban ones fox densities can easily exceed ten adult foxes per km^2 (22, 24). Furthermore in summer many subadult foxes are present. A previous camera trap study conducted in Zurich showed that around half of the baits which disappeared were taken by foxes but the others were consumed by hedgehogs, dogs, rodents and snails (Hegglin et al., submitted). Therefore, bait densities exceeding 20 baits per km^2 seems to be appropriate to reach most foxes in urban habitats. In addition, the manual distribution of baits at selected sites attractive for foxes can improve bait uptake of foxes (Hegglin et al., submitted).

Effect of small scale anthelmintic baiting

Our results show clearly that the *E. multilocularis* egg contamination in urban areas can be reduced to a very low level by the manual distribution of anthelmintic baits in monthly intervals. This is even possible within defined urban patches of only 1-km^2 situated in a high endemic area. Although the initial rate of coproantigen-positive feces was high (38.6%), this rate decreased to 5.4% already during the first year of baiting. Additionally, the coproantigen-positive feces in baited areas significantly less frequently contained *E. multilocularis* eggs. In contrast to our results, a large scale praziquantel baiting campaign in a rural area of South Germany covering 566 km^2 showed a strong effect in the 156 km^2 core area, but in the 6 to 10 km wide border area the effect was much less pronounced (18). It was suggested that immigration of young, infected foxes may have caused this border effect. In Hokkaido, Japan, an anthelmintic baiting study was carried out in a smaller, rural area of 90 km^2, which resulted in a drastic reduction of environmental contamination comparable to our study (20). The main difference of the German study to the Japanese and our studies may be explained by the different baiting strategies. In Germany around half part of the baits were randomly delivered by aircraft and intervals between two baiting actions varied between two and four months. In our study all baits were delivered manually around attractive fox places at monthly intervals. A model for *E. multilocularis* control revealed that baiting intervals of four to six weeks would be most efficient (33).

The strong local effect in this study shows that in the urban situation the population dynamics of *E. multilocularis* is mainly determined by factors of very restricted spatial extension. Knowledge about spatial dynamic of fox populations is crucial to understand the dispersion capacity of *E. multilocularis*. In urban settings rich food resources can sustain high fox population densities (34) which go along with small home ranges and low dispersing distances (35, 36). In addition, urban fox populations are generally organized in family groups, where predominantly young vixens remain in the parental home range and help rear pups (36, 37). Consequently, offspring frequently inherit parental territory and does not have to disperse. Furthermore, a low urban immigration rate, which has been substantiated by genetic microsatellite analyses for the Zurich urban fox population (38), and a low hunting pressure (see methods) contribute to the moderate spatial dynamics of the urban fox population, which we assume to be a precondition for the effectiveness of the small-scale anthelmintic treatment.

Reduction of infection pressure

During the first year of baiting, when the proportion of *E. multilocularis*-coproantigen positive feces had already decreased significantly, no difference in the prevalences in *A. terrestris* between bait and control areas was detected. The significantly lower prevalence of *A. terrestris* trapped in bait areas during the second year of baiting demonstrates that lower *E. multilocularis* egg contamination resulted in a lower infection pressure for intermediate hosts. Nevertheless, at the end of the baiting study, *E. multilocularis* egg-containing feces and infected intermediate host could still be detected in the 1-km^2 and the 6-km^2 bait areas. This shows that the life cycle of the parasite in the baited areas was not completely interrupted. It is evident that dispersing and transient foxes can always contaminate baited areas, even in much larger areas. Furthermore, eggs of this cestode are very stable under suitable environmental conditions (39), infected intermediate hosts can stay infectious over several months (40) and baited foxes can reinfect just after treatment by consuming an infected intermediate host. In addition, the intervention studies in Germany (18, 19) demonstrated that *E. multilocularis* has the potential to recover from a population breakdown within less than two years (Romig, pers. comm., and Tackmann, pers. comm). Therefore, a baiting strategy focussing on extinction of the parasite in large areas might fail and permanent intervention to lower *E. multilocularis* egg contamination in defined, risk areas might be more realistic and cost efficient.

Conclusions

We demonstrated the feasibility of small scale anthelmintic baiting of foxes to reduce *E. multilocularis* egg contamination in urban areas intensively used by the public for recreational activities such as gardening or outdoor sports. In addition, the lower rate of infected voles also reduces the risk of domestic carnivores becoming infected by preying on voles, and consequently the risk of egg transmission by pet animals. Therefore we recommend that public health policy should focus on such defined, high endemic areas to reduce a potential risk for AE.

Acknowledgements

The authors thank Claudia Stieger, Rita Bosshart, Gioia Schwarzenbach, Isabelle Tanner and all other collaborators for help in the extensive field and laboratory work. We also thank Christian Stauffer and the game wardens of the city of Zurich for their generous collaboration. Fabio Bontadina and Paul Torgerson gave valuable comments on an earlier draft of the manuscript. This investigation was carried out within the context of the Integrated Fox Project, an interdisciplinary research project on the dynamics of the fox population in Switzerland. The study was supported by the Swiss Federal Office of Veterinary Medicine, Berne (Projekt Nr. 1.99.03) and the Swiss Federal Office for Education and Science (EchinoRisk Projekt QLK2-CT-2001-001995 / BBW Nr. 00.0586-2).

References

1. Eckert J, Deplazes P. Alveolar echinococcosis in humans: the current situation in Central Europe and the need for countermeasures. Parasitology Today 1999;15:315-9.
2. Wilson JF, Rausch RL. Alveolar hydatid disease. A review of clinical features of 33 indigenous cases of *Echinococcus multilocularis* infection in Alaskan Eskimos. Am. J. Trop. Med. Hyg. 1980;29:1340-1355.
3. Ammann R, Eckert J. Clinical Diagnosis and Treatment of Echinococcosis in Humans. In: Thompson RCA, Lymbery AJ, editors. Echinococcus and Hydatid Disease. Australia: CAB International; 1995.
4. Hildreth MB, Sriram S, Gottstein B, Wilson M, Schantz PM. Failure to identify alveolar echinococcosis in trappers from South Dakota in spite of high prevalence of *Echinococcus multilocularis* in wild canids. J. Parasitol. 2000;86:75-77.
5. Eckert J, Rausch RL, Gemmell MA, Giraudoux P, Kamiya M, Liu F-J, et al. Epidemiology of *Echinococcus multilocularis*, *Echinococcus vogeli* and *Echinococcus oligarthus*. In: Eckert J, Gemmel MA, Meslin F-X, Pawlowski ZS, editors. WHO/OIE Manual on echinococcosis in humans and animals. Paris; 2001. p. 164-194.
6. Deplazes P, Eckert J. Veterinary aspects of alveolar echinococcosis - zoonosis of public health significance. Veterinary Parasitology 2001;98:65-87.
7. Viel JF, Giraudoux P, Abrial V, Bresson-Hadni S. Water vole (Arvicola terrestris Scherman) density as risk factor for human alveolar echinococcosis. Am. J. Trop. Med. Hyg. 1999;61:559-565.
8. Gottstein B, Saucy F, Deplazes P, Reichen J, Demierre G, Busato A, et al. Is high prevalence of *Echinococcus multilocularis* in wild and domestic animals associated with disease incidence in humans? Emerg. Infect. Dis. 2001;7:408-12.
9. Rausch RL, Wilson JF, Schantz PM. A programme to reduce the risk of infection by *Echinococcus multilocularis*: the use of praziquantel to control the cestode in a village in the hyperendemic region of Alaska. Annals of Tropical Medicine & Parasitology 1990;84:239-250.
10. Rausch RL. Life cycle patterns and geographic distribution of *Echinococcus* species. In: Thompson RCA, Lymbery AJ, editors. Echinococcus and Hydatid Disease. Oxon, UK: CAB International; 1995.
11. Adkins CA, Stott P. Home ranges, movements and habitat associations of red foxes *Vulpes vulpes* in suburban Toronto, Ontario, Canada. Canadian Journal of Zoology 1998;244:335-346.
12. Tsukada H, Morishima Y, Nonaka N, Oku Y, Kamiya M. Preliminary study of the role of red foxes in *Echinococcus multilocularis* transmission in the urban area of Sapporo, Japan. Parasitology 2000;120:423-428.
13. Gloor S, Bontadina F, Hegglin D, Deplazes P, Breitenmoser U. The rise of urban fox populations in Switzerland. Mammalian Biology 2001;66:155-164.
14. Romig T, Bilger B, Mackenstedt U. [Current spread and epidemiology of Echinococcus multilocularis]. Deutsche Tierärzliche Wochenschrift 1999;106:352-7.
15. Deplazes P, Gloor S, Stieger C, Hegglin D. Urban transmission of *Echinococcus*

multilocularis. In: Craig P, Pawlowski Z, editors. Cestode Zoonoses: Echinococcosis and Cysticercosis; 2002: IOS Press, Amsterdam, Netherlands; 2002. p. 287-297.

16. Hofer S, Gloor S, Muller U, Mathis A, Hegglin D, Deplazes P. High prevalence of *Echinococcus multilocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zurich, Switzerland. Parasitology 2000;120:135-142.
17. Craig PS, Giradoux P, Shi D, Bartholomot G, Barnish G, Delattre P, et al. An epidemiological and ecological study on human alveolar echinococcosis transmisson in Gansu, China. Acta Trop. 2000;77:167-177.
18. Schelling U, Frank W, Will R, Romig T, Lucius R. Chemotherapy with praziquantel has the potential to reduce the prevalence of *Echinococcus multilocularis* in wild foxes (*Vulpes vulpes*). Annals of Tropical Medicine & Parasitology 1997;91:179-186.
19. Tackmann K, Loschner U, Mix H, Staubach C, Thulke HH, Ziller M, et al. A field study to control *Echinococcus multilocularis*-infections of the red fox (*Vulpes vulpes*) in an endemic focus. Epidemiol. Infect. 2001;127:577-587.
20. Tsukada H, Hamazaki K, Ganzorig S, Iwaki T, Konno K, Lagapa JT, et al. Potential remedy against *Echinococcus multilocularis* in wild red foxes using baits with anthelmintic distributed around fox breeding dens in Hokkaido, Japan. Parasitology 2002;125:119-29.
21. Stieger C, Hegglin D, Schwarzenbach G, Mathis A, Deplazes P. Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*. Parasitology 2002;124:631-640.
22. Contesse P, Hegglin D, Gloor S, Bontadina F, Deplazes P. The diet of urban foxes (Vulpes vulpes) and the availability of anthropogenic food in the city of Zurich, Switzerland. Mammalian Biology accepted.
23. Anonymous. Statistisches Jahrbuch der Stadt Zürich 2000 (In German). Zurich: Statistical department of the city of Zurich; 2000.
24. Gloor S. The rise of urban foxes (*Vulpes vulpes*) in Switzerland and ecological and parasitological aspects of a population in the recently colonised city of Zurich [Dissertation]. Zurich: University of Zurich; 2002.
25. Deplazes P, Alther P, Tanner I, Thompson RC, Eckert J. *Echinococcus multilocularis* coproantigen detection by enzyme-linked immunosorbent assay in fox, dog, and cat populations. J. Parasitol. 1999;85:115-21.
26. Raoul F, Deplazes P, Nonaka N, Piarroux R, Vuitton DA, Giradoux P. Assessement of the epidemiological status of *Echinococcus multlocularis* in foxes in France using ELISA coprotests on fox faeces collected in the field. International Journal for Parasitology 2001;31:1579-1588.
27. Mathis A, Deplazes P, Eckert J. An improved test system for PCR-based specific detection of *Echinococcus multilocularis* eggs. J. Helminthol. 1996;70:219-222.
28. Dinkel A, von Nickisch-Rosenegk M, Bilger B, Merli M, Lucius R, Romig T. Detection of Echinococcus multilocularis in the definitive host: coprodiagnosis by PCR as an alternative to necropsy. J. Clin. Microbiol. 1998;36:1871-1876.
29. Estabrook CB, Estabrook GF. Actus: a solution to the problem of small samples in the of analysis of two-way contingency tables. Historical Methods 1989;82:5-8.

30. Rice WR. Analyzing tables of statistical tests. Evolution 1989;43:223-225.
31. Clopper CJ, Pearson ES. The use of confidence or fiducial limits illustrated in the case of the binomial. Biometrika 1934;26:404-413.
32. Linhart SB, Kappeler K, L. A. Winderg LA. A review of baits and bait delivery systems for free-ranging carnivores and ungulates. In: Contraception in Wildlife: Animal and Plant Health Inspection Service, United States Department of Agriculture, USA; 1997. p. 69-132.
33. Hansen F, Tackmann K, Jeltsch F, Thulke H-H. Köderauslageintervalle und Dauer der Bekämpfung des Kleinen Fuchsbandwurms: eine Modellierstudie. Berl. Munch. Tierarztl. Wochenschr. in press.
34. Saunders G, White PCL, Harris S, Rayner JMV. Urban foxes (*Vulpes vulpes*): food acquisition, time and energy budgeting of a generalized predator. In: Dunstone N, Gorman ML, editors. Mammals as predators; 1993 193; London: Oxford University Press; 1993. p. 215-234.
35. Trewhella WJ, Harris S, McAllister FE. Dispersal distance, home-range size and population density in the red fox (*Vulpes vulpes*): a quantitative analysis. Journal of Applied Ecology 1988;25:423-434.
36. Baker PJ, Funk SM, Harris S, White PCL. Flexible spatial organization of urban foxes, *Vulpes vulpes*, before and during an outbreak of sarcoptic mange. Animal Behaviour 2000;59:127-146.
37. Macdonald DW. Resource dispersion and social organization of the Red fox, *Vulpes vulpes*. Proceedings of the Worldwide Furbearer Conference 1981;1:918-949.
38. Wandeler P, Funk SM, Largiadèr R, Gloor S, Breitenmoser U. The city-fox phenomenon: genetic consequences of a recent colonization of urban habitat. Mol. Ecol. in press.
39. Veit P, Bilger B, Schad V, Schafer J, Frank W, Lucius R. Influence of environmental factors on the infectivity of *Echinococcus multilocularis* eggs. Parasitology 1995;110:79-86.
40. Rausch RL, Wilson JF. Rearing of the adult *Echinococcus multilocularis* Leuckart, 1863, from sterile larvae from man. Am. J. Trop. Med. Hyg. 1973;22:357-360.

Manuskript H (for submission):
An experimental field approach to parasitism and immune defence in voles

Gioia Schwarzenbach[1], Daniel Hegglin[2], Claudia Stieger[2], Peter Deplazes[2] and Paul I. Ward[1]

[1] Zoological Museum, University of Zurich, Switzerland
[2] Institute of Parasitology, University of Zurich, Switzerland

for submission

Summary

The fox tapeworm *Echinococcus multilocularis* is typically perpetuated in a cycle with red foxes as definitive hosts and various rodent species as intermediate hosts. In this study, foxes were baited with a highly efficient drug against cestodes (praziquantel) in five blocks of one square kilometer. Voles, *Arvicola terrestris*, the most abundant intermediate host species, were trapped in the five baited blocks and in five non-baited control blocks. Baiting the foxes reduced the prevalence of *E. multilocularis* in fox faecal samples in the baited blocks, but voles trapped in the two blocks did not differ in their infection rates. However, voles from the baited blocks had significantly smaller spleen masses and were significantly more frequently infested with mites than those from the control blocks, reflecting different immunological activities. Our study has demonstrated that environmental contamination with *E. multilocularis* eggs, and perhaps those of other tapeworms, influences the immune system of the intermediate host species *A. terrestris* in the wild.

Introduction

Human Alveolar Echinococcosis, one of the most lethal helminth zoonoses, is caused by infection with *Echinococcus multilocularis* (Amman & Eckert 1995). Red foxes *(Vulpes vulpes)* are the main definitive host of the tapeworm *E. multilocularis* and source of human infections. Since red fox populations have increased recently in several European countries (Christensen 1985; Møller-Nielsen 1990; Breitenmoser *et al*. 2000), their growing populations, especially in urban areas, may increase health risks for urban citizens.
In Europe, *E. multilocularis* is typically perpetuated in a cycle including foxes and various rodent species as intermediate hosts (Eckert & Deplazes 1999). Adult tapeworms in foxes produce eggs for one to four months and these eggs reach the environment in fox faeces (Nonaka *et al.* 1996). When ingested by an intermediate host, the oncosphere hatches in the gut. It penetrates the intestinal mucosa, enters venous or lymphatic vessels and then develops predominantly in the liver, with subsequent metastasis formation in other sites (see Schantz & Gottstein 1986). In the intermediate host, protoscoleces production takes place within 20–35 days, and infective protoscoleces can be found 40–60 days after infection (Eckert 1998). A definitive host must ingest metacestodes which contain infective protoscoleces to complete the cycle.
The mammalian spleen is an important component of the immune system; it helps the body to resist parasites (Kopp 1990) and induces immune responses by B– and T–lymphocytes (Steininger & Barth 1999). An increase in spleen mass occurs in response to infections and passive immunisations (John 1995; Skarstein *et al.* 2001). The spleen also plays an important role in cell-mediated immunity as a storage organ for mature cytotoxic T-cells (Kopp 1990). In early *E. multilocularis* infection, the suppression of larval growth is critical for the final outcome (Gottstein 1992), and infected laboratory rodents show marked activation of cell-mediated immunity (e.g. Ali-Khan 1978b; Fotiadis *et al.* 1999). During metacestode proliferation and protoscoleces maturation, immuno-suppression occurs (Kizaki *et al.* 1991; Emery *et al.* 1996). During parasite growth, there is a decline in peritoneal lymphocyte, monocyte and eosinophil cell numbers and an increase in spleen mass (Ali-Khan 1974; Ali-Khan 1978a; Devouge & Ali-Khan 1983).
The most important intermediate hosts of *E. multilocularis* in Europe are *Microtus arvalis* and *Arvicola terrestris* (Eckert 1999). Although foxes prefer small microtine rodents as prey, they switch diet when *A. terrestris* are highly abundant (Weber & Aubry 1993). Recent analyses of urban foxes in Zürich found that *A. terrestris* was the most frequent potential intermediate host (Contesse *et al.* 1999). Little is known about parasite prevalences in intermediate hosts, although compared to prevalences in foxes (20-60%), they appear to be low (1-6%) (Eckert 1999). However, a study in Zürich found prevalences of up to 20% in *A. terrestris* and in urban foxes during winter, rates as high as 47 % in the urban and 67 % in adjacent recreational areas (Hofer *et al.* 2000).
The prevalence of *E. multilocularis* in wild foxes can be reduced by monthly distribution of baits containing praziquantel (Droncit® Bayer AG, Germany), a highly efficient drug against adult cestodes (Schelling & Frank 1997, Tackman *et al.* 2001). However, little attention has been paid to the role of the intermediate hosts in transmission dynamics,

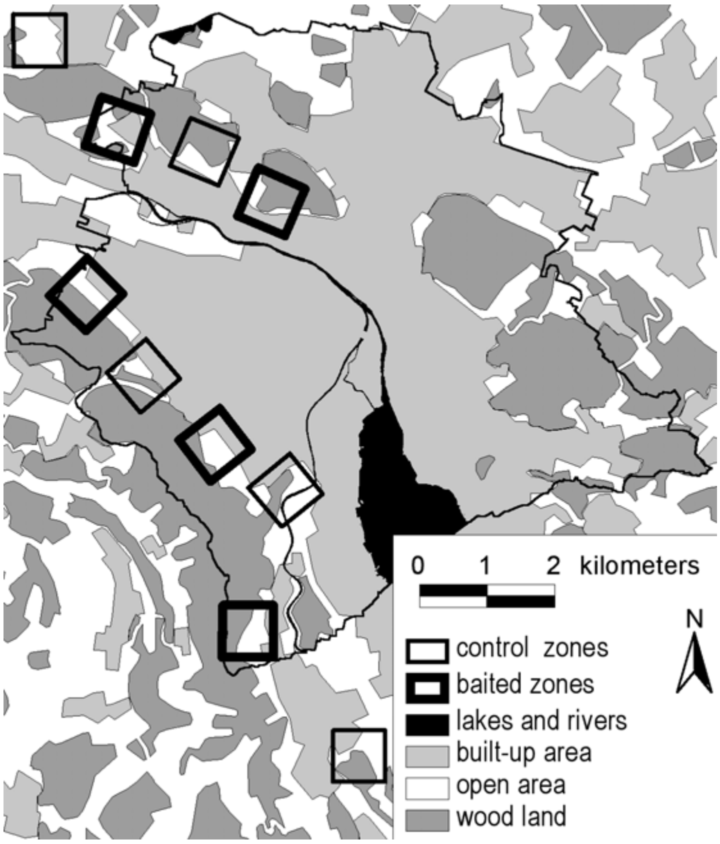


Fig. 1. Study site: city of Zurich and adjacent area

although several studies have indicated its importance (Giradoux *et al.* 1997; Eckert 1999). For example, even if final hosts are free of infection, the parasite may survive within an area within the intermediate hosts, especially as the eggs of *E. multilocularis* may survive for several months (Veit *et al.* 1995), and infected intermediate hosts carry metacestodes for an unknown period.

Studies on the natural life cycle of the parasite *E. multilocularis* and its transmission dynamics are rare. We baited foxes with praziquantel in five blocks of one square kilometre and compared voles from these blocks with voles from five non-baited control blocks. Dependent on baiting successfully reducing parasite prevalence in foxes, two different environmental treatments were created in which the voles were exposed to different infection risks with *E. multilocularis*, and possibly other tapeworms. We investigated immunological activity by measuring spleen mass. We also measured the prevalences of ectoparasitic mites. Thus enabling us to examine relationships between infections with different parasites.

Materials and Methods

Study site

The city of Zürich is surrounded by forests and agricultural land. There is a high density of 11.2 foxes per km2 and the urban transmission cycle of the parasite E.

multilocularis occurs predominantly in areas adjacent to the city of Zürich (Deplazes et al. 2002; Gloor 2002; Stieger et al. 2002). We therefore selected five sites near Zürich and marked out within each of these sites two blocks of one square kilometre. One was an experimental block, where baits containing praziquantel were distributed monthly, and the other was a control block. There was at least 750 meters between an experimental block and a control block, to minimise the chance of individual foxes using two study blocks. The blocks all shared similar portions of urban area (1/3) and agricultural landscape and woodland (2/3) in a pattern typical for the area (Fig. 1).

Anthelmintic treatment of foxes

Preliminary experiments had confirmed good acceptance of baits (Hegglin, unpublished). From April 2000, pellets were distributed monthly in the baited blocks at doses of 50 baits per square kilometre. They were distributed where they were likely to be found by foxes, for example near a compost, on a path frequently used by foxes, on a vole tumulus or close to dens.

Faecal samples were collected at least monthly in all blocks. A method of identifying fox faeces was established. Several criteria, such as size, shape and smell of the dung, were used to distinguish fox faeces from dog faeces (Stieger *et al.* 2002). Only faecal samples collected within a radius of 750 metres from the centre of the study blocks were analysed. This maximised the likelihood that only faeces of territorial foxes living within the blocks were used. *E. multilocularis* was detected by screening samples with a coproantigen ELISA (Em-ELISA) (Deplazes et al 1999).

Arvicola terrestris

The A. terrestris trap sites were located mainly on grassland. In every sampling block, one or two grassland patches that showed the highest relative densities of voles were selected (see Giradoux et al. 1995). From May to October 2000, four trapping sessions were conducted on every trap site at around six–week intervals. Between 20 to 30 traps were set inside vole galleries per trapping session. We used unbaited Topcat traps (Topcat GmbH, Wintersingen, Switzerland). A trapping session was ended if 10 voles were caught. Voles were collected after death and stored individually at –20° C. Body weight to the nearest 0.01g and body length to the nearest 1mm, from the tip of the nose to the first vertebra of the tail, were recorded. The presence of ectoparasitic mites (Laelaps species) was recorded by carefully combing the coat against the grain and examining the plastic bag the vole was stored in. At necropsy, the spleen was removed, cleaned of other tissue and weighed to the nearest 1mg. In females, the presence and number of embryos and placental scars was recorded and it was noted whether they were lactating. The liver in particular, but also other organs such as lung, kidney, spleen and reproductive and intestinal tracts, were examined for lesions or irregularities. Metacestodes of E. multilocularis were identified morphologically and by PCR (Bretagne et al. 1993) after proteinkinase K digestion of the chopped material. Identification of lesions caused by other cestodes was based on gross morphology and by comparing hook morphology and length.

Statistics

Data were analysed using ANCOVA and logistic regression (SPSS 10 PC-Version, 1999). To evaluate the infection rate of foxes in baited and control zones, we pooled the data of faecal samples collected in the two periods from April to June 2000 and from July to October 2000. The small number of faecal samples collected in some months prevented analysis of shorter time intervals. To evaluate parasite prevalence in voles trapped in the two treatments, we pooled the data from May to June 2000 and from July to October 2000. To reveal effects on a finer time scale, we used two-month intervals (May and June, July and August, September and October) to carry out further analyses with the vole data. Spleen mass was log transformed. Body length was used as a covariate. Since body length influenced spleen mass significantly, we removed the effects of body length by taking the residuals of a linear regression of transformed spleen mass on body length.

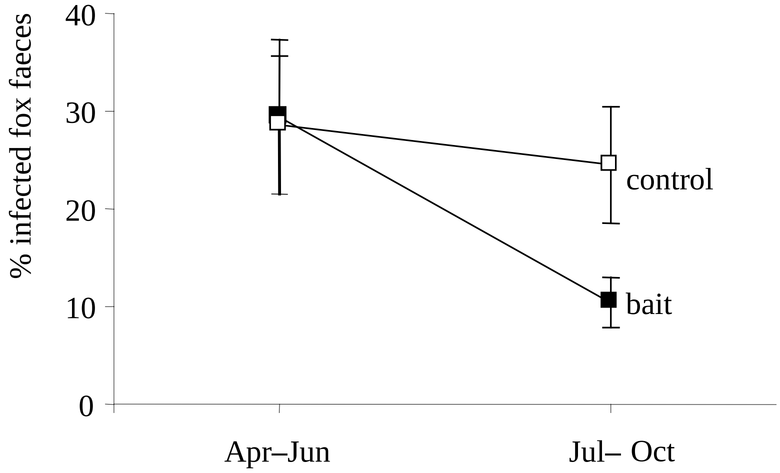


Fig. 2. Prevalence (mean percentage of faecal samples infected ± SE) of *E. multilocularis* (total n=273) in baited and control zones collected on the outskirts of Zurich from April to October 2000.

Table 1: Analysis of covariance of log(spleen mass) (overall adjusted R^2=0.160)

Source of variation	Type III Sum of Squares	df	Mean Square	F	Significance
BODY LENGTH (covariate)	0.35	1	0.35	11.50	0.001
AREA	0.98	4	0.25	8.07	<0.001
BAIT	0.24	1	0.24	8.02	0.005
TIME PERIOD	0.08	2	0.04	1.33	0.265
MITE	<0.001	1	<0.001	0.01	0.926
SEX	<0.001	1	<0.001	0.15	0.703
INFECTION	0.08	1	0.08	2.65	0.105
BAIT*TIME PERIOD	0.51	2	0.25	8.31	<0.001
Error	9.98	328	0.03		

Results

Prevalence of *E. multilocularis* in fox faecal samples

Logistic regression with the factors (BAIT, treatment of the foxes), (AREA, five different areas) and two time periods (SEASON, April to June and July to October) was used to investigate whether baiting the foxes reduced the portion of coproantigen-positive faeces. The portion decreased during the year and was lower in baited zones (AREA, Wald χ^2 = 6.2, 4 df, P = 0.186, BAIT, Wald χ^2 = 4.5, 1 df, P = 0.035, SEASON, Wald χ^2 = 7.9, 1 df, P = 0.005, SEASON BY BAIT, Wald χ^2 = 3.0, 1 df, P = 0.084) (Fig.2).

Arvicola terrestris

Of 534 voles, 213 were male and 321 female. Of the females, 95 (29.6%) showed signs of reproduction. Male voles are either larger than, or the same size as, females

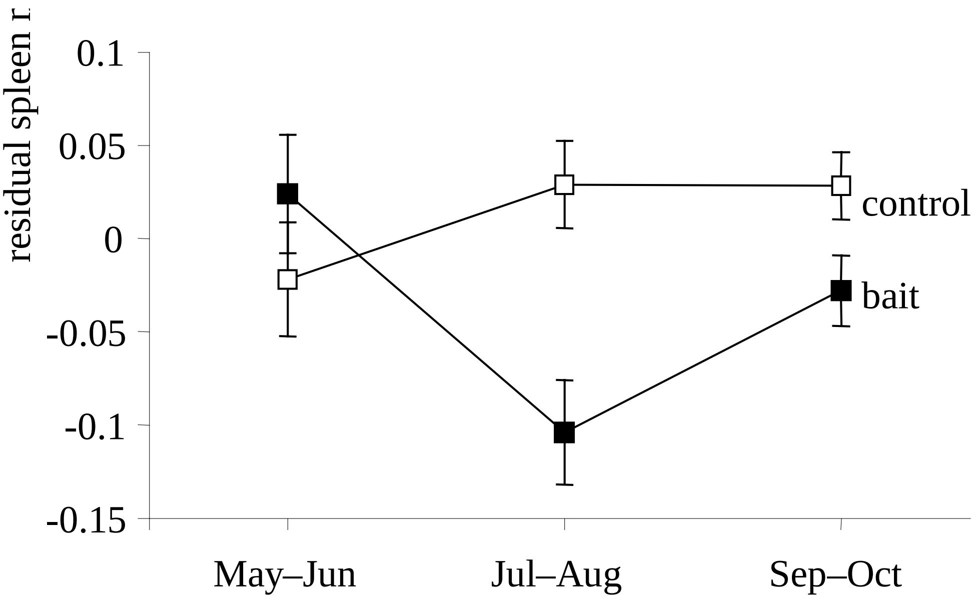


Fig. 3. Mean relative spleen mass ± SE of voles at three different time periods (n=342).

(Heske & Ostfield 1990). The sexually active females caught all weighed more than 60 grams, and their body lengths exceeded 120 mm. Animals below both these thresholds (71, 13.1%) were considered juvenile and omitted from the analysis. Of 469 adult voles, we detected liver lesions in 157 (33.5%) and E. multilocularis infections in 41 (8.7%). In 17 of the infected animals, we found 14 to 244400 protoscoleces; this means that only 3.6% of the adult voles were actually infective when captured. Most of the lesions not caused by E. multilocularis were from metacestodes of Taenia taeniaeformis (Strobilocercus fascioloaris) (60, 12.8%). Only five (1.06%) animals were infected with both E. multilocularis and T. taeniaeformis. Metacestodes of T. crassiceps were detected in four (0.8%) voles, and of these two (0.4%) were simultaneously infected with T. taeniaeformis. Two T. crassiceps metacestodes were in subcutaneous cysts, once in the pleural cavity and once in the pericardium. Two lesions (0.4%) were caused by unidentified Taenia. In 50 (10.6%) voles, the cause of the lesion could not be determined.

We found infected voles in all but one of the ten blocks. Prevalence varied from 3.3 to 16.2 % per block. A binary logistic regression with the main factors (BAIT), (AREA), vole sex (SEX), the dichotomous variable (MITE), whether a vole was infected with mites, the three two-month periods (TIME PERIOD) and, as covariates, body length and transformed spleen mass, revealed no significant effects on *E. multilocularis* prevalence in voles (all $P > 0.05$; overall prevalence 8.74 ± 1.31%).

ANCOVA was used to investigate the influence of the factors treatment of the foxes (BAIT), vole sex (SEX), the dichotomous variables (INFECTION) and (MITE) and the three two-month periods (TIME PERIOD) on spleen mass. Body length was entered as a covariate. The analysis also included (AREA), to remove the variance in spleen size due to variation amongst the areas. All four-way and three-way interactions were non-significant, and were therefore removed from the final model, as were all non-significant two-way interactions. Spleen mass was positively related to body length ($\beta = 0.176$) and varied between areas. Spleen mass decreased with time in the baited blocks only (Table 1; Fig. 3). Furthermore, infected voles had slightly, albeit not significantly, heavier spleens than uninfected voles (residual mass 0.069 ± 0.040 versus -0.007 ± 0.010), but infection stage had no effect.

Ectoparasitic mites

For the frequency of mite infestation, there were no significant four-way or three-way interactions. These were therefore removed from the final model, as were all non-significant two-way interactions. It was affected significantly by the interaction of BAIT and TIME PERIOD ($\chi^2 = 6.09$, 1 df, $P = 0.048$); other effects SEX (logistic regression, $\chi^2 = 4.61$, 1 df, $P = 0.032$), BAIT ($\chi^2 = 5.17$, 1 df, $P = 0.023$), TIME PERIOD ($\chi^2 = 40.95$, 2 df, $P < 0.001$), INFECTION ($\chi^2 = 2.40$, 1 df, $P = 0.12$), AREA ($\chi^2 = 8.82$, 4 df, $P = 0.066$). In the later two time periods, voles from baited blocks were more likely to be infested than those from control blocks (May – June $44.4 \pm 8.4\%$ versus $41.9 \pm 7.6\%$; July – August $40.0 \pm 9.1\%$ versus $14.8 \pm 4.58\%$; September – October $74.2 \pm 5.42\%$ versus $62.3 \pm 4.73\%$ respectively). Males were more likely to be infested than females (58.3 ± 4.2 % versus 43.8 ± 3.5 % respectively). Infection with *E. multilocularis* also slightly decreased the frequency of mite infestation ($30.3 \pm 8.1\%$ versus $49.1 \pm 2.7\%$ respectively).

Discussion

Baiting the foxes with praziquantel reduced the proportion of fox faecal samples infected with *E. multilocularis* collected in baited blocks. Fewer eggs, of this tapeworm and presumably of other tapeworms, were therefore deposited in baited blocks than in control blocks. Since the environmental contamination with eggs decreased throughout the experiment, voles in baited zones presumably had a lower contact rate with infective eggs. Although there was no reduction in the infection rate of voles, spleen mass was significantly reduced over time in baited blocks. This was not the case in non-baited control blocks. The frequency with which voles were infested by mites was higher in baited blocks.

E. multilocularis infection rates in voles are generally low; in geographically extensive studies they are usually below 1% (Eckert 1999). We found prevalences of 3.3 to 16.2% in all but one study block, indicating that the study was conducted in a highly infected endemic area. This confirms the existence of locally highly endemic foci (Pétavy & Deblock 1983; Gottstein *et al.* 1996; Hofer *et al.* 2000).

Since infected voles survive for several months, some of the voles trapped were probably infected before or shortly after the beginning of baiting. Parasite eggs may survive for up to eight months in autumn and winter and for up to three months in summer (Veit *et al.* 1995). Therefore, even when final hosts are free of infection, the parasite may survive within a treated area because the voles still come into contact with infective eggs and thus represent sources of new infections.

The average spleen mass of voles in the baited blocks decreased over time, but this did not occur in the control blocks. An increase in spleen mass during infection with *E. multilocularis*, reflecting increased immune defence, has been reported previously (e.g. Ali-Khan 1978a; Ali-Khan 1978b; Playford & Kamiya 1992; Fotiadis *et al.* 1999). During the early stage of an *E. multilocularis* infection, where the final outcome of the disease depends upon a successful immune defence against the migrating oncosphere, a marked activation of the cell-mediated immunity against the parasite occurs (Ali-Khan 1978b; Playford & Kamiya 1992; Fotiadis *et al.* 1999). *E. multilocularis* growth appears to be controlled by the host T-cell, and, at least in the early phase of the disease, T-lymphocytes probably play the most important role in the immune response to the parasite (Baron & Tanner 1976; Kamiya *et al.* 1980; Playford & Kamiya 1992). The spleen plays an important role in cell-mediated immunity as the storage organ of mature cytotoxic T-cells (Kopp 1990). In contrast to voles in baited blocks, where the risk of infection decreased over the season, voles in control blocks exposed to high levels of contamination with eggs would have had to maintain a high level of cell-mediated immunity to combat infection, resulting in elevated spleen mass.

We found different frequencies of voles infested with mites in the two treatments. Fewer voles were infested with mites in control blocks, and voles infected with *E. multilocularis* also tended to have fewer mites. Since cell-mediated immunity and T-cells play an important role in the immune defence against mites (OBrien *et al.* 1996), this supports the hypothesis that exposure to one parasite (*E. multilocularis*) can lead to an activated, general cell-mediated immunity, and consequently to an increased immune response to another parasite (mites). Elevated cell-mediated immunity and the resulting production of T-cells following infections with *E. multilocularis* (Ali-Khan 1978b; Playford & Kamiya 1992; Fotiadis *et al.* 1999) may thus simultaneously increase immune defence against several challenges. Furthermore, more males harboured mites than females. Gender differences in natural parasitic infections are frequently observed in vertebrates (reviewed by Zuk & McKean 1996). These differences are usually attributed to ecological (i.e. different exposure to the parasites) or physiological (i.e. hormonal) differences between the sexes (Zuk & McKean 1996; Travi *et al.* 2002).

We have demonstrated that environmental contamination with eggs of *E. multilocularis,* and possibly other tapeworms, influences the immune system in the intermediate host *Arvicola terrestris*. We have also shown that monthly distribution of bait pellets containing praziquantel can reduce the prevalence of *E. multilocularis* in foxes, even when carried out in blocks of one square kilometre. Further studies of the infection pressure with *E. multilocularis* in faecal samples and further trapping sessions are required to understand the longer term consequences of baiting in both the final and the intermediate host(s).

Acknowledgements

We are grateful to Dr. Wolf Blanckenhorn for discussion and comments that improved the manuscript and for his help with the statistical analysis. We would also like to thank Isabelle Tanner for her assistance in the lab and Hansueli Ochs for identifying the mites.

References

Ali-Khan, Z. 1974 Host-parasite relationship in echinococcosis. I. Parasite biomass and antibody response in three strains of inbred mice against graded doses of *Echinococcus multilocularis* cysts. *J. Parasitol.* **60**, 231-235.

Ali-Khan, Z. 1978a Cellular changes in lymphoreticular tissues of C57/J mice infected with *Echinococcus multilocularis* cysts. *Immunology* **34**, 831-839.

Ali-Khan, Z. 1978b *Echinococcus multilocularis* cell mediated immune responses in early and chronoic alveolar murine hydatiosis. *Exp. Parasitol.* **46**, 157-165.

Amman, R. & Eckert, J. 1995 Clinical diagnosis and treatment of echinoccoosis in humans. In *Echinococcus and Hydadit Disease* (ed. R. C. A. Thompson & A. J. Lymbery), pp. 411-463.

Breitenmoser, U., Muller, U., Kappeler, A. & Zanoni, R. G. 2000 The final phase of the rabies epizootic in Switzerland. *Schweiz. Arch. Tierheilkd.* **142**, 447-454.

Bretagne, S., Guillou, J., Morand, M. & Houin, R. 1993 Detection of *Echinococcus multilocularis* DNA in fox faeces using DNA amplification. *Parasitology* **106**, 193-199.

Christensen, H. 1985 Urban fox populations in Oslo. *Revue d'écologie la terre et la vie* **40**, 185-186.

Contesse, P., Hegglin, D., Gloor, S., Bontadina, F. & Deplazes, P. 2003 Anthropogenic food resources allow increase in an Swiss urban fox (*Vulpes vulpes*) population. Mammalian Biology (accepted).

Deplazes, P. & Gottstein, B. 1991 A monoclonal antibody against *Echinococcus multilocularis* Em2 antigen. *Parasitology* **103**, 41-49.

Deplazes, P., Alther, P., Tanner, I., Thompson, R. C. A., & Eckert, J. 1999 *Echinococcus multilocularis* coproantigen detection by enzym-linked immunosorbent assay in fox, dog, and cat populations. *J. Parasitol.* **85**, 115-121.

Deplazes, P., Gloor, S., Stieger, C. & Hegglin, D. 2002 Urban transmission of *Echinococcus multlocularis*. In *Cestode Zoonoses: Echinococcosis and Cysticercosis* (ed. P. Craig & Z. Pawloski), pp. 287-297. Amsterdam, Netherlands: IOS Press.

Devouge, M. & Ali-Khan, Z. 1983 Intraperitoneal murine alveolar hyaditosis: Relationship between the size of larval cyst mass, immigrant inflammatory cells, splenomegaly and thymus involution. *Tropenmed. Parasitol.* **34**, 15-20.

Eckert, J. 1998 *Echinococcus multilocularis, Echinococcus oligarthrus and Echinococcus vogeli*. In *Zoonoses : biology, clinical practice, and public health control* (ed. L. S. S. R. Palmer, and D. I. H. Simpson.). Oxford: Oxford University Press, Oxford medical publications.

Eckert, J. & Deplazes, P. 1999 Alveolar Echinococcosis in Humans: The current situation in central Europe and the need for countermeasures. *Parasitol. Today* **15**, 315-319.

Eckert, J., Rausch, R. L., Gemmell, M. A., Giradoux, P:, Kamiya,M., Feng jie Liu, Schantz, P. M.,and Romig, T. 1999 Epidemology of *Echinococcus multilocularis*, *Echinococcus vogeli* and *Echinococcus oligarthrus*. *Manual on Echinococcus in humans and animals. World Health Organisaion, Geneva*.

Emery, I., Liance, M., Deriaud, E., Vuitton, D. A., Houin, R. & Leclerc, C. 1996

Characterization of T-cell immune responses of *Echinococcus multilocularis*-infected C57BL/6J mice. *Parasite Immunol.* **18**, 463-472.

Fotiadis, C., Sergiou, C., Kirou, J., Troupis, T. G., Tselentis, J., Doussaitou, P., Gorgoulis, V. G. & Sechas, M. N. 1999 Experimental echinococcus infection in the mouse model: Pericystic cellular immunity reaction and effects on the lymphoid organs of immunocompetent and thymectomized mice. *In vivo* **13**, 541-546.

Giradoux, P., Delattre, P., Habert, M., Quere, J. P., Deblay, S., Defaut, R., Duhamel, R., Moissenet, M. F., Salvi, D. & Druchet, D. 1997 Population dynamics of fossorial water vole (*Arvicola terrestris* scherman): a land usage and landscape perspective. *Agriculture, Eco. Environ.* **66**, 47-60.

Giradoux, P., Pradier, B., Delattre, P., Deblay, S., Salvi, D. & Defaut, R. 1995 Estimation of water vole abundance by using surface indices. *Acta Theriol.* **40**, 77-96.

Gloor, S. 2002 The rise of urban foxes, (*Vulpes vulpes*) in Switzerland and ecological and parasitological aspects of a fox population in the recently colonised city of Zurich. In *Dissertation*. Zurich, Switzerland: University of Zurich.

Gottstein, B. 1992 *Echinococcus multilocularis* infection: Immunology and immunodiagnosis. *Adv. Parasitol.* **31**, 321-380.

Gottstein, B., Saucy, F., Wyss, C., Siegenthaler, M., Jacquier, P., Schmitt, M., Brosshard, M. & Demierre, G. 1996 Investigations on a Swiss area highly endemic for *Echinococcus multilocularis*. *App. Parasitol.* **37**, 129-136.

Heske, E. J. & Ostfield, R. S. 1990 Sexual dimorphism in size, relative size of testes, and maiting systems in north american voles. *J. Mammal.* **71**, 510-519.

Hofer, S., Gloor, S., Müller, U., Hegglin, D. & Deplazes, P. 2000 High prevalences of *Echinococcus multlocularis* in urban red foxes (*Vulpes vulpes*) and voles (*Arvicola terrestris*) in the city of Zurich. *Parasitology* **120**, 135-132.

John, J. L. 1995 Parasites and the avian spleen-helminths. *Biol. J. Linn. Soc.,* **54**, 87-106.

Kamiya, H., Kamiya, M., Ohbayashi, M. & Nomura, T. 1980 Studies on the host resistance to infections with *Echinococcus multilocularis*. 1. Difference of susceptibility of various rodents, especially of congenitally athymic nude mice. *Jap. J. Vet. Res.* **29**, 87-100.

Kizaki, T., Kobayashi, S., Ogasawara, K., Good, R. A., Day, N. K. & Onoe, K. 1991 Immune suppression induced by protoscoleces of *Echinococcus multilocularis* in mice: Evidence for the presence of CD8 dull suppressor cells in spleens of mice intraperitoneally infected *Echinococcus multilocularis*. *J. Immunol.* **147**, 1659-1666.

Kopp, W. C. 1990 The immune functions of the spleen. In *The spleen: Structure, Function and Clinical significance.* (ed. A. J. Bowdler), pp. 261-265. London: Chapman and Hall.

Mathis, A., Deplazes, P. & Eckert, J. 1996 An improved test system for PCR-based specific detection of *Echinococcus multilocularis* eggs. *J. Helminthol.* **70**, 219-222.

Møller-Nielsen, S. M. 1990 The food of rural and suburban woodland foxes *Vulpes vulpes* in Denmark. *Natura Jutlandica* **23**, 25-32.

Nonaka, N., Iida, M., Yagi, K., Ito, T., Ooi, H. K., Oku, Y. & Kamiya, M. 1996 Time course of coproantigen excretion in Echinococcus multilocularis infections in foxes and an alternative definitive host, golden hamsters. *Int. J. Parasit.***26**, 1271-1278.

OBrien, R. M., May, O., Clarke, A. H. & Thomas, W. R. 1996 Immunologic responses following respiratory sensitization to house dust mite allergens in mice. *Imm. Cell. Biol.* **74**, 174-179.

Pétavy, A. F. & Deblock, S. 1983 Connaissance du foyer auvergnant d'échinococcose alvéolaire. *Ann. Parasitol. Hum. Comp.* **58**, 439-453.

Playford, M. C. & Kamiya, M. 1992 Immune-response to *Echinococcus multilocularis* infection in the house mouse model - A review. *Jap. J. Vet. Res.* **40**, 113-130.

Schantz, P. M. & Gottstein, B. 1986 *Echinococcus* (hyaditosis). In *Immunodiagnosis of parasitic diseases* (ed. K. M. Walls & P. M. Schantz), pp. 69-107. Orlando: Academic Press.

Schelling, U. & Frank, W. 1997 Chemotherapy with praziquantel has the potential to reduce the prevalence of *Echinococcus multilocularis* in wild foxes (*Vulpes vulpes*). *Ann. Trop. Med. Parasitol.* **91**, 179-186.

Skarstein, F., Folstrad, I. & Liljedal, S. 2001 Whether to reproduce or not: immune suppression and costs of parasites during reproduction in the Arctic charr. *Can. J. Zool.* **79**, 271-278.

Steininger, B. & Barth, P. 1999 Microanatomy and function of the spleen. *Adv. Anat., Embryol. Cell Biol.* **151**, 1-112.

Stieger, C., Hegglin, D., Schwarzenbach, G., Mathis, A. & Deplazes, P. 2002 Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*. *Parasitology* **124**, 631-640.

SPSS Statistical Package for PC, SPSS PC-Version, 1999, Chicago.

Tackman, K., Loschner, U., Mix, H., Staubach, C., Thulke, H., Ziller, M. & Conraths, F. 2001 A field study to control *Echiniococcus multilocularis*-infections of the red fox *(Vulpes vulpes)* in an endemic focus. *Epidemiol. Infect.* **127**, 577-587.

Travi, B., Osorio, Y., Melby, P., Chandrasekar, B., Arteaga, L. & Saravia, N. 2002 Gender is a major determinant of the clinical evolution and immune response in hamsters infected with *Leishmania* spp. *Infect. Immunol* .**70**, 2288-2296.

Veit, P., Bilger, B., Schad, V., Schäfer, J., Frank, W. & Lucius, R. 1995 Influence of environmental factors on the infectivity of *Echinococcus multilocularis* eggs. *Parasitology* **110**, 79-86.

Weber, J. M. & Aubry, S. 1993 Predation by foxes, *Vulpes vulpes*, on the fossorial form of the water vole, *Arvicola terrestris* scherman, in western Switzerland. *J. Zool.* **229**, 553-559.

Zuk, M. & McKean, K. A. 1996 Sex differences in parasite infections: Patterns and processes. *Int. J. Parasitol.* **26**, 1009-1023.

Anhang I (Archives of Environmental Contamination and Toxicology):
Comparison of heavy metal concentrations in tissues of red foxes from adjacent urban, suburban and rural areas

Ramiro Dip[1], Claudia Stieger[2], Peter Deplazes[2], Daniel Hegglin[2,3], Uli Müller[4], Oscar Dafflon[5], Herbert Koch[5] and Hanspeter Naegeli[1]

[1] Institute of Pharmacology and Toxicology, University of Zurich, Switzerland
[2] Institute of Parasitology, University of Zurich, Switzerland
[3] Work Group Urban Ecology and Wildlife Research, Zurich, Switzerland
[4] Swiss Rabies Center, University of Bern, Bern, Switzerland
[5] Federal Veterinary Office, Bern, Switzerland

Dip R, Stieger C, Deplazes P, Hegglin D, Müller U, Dafflon O, Koch H, Naegeli H. Comparison of heavy metal concentrations in tissues of red foxes from adjacent urban, suburban and rural areas. Archives of Environmental Contamination and Toxicology. 2001;40:551-556.

Abstract

The red fox (*Vulpes vulpes*) is a representative of the canid family with wide distribution in the Northern Hemisphere and Australia. The increasing utilization of urbanized habitats by red foxes prompted us to test whether this species may be used to monitor the presence of anthropogenic pollutants in cities or suburbs. For that purpose, we compared the concentrations of heavy metals (Cd, Pb, Cu, Zn) in foxes from urban, suburban and rural areas within the municipality of Zürich (Switzerland). The kidney and liver of suburban and rural foxes contained the highest Cd concentrations, whereas urban foxes contained the highest Pb levels. In the kidney of suburban foxes, Cd concentrations increased from a median value of 0.73 mg/kg in juvenile animals to 1.82 mg/kg in adults. Similarly, the liver of suburban foxes contained increasing Cd levels from a median of 0.21 mg/kg in juvenile animals to 0.94 mg/kg in adults. An age-dependent storage of Cd was also found in foxes from the rural surroundings, but no such accumulation occurred in urban foxes from the city center, where even adult animals contained very low Cd levels. Conversely, foxes from the urban center were characterized by elevated Pb concentrations during the first two years of life, but this transient Pb accumulation was absent in suburban or rural animals. The liver of juvenile foxes contained a median Pb concentration of 0.99 mg/kg in the city compared to only 0.47 and 0.37 mg/kg in the suburban and rural area, respectively. Thus, we found that animals from separate environmental compartments contain different patterns of tissue residues, implying that red foxes may provide a bioindicator species to detect certain toxic hazards in urbanized habitats.

Introduction

Life on our planet is threatened by anthropogenic pollutants that accumulate in the atmosphere, water or soil, but exposure to such pollutants does not always produce toxic effects in living organisms. On the contrary, a potentially hazardous chemical becomes toxic only when it reaches an active site in the target species at sufficiently high concentrations to generate adverse reactions. Before establishing reliable risk assessment studies it is, therefore, necessary to determine the bioavailability of potentially toxic chemicals, *i.e.*, the efficiency by which such chemicals are transported from environmental matrices to biological receptors (Thibodeaux 1979; Hutton 1982; MacKay 1991; Eaton and Klaassen 1996).

Typically, the bioavailabilty of environmental pollutants is assessed by measuring chemical residues in tissues or fluids of animals living in appropriate aquatic or terrestrial habitats. Many different species can be used to estimate the impact of toxic chemicals on aquatic organisms (Kendall *et al*., 1996), but the choice of suitable terrestrial indicators is more problematic. For example, wild animal species such as chamois, European hare, moose, red deer, reindeer or roe deer have been proposed for biomonitoring studies (Doganoc and Gacnik 1995; Frøslie *et al*., 1986; Kottferová and Koréneková 1998; Markov 1996; Santiago *et al*., 1998). However, these species may not serve as representative indicators of pollution outside of their normal habitats (forests, farmland or other rural areas). In addition, these herbivorous species often occupy very large territories and, therefore, may not be helpful in localizing specific sources of toxic hazards. In contrast, red foxes (*Vulpes vulpes*) adapt to a variety of environmental conditions and, in urbanized areas, occupy small territories of 0.5 km^2 or less (Harris 1977; Harris and Trewhella 1988; Doncaster and Macdonald 1991). The use of red foxes for biomonitoring purposes has already been proposed before, but previous reports were limited to the analysis of foxes living in rural habitats (Brunn *et al*., 1991; Ansorge *et al*., 1993; Bukovjan 1997; Corsolini *et al*., 1999; Gunstheimer *et al*., 1997).

The present study was motivated by the observation that, in many European countries, red foxes have invaded suburban and even urban habitats (Harris 1977; McDonald and Newdick 1982; Christensen 1985; Schöffel *et al*., 1991; Willingham *et al*., 1996), where these animals are exposed, at least in part, to the same pollutants as the human population. During the last 10 years, a considerable increase of the overall fox density was also observed in Switzerland (Breitenmoser *et al*., 1995). For example, the fox population permanently living in the city of Zürich is estimated to consist of 300-400 adult animals with cubs being bred in public parks and in private gardens (Hofer *et al*., 2000). The aim of this study was to explore whether red foxes living in cities may be used to monitor the presence of toxic hazards in their specific urban and suburban environments. For that purpose,

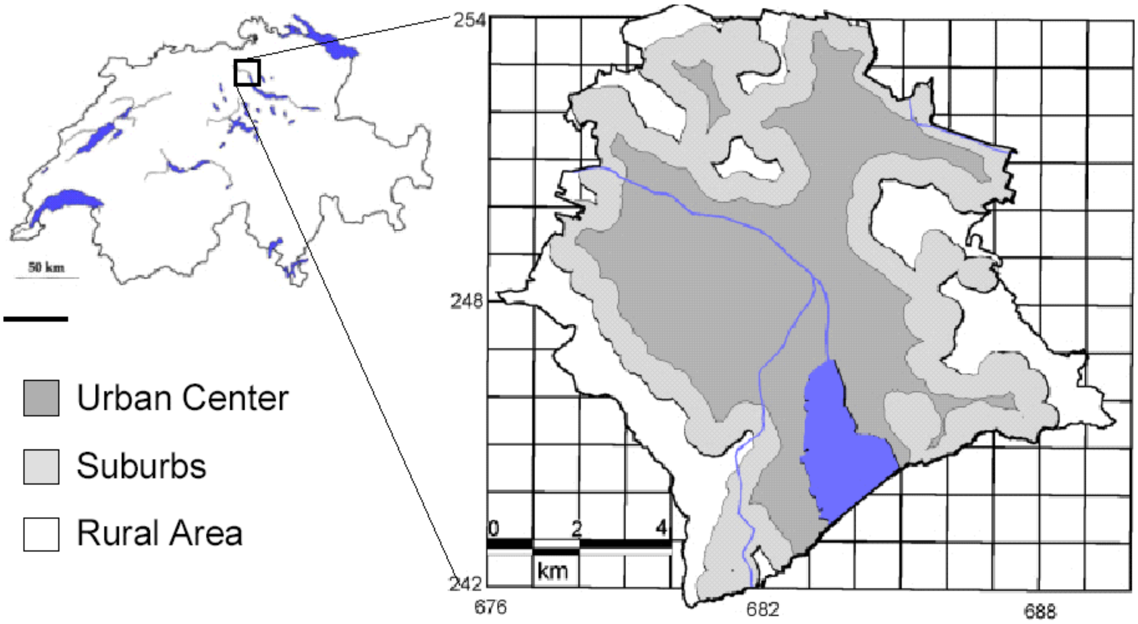


Fig. 1. Study area. The varying distances between neighbouring buildings were used to divide the municipality of Zürich into a rural (distances > 100 m), suburban and urban compartment (distances < 100 m). The suburban area constitutes a transition zone of 500 m between the rural and urban compartments. White: rural area; light grey: suburban area; dark gray: urban area; blue: lake and rivers.

we compared the tissue concentrations of various heavy metals in foxes from adjacent urban, suburban and rural areas. Interestingly, we found that urban foxes accumulate a different mixture of toxic residues compared to the surrounding suburban and rural populations.

Materials and Methods

Study area

The municipality of Zürich (92 km^2, 360’000 inhabitants) was divided into urban, suburban and rural areas (Fig. 1). The rural area consists mainly of forests, parks, farmland and allotment gardens, in which the distance between neighbouring buildings extends to over 100 m. In the urban area, the distance between buildings is reduced to less than 100 m. At the transition between these rural and urban compartments, we delineated a suburban ribbon that has a width of 0.5 km.

Foxes

A total of 100 red foxes were obtained between January 1997 and February 1998. The majority of animals (about 75%) were shot in the course of population control programs organized by the city forest service. The remaining animals were killed during road or traffic accidents. The carcasses were wrapped in plastic bags and stored at –20°C until necropsy. Tissues were carefully examined for postmortem degradation and for the presence of shots or shot injuries and, if present, such samples were eliminated from further analysis. On the basis of these criteria, a total of 13 animals were excluded from this study. The age of each animal was determined by counting annuli in the cementum of one canine tooth of the lower jaw (Harris 1978; Grue and Jensen 1979; Kappeler 1985; Goodard and Reynolds 1993).

Sample analysis

Metal concentrations were assayed in samples of homogenized tissue that were digested in the presence of nitric acid using an MDS-210 microwave (ProLab). Cd and Pb measurements were performed by atomic absorption spectrometry in combination with a graphite furnace using the 4100ZL spectometer from Perkin-Elmer. Cu and Zn was determined by flame atomic absorption spectrometry using the Aanalyst 300 spectometer from Perkin-Elmer. All results are given in mg/kg on a wet weight basis. Each series of analysis included a blank, a standard calibration curve, and spiked specimens. The accepted recoveries for spiked samples ranged from 85% to 115%. The coefficient of variation on replicate samples was < 7%. The limit of detection for the different metals in tissue samples was 5 µg/kg (Cd), 50 µg/kg (Pb), 5 mg/kg (Cu) and 1 mg/kg (Zn).

Statistics

Heavy metal concentrations in foxes from suburban, urban and rural environmental compartments were compared using the Mann-Whitney *U*-test. Differences were considered significant at $P < 0.05$.

Table 1. Summary of heavy metal residues in the tested fox population (N = 87) within the municipality of Zürich (all values are given in mg/kg on a wet weight basis).

	Cd		Pb		Cu		Zn	
	Kidney	Liver	Kidney	Liver	Kidney	Liver	Kidney	Liver
Median	0.97	0.32	0.37	0.58	4.8	16.2	20.2	41.8
Minimum	0.08	0.03	0.11	0.13	2.5	2.3	9.5	19.5
Maximum	7.33	2.59	1.33	2.59	20.7	157.7	58.0	116.6
Mean	1.45	0.52	0.57	1.20	6.3	20.2	21.2	44.9
S.D.[a]	1.43	0.51	0.90	3.61	4.1	18.8	7.8	16.7

[a] S.D., standard deviation.

Results

Sample Site, Fox population and Data Collection

The municipal territory of Zürich consists of a central urban area comprising 26 km^2. This urban centre is surrounded by a suburban ribbon of 33 km^2 and several rural areas, mainly consisting of forests and farmland, located at the city border (Fig. 1). Kidney and liver tissues were obtained from a total of 87 red foxes collected between January 1997 and February 1998. Eighteen animals were from the central urban area, 49 animals were collected in the suburban surroundings and another 20 foxes were from the rural environments. Upon age determination, these animals were divided into three groups that included juvenile foxes with an age of 12 months or less (N = 39), young foxes that were between 13 and 24 months old (N = 24), and adult foxes with an age of more than 2 years (N = 24).

Heavy metal concentrations in the kidney and liver samples were determined by atomic absorption spectrometry. In Table 1, both arithmetic means and medians are given to facilitate comparisons with other reports in the literature. From the Cd concentrations of all animals we calculated median values of 0.97 mg/kg in the kidneys and 0.32 mg/kg in the liver. The median Pb concentrations in kidney and liver amounted to 0.37 and 0.58 mg/kg, respectively. Thus, the overall Cd and Pb concentrations were in a comparably low and non-toxic range as the values reported by Corsolini *et al.* (1999), who monitored residues of pollutants in a fox population from central Italy. On the other hand, we found higher Cd but lower Pb concentrations compared to the study of Ansorge *et al.* (1993), who monitored the residues in the kidney of a fox population from East Germany. Also, we observed similar Pb and Zn concentrations as in the study of Bukovjan (1997), who analyzed the heavy metal contamination of foxes in the Czech Republic. On the other hand, our analysis yielded considerably higher Cd and Cu concentrations than the study performed by Bukovjan (1997). Unlike previous reports (Ansorge *et al.*, 1993; Corsolini *et al.*, 1999), we were unable to detect a statistically significant difference in the level of heavy metal residues when the fox population of this study was separated according to sex.

Cd Residues

We observed a nearly 100-fold range of Cd concentrations in the kidney, from 0.08 mg/kg in one of the juvenile animals to over 7 mg/kg in some adult animals (Table 1). Even within the group of foxes that were older than 24 months, Cd concentrations in the kidney yielded a nearly 30-fold variability with values ranging from 0.26 mg/kg to 7.33 mg/kg. Thus, the wide variation of Cd levels could be attributed only in part to the expected differences between juvenile and adult animals due to continued retention of this metal in soft tissues (Klaassen *et al.*, 1999). In fact, Figure 2A shows that only red foxes living in suburban and rural habitats accumulated Cd in an age-dependent manner. For example, the median Cd concentration of suburban foxes increased from 0.73 mg/kg in the kidney of juvenile foxes to 1.82 mg/kg in the kidney of adult animals. In contrast, there was no accumulation of Cd in urban foxes and, in fact, even adult animals living in the city center contained very low levels of this metal in their kidneys (median value of 0.49 mg/kg). An age-dependent storage of Cd was also found in the corresponding liver tissue, but again exclusively in the animals obtained from suburban or rural areas, whereas the liver of urban foxes contained low amounts of this metal (Figure 2B). Thus, we found that foxes from distinct but adjacent environmental compartments contain significantly different levels of a potentially toxic pollutant, in this case Cd. Regardless of the mechanism underlying this difference, our finding supports the notion that urban and suburban/rural foxes constitute separate populations with little dispersal movement in either direction.

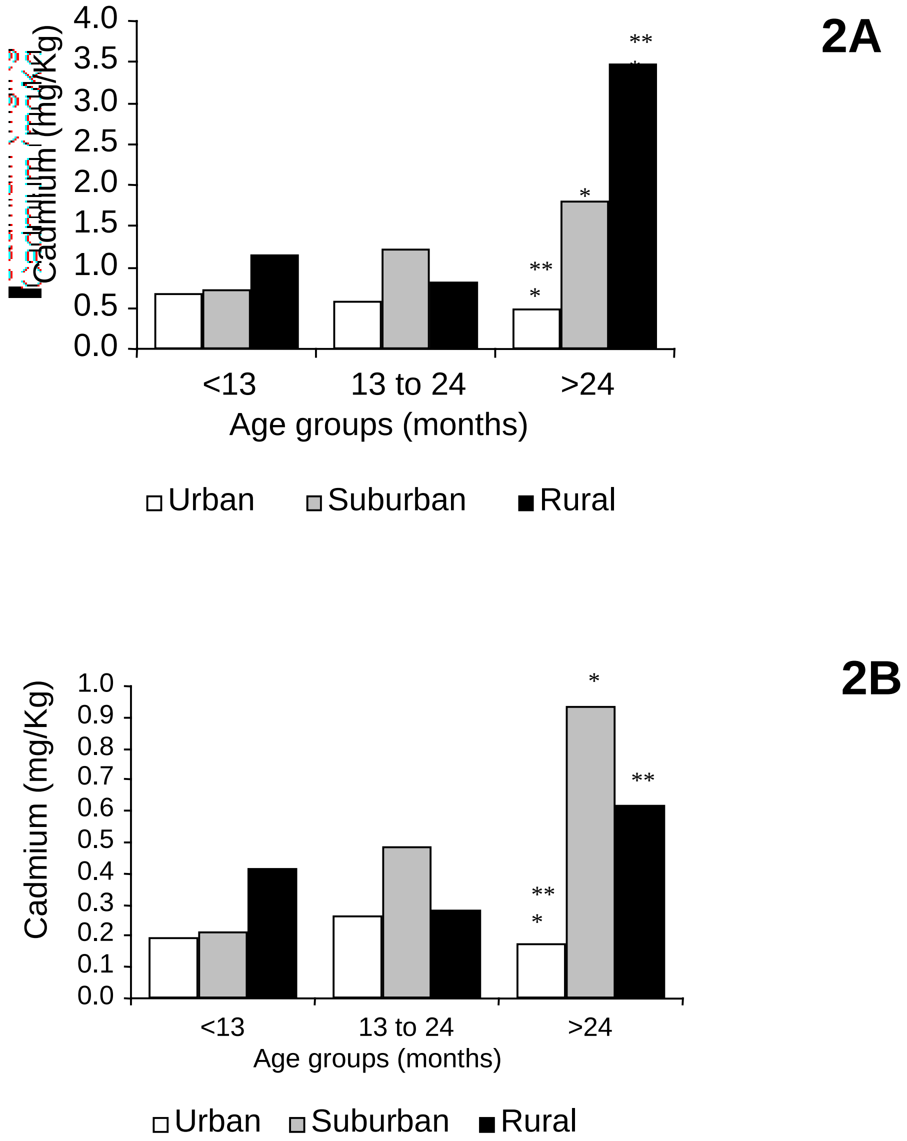


Fig. 2. Concentrations of Cd (medians) in the kidney (A) and liver (B) of foxes. All values are indicated in mg/kg on a wet weight basis. The asterisks denote statistically significant differences between adult animals of different environmental compartments: *, $P < 0.05$ between the values of urban and suburban foxes; **, $P < 0.05$ between the values of urban and rural foxes.

Pb Residues

A diametrically opposite pattern of contamination was observed when we measured the concentrations of Pb in the same tissue samples. First, we found that juvenile animals contained higher Pb levels than adult foxes. Second, this transient accumulation of Pb was detected only in the animals living under urban conditions. In the liver, there was a 20-fold range of Pb concentrations from 0.13 mg/kg in one of the suburban foxes to 2.59 mg/kg in one of the urban foxes (Table 1). Further analysis of these results revealed that the highest Pb levels were found in the liver of urban foxes with median concentrations of 0.99 mg/kg in juvenile animals of 12 months or less, and 1.10 mg/kg in young animals aged between 13 and 24 months (Figure 3). Such a transiently increased Pb concentration is compatible with the higher bioavailability of this heavy metal in young animals compared to adults (Goyer 1996). Consistent with subsequent elimination or immobilization into bones, Pb concentrations in the liver dropped with increasing age and reached a median value of only 0.58 mg/kg in adult urban foxes. We also observed that both suburban and rural animals contained significantly lower levels of Pb during the first two years of life compared to urban foxes. In fact, Pb concentrations in the liver of juvenile animals were 0.47 mg/kg in the suburbs and 0.36 mg/kg in the rural environment, and these low Pb contents were maintained in suburban and rural foxes throughout their life (Figure 3). The analysis of kidney samples yielded a similar distribution of Pb residues, i.e., highest values in young urban animals and lowest values in adult suburban foxes, although in this case the differences did not reach the required degree of statistical significance (data not shown).

Cu and Zn Residues

In contrast to the results obtained by measurement of Cd and Pb concentrations, no significant difference between fox populations or age groups were found when we analyzed Cu and Zn levels. The arithmetic means and medians are again summarized in Table 1. Interestingly, a few single animals showed rather high levels of Cu or Zn relative to the overall values found in the general population. For example, a female fox (27 months old) from the suburban area contained Cu at concentrations of 157.7 mg/kg in the liver and 11.6 mg/kg in the kidney. The highest Cu concentration in the kidney (20.7 mg/kg) was found in a male urban fox of 11 months. On the other hand, the highest Zn concentration (116.6 mg/kg) was found in the liver of a male fox (23 months old) from the suburban area. The kidney of this animal contained Zn at a concentration of 51.1 mg/kg. Finally, the highest Zn value in kidney (58.0 mg/kg) was found in another animal (male, 11 months) from the urban center. These Cu and Zn concentrations reached values that were up to 8.4-fold higher than the arithmetic means or medians of Table 1. Recent ingestion of contaminated water or food is likely to be responsible for these single cases of increased Cu and Zn levels.

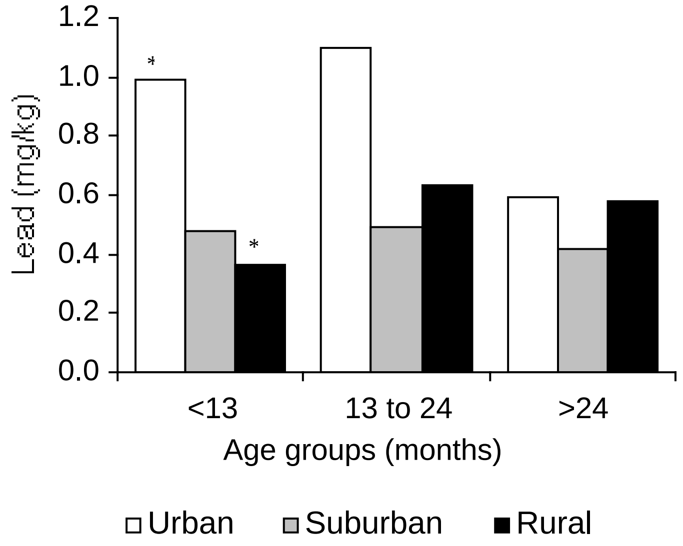


Fig. 3. Concentrations of Pb (medians) in the liver of foxes. All values are indicated in mg/kg on a wet weight basis. The asterisk indicates a statistically significant ($P < 0.05$) difference between the Pb concentrations of urban and rural foxes.

Discussion

The outstanding result of this study is that the urban fox population contains lower Cd but higher Pb tissue levels than the surrounding suburban and rural populations. A material flux analysis indicates that the major storage site for Cd in Switzerland is the soil, with over 4'000 t of Cd being located in the matrix of the upper soil layers (Kaufmann *et al.*, 1997). Thus, the accumulation of Cd in suburban and rural foxes may reflect the mobilization of this heavy metal from the soil matrix and its subsequent transfer into mammalian organisms (Goyer 1996; Langgemach *et al.*, 1995). It seems unlikely that the soil of parks and gardens in the city center is less contaminated with Cd than the soil of suburban or rural areas. Thus, the lower Cd concentration in urban foxes may not reflect different levels of environmental contamination but, because Cd is assimilated mainly through the diet, a different feeding behaviour between urban and suburban/rural foxes. In fact, the analysis of stomach contents of the animals of this study indicates that the diet of urban foxes is dominated by food of anthropogenic origin found in household rubbish (D. Hegglin, unpublished results). These dietary components were originally intended for human consumption and, due to appropriate monitoring programs, contain low Cd concentrations that do not exceed the currently tolerated maximal residue level. In contrast, suburban and rural foxes rely on natural food sources including earthworms, rodents and other small mammals (D. Hegglin, unpublished results). Invertebrates living in the soil are particularly prone to Cd accumulation (see for example Hendriks *et al.*, 1995), such that ingestion of these organisms (or ingestion of small mammals feeding on them) may account for the increased Cd uptake of suburban and rural foxes.

Pb has been recognized as the most widespread metal pollutant in cities (Goyer 1996). The increased Pb concentration detected in the liver of urban foxes compared to their suburban or rural counterparts supports the conclusion that urban and suburban/rural foxes constitute separate populations characterized by a different composition of tissue residues. Also, the increased Pb level of urban foxes is reminiscent of the higher Pb exposure of children reported in certain urban communities. In the affected areas, even low levels of Pb uptake in children have been associated with neurobehavioral and cognitive deficits (Marecek *et al.*, 1983; Baghurst *et al.*, 1992; Pocock *et al.*, 1994). Thus, the analysis of urban foxes may reveal the presence of Pb or certain other toxic hazards, possibly warning us of the impact of pollution before signs of toxicity appear in the human population. Future monitoring studies will be devoted to the analysis of other hazardous pollutants including chlorinated hydrocarbon insecticides, polychlorinated biphenyls or dioxins.

References

Ansorge H, Graeser K, Fink, H-G (1993) Schwermetallrückstände beim Rotfuchs (Vulpes vulpes). Beiträge zur Jagd- und Wildforschung 18:79-82

Baghurst PA, McMichael AJ, Wigg NP, Vimpani GV, Robertson EF, Roberts RJ, Tong SL (1992) Environmental exposure to lead and children's intelligence at the age of seven years. The Post Pirie Cohort Study. N Engl J Med 327:1279-1284

Breitenmoser C, Kaphegyi T, Kappeler A, Zanoni R (1995) Significance of young foxes for the persistence of rabies in Northwestern Switzerland. In: Schwyzer M, Ackermann M, Bertoni G, Kocherhans R, McCullough K, Wittek R, Zanoni R (eds) Proceedings of the 3rd Congress of the European Society of Veterinary Virology: Immunobiology of Viral Infections, pp. 391-396

Brunn H, Georgii S, Bachour G, Elmadfa I (1991) Free-living animals as an indicator of environmental contamination. Tierärztl Umschau 46:549-553

Bukovjan K (1997) Concentration of selected foreign substances in the tissues of fox Vulpes vulpes L. Folia Venatoria 26/27:107-112

Christensen H (1985) Urban fox population in Oslo. Terre Vie 40:185-186

Corsolini S, Focardi S, Leonzio C, Lovari S, Monaci F, Romeo G (1999) Heavy metals and chlorinated hydrocarbon concentrations in the red fox in relation to some biological parameters. Environ Monit Ass 54:87-100

Doganoc DZ, Gacnik KS (1995) Lead and cadmium in meat and organs in Slovenia. Arch Environ Contam Toxicol 54:166-170

Doncaster CP, Macdonald DW (1991) Ecology and ranging behaviour of red foxes in the city of Oxford. Hystrix 3:11-20

Eaton DL, Klaassen CD (1996) Principles of Toxicology. In: Klaassen CD (ed) Casarett & Doull's Toxicology, 5th Edition, McGraw-Hill, New York, p 13-33

Frøslie A, Haugen A, Holt G, Norheim G (1986) Levels of cadmium in liver and kidneys from Norwegian cervides. Bull Environ Contam Toxicol 37:453-460

Goodard HN, Reynolds JC (1993) Age determination in the red fox (Vulpes vulpes L.) from tooth cementum lines. Gibier Faune Sauvage 10:173-187

Goyer RA (1996) Toxic effects of metals. In: Klaassen CD (ed) Casarett & Doull's Toxicology, 5th Edition, McGraw-Hill, New York, pp 691-736

Grue H, Jensen B (1979) Review of the formation of incremental lines in tooth of terrestrial mammals. Danish Rev Game Biol 11:1-48

Gunstheimer G, Gunstheimer U, Anke M. (1996) The red fox as a bioindicator of mercury exposure. In: Botev N (ed) Proceedings of the International Union of Game Biologists (IUGB) XXII Congress, pp 439-443

Harris S (1977) Distribution, habitat utilization and age structure of a suburban fox (Vulpes vulpes) population. Mammal Rev 7:25-39

Harris S (1978) Age determination in the red fox (Vulpes vulpes) – an evaluation of technique efficiency as applied to a sample of suburban foxes. J Zool 184:91-117

Harris S, Trewhella WJ (1988) An analysis of some of the factors affecting dispersal in an urban fox (Vulpes vulpes) population. J Appl Ecol 25:409-422

Hendriks AJ, Ma WC, Brouns JJ, de Ruiter Dijkman, EM, Gast R (1995) Modelling and monitoring organochlorine and heavy metal accumulation in soils, earthworms, and shrews in Rhine-delta foodplains. Arch Environ Contam Toxicol 29:115-127

Hofer S, Gloor S, Müller U, Mathis A, Hegglin D, Deplazes P (2000) Urban cycle of Echinococcus multilocularis in the city of Zürich, Switzerland. Parasitol 120:135-142

Hutton M (1982) The role of wildlife species in the assessment of biological impact from chronic exposure to persistent chemicals. Ecotoxicol Environ Safety 6:471-478

Kaufmann M, von Schulthess C, Ziegler M (1997) Cadmium. Stoffflussanalyse. BUWAL, Bern

Kappeler A (1985) Untersuchung zur Altersbestimmung und zur Altersstruktur verschiedener Stichproben aus Rotfuchs-Populationen (Vulpes vulpes L.) in der Schweiz. Diploma thesis, University of Bern

Kendall RJ, Bens CM, Cobb GP, Dickerson RL, Dixon KR, *et al*. (1996) Aquatic and terrestrial ecotoxicology. In: Klaassen CD (ed) Casarett & Doull’s Toxicology, 5th Edition, McGraw-Hill, New York, pp 883-905

Klaassen CD, Liu J, Choudhuri S (1999) Metallothionein: an intracellular protein to protect against cadmium toxicity. Annu Rev Pharmacol Toxicol 39:267-294

Kottferová J, Koréneková B (1998) Distribution of Cd and Pb in the tissues and organs of free-living animals in the territory of Slovakia. Bull Environ Contam Toxicol 60:171-176

Langgemach T, Deutrich V, Metz R (1995) Investigation of heavy metal concentrations in game animals in areas treated with human sewage. Tierärztl Umschau 50:480-490

Macdonald SW, Newdick, MT (1982) The distribution and ecology of foxes, Vulpes vulpes (L.), in urban areas. In: Bornkamm R, Lee JA, Seeward MR (eds) Proceedings of the 2nd European Ecological Symposium: Urban, Blackwell, Oxford pp 123-135

MacKay D (1991) Multimedia environmental models: the fugacity approach. Lewis, Chelsea

Markov G (1996) Roe deer (Capreolus capreolus L., 1758), a zoomonitor for the estimation of the natural environment quality in Bulgaria. In: Botev N (ed) Proceedings of the International Union of Game Biologists (IUGB) XXII Congress, pp 444-447

Marecek J, Shapiro IM, Burke A, Katz SH, Hediger ML (1983) Low-level lead exposure in childhood influences neuropsychological performance. Arch Environ Health 38:355-359.

Pocock SJ, Smith M, Baghurst P. (1994) Environmental lead and children’s intelligence: a systematic review of the epidemiological evidence. Br Med J 309:1189-1197

Santiago D, Motas-Guzman M, Reja A, Maria-Mojica P, Rodero B, Garcia-Fernández AJ (1998) Lead and cadmium in red deer and wild boar from Sierra Morena Mountains (Andalusia, Spania). Bull Environ Contam Toxicol 61:730-737

Schöffel I, Schein E, Wittstadt U, Hentsche J (1991) Zur Parasitenfauna des Rotfuchses in Berlin (West). Berl Münch Tierärztlich Wochenschrift 104:153-157

Thibodeaux LJ (1979) Chemodynamics: environmental movement of chemicals in air, water, and soil. Wiley, New York

Willingham AL, Ockens NW, Kapel, CM, Monrad J (1996) A helminthological survey of wild red foxes (Vulpes vulpes) from the metropolitan area of Copenhagen. J Helminth 70:259-263

Anhang II (for submission):
Age- and sex-dependent distribution of persistent organochlorine pollutants in urban foxes

Ramiro Dip[1], Daniel Hegglin[2], Peter Deplazes[2], Oscar Dafflon[3], Herbert Koch[3] and Hanspeter Naegeli[1]

[1] Institute of Pharmacology and Toxicology, University of Zurich, Switzerland
[2] Institute of Parasitology, University of Zurich, Switzerland
[3] Federal Veterinary Office, Bern, Switzerland

Key words: indicator species, pollutants, DDT, dieldrin, PCB, risk groups

for submisson

Abstract

The increasing appearance of red foxes (*Vulpes vulpes*) in urban and suburban habitats provides a potential indicator species to monitor the spread of anthropogenic pollutants in densely populated human settlements. Here, red foxes were collected in the municipal territory of Zürich (Switzerland) and the concentration of persistent organochlorine pollutants was determined in the perirenal adipose tissue. This pilot study revealed an unexpected pattern of contamination by polychlorinated biphenyls (PCBs) with significantly higher levels of the predominant congeners PCB138, PCB153 and PCB180 in juvenile foxes relative to adult animals. Further data analysis demonstrated that the observed difference was mainly attributable to an age-dependent reduction of PCB concentrations in females, while male foxes retained approximately the same PCB burden throughout their life span. A similar sex-related bias between population members has been observed before in some cetacean species. Interestingly, the reduction of organochlorine contents with progressive age is reminiscent of human studies, where an extensive maternal transfer of xenobiotics to the offspring has been shown to result in increased exposure levels of infants relative to adults. Thus, the analysis of urban and suburban foxes may not only serve to estimate the magnitude of environmental pollution in cities and their surroundings but also anticipate the possible accumulation of toxic chemicals in highly sensitive human risk groups. To our knowledge, this is the first example of an urban wildlife species that faithfully reflects the dynamic distribution of environmental pollutants in the corresponding human population.

Introduction

Species diversity and human health are constantly threatened by the production and release of toxic chemicals into the atmosphere, water or soil. Polychlorinated biphenyls (PCBs) and chlorinated pesticides belong to a class of ubiquitous anthropogenic pollutants that are highly lipophilic and refractory to chemical degradation. Due to these inherent physicochemical properties (lipid solubility and chemical stability) and the slow rate of biotransformation in all organisms, such organochlorine pollutants accumulate to toxic levels in both aquatic and terrestrial food chains (Ecobichon 1996; Hill 1999; Loizeau et al. 2001; Jorgenson 2001). Chronic exposure to persistent organochlorine chemicals has been associated with deleterious effects in fish and wildlife, leading to poor fertility, impaired immune functions and population declines in the contaminated areas (Fry and Toone 1981; Guillette et al. 1996; Colborn et al. 1993; Tyler et al. 1998). Similarly, epidemiological studies suggest that various diseases of the reproductive system in humans, ranging from breast or testicular cancer to a worldwide drop of sperm number and quality, may be linked to organochlorine pollutants (Krieger et al. 1994; Hunter et al. 1997; Golden et al. 1998). Furthermore, prenatal or perinatal exposure to persistent organochlorine chemicals has been implicated as a risk factor for low birth weight, thyroid and immunological defects, and the development of neurobehavioural deficits in pediatric cohorts (Seegal 1994; Winneke et al. 1998; Vreugdenhil et al. 2002; critically reviewed by Kimbrough et al. 2001).
A potentially hazardous chemical becomes toxic only when it reaches an active site in the target species at sufficiently high concentrations to generate adverse reactions. Thus, exposure levels in combination with toxicokinetic indices such as uptake, metabolism and elimination rates are important parameters that determine the health risk resulting from a particular toxic substance. Before establishing reliable risk assessment studies it is, therefore, necessary to determine the bioavailability of potentially toxic chemicals, i.e., the efficiency by which such chemicals are transported from environmental matrices to relevant biological receptors (Thibodeaux 1979; Hutton, 1982; MacKay 1991; Eaton and Klaassen 1996). Typically, the bioavailabilty of environmental pollutants is assessed by measuring chemical residues in tissues and fluids of animals or humans. Many different species can be used to estimate the impact of toxic chemicals on aquatic habitats (Kendall et al. 1996; Wells 1999), but the choice of suitable terrestrial indicators is more problematic. For example, wild animal species such as chamois, European hare, moose, red deer, reindeer, roe deer, pigeons or wild mink have been proposed for biomonitoring studies (Doganoc and Gacnik 1995; Frøslie et al. 1986; Hutton 1982; Kottferová and Koréneková 1998; Markov 1996; Poole et al. 1998;

Santiago et al. 1998). Unfortunately, with few exceptions these wildlife species are only represented in their natural habitats, including forests or other rural areas, and often occupy very large territories, such that they may not be helpful in identifying local sources of contamination that are directly relevant to the exposure level of people.

The red fox (Vulpes vulpes) is an opportunistic species that adapts to a multitude of different environmental conditions (Nowak 1991). In view of their wide distribution, red foxes have already been used to monitor anthropogenic pollutants mostly in rural habitats (Brunn et al. 1991; Ansorge et al. 1993; Bukovjan 1997; Georgii et al. 1994; Corsolini et al. 2000). In many European countries, however, red foxes have invaded suburban and even urban environments (McDonald and Newdick 1982; Schöffel et al. 1991; Willingham et al. 1996), where these animals are exposed, at least in part, to the same pollutants as the local human population. A considerable increase of the overall fox density is observed in Zürich, the largest city of Switzerland, where the fox population consists of 6.9-10.3 adult animals per km^2, with cubs being reared in public parks and in private gardens (Hofer et al. 2000; Gloor et al. 2001). Contrary to the typically large territories encountered in rural habitats, the home range of urban foxes is limited to small areas of 0.5 km^2 or less (Harris 1977; Harris and Trewhella 1988; Doncaster and Macdonald 1991). An important consequence of this reduced mobility is that the composition of residues in the tissues of urban and suburban foxes may serve as a more appropriate indicator of environmental pollution, as it reflects the particular contamination of each individual home range. This view was confirmed by the finding that red foxes collected from separate sites in the city of Zürich contain distinctly different levels of heavy metals (Dip et al. 2001). In the present report, the distribution of organochlorine pollutants in the city of Zürich was examined using, as biological indicator, the fox population that is permanently living in the urban and suburban target area.

Materials and Methods

Foxes

Red foxes were collected between January 1999 and February 2000 in the municipality of Zürich. The study area consists of an urban and suburban center of 60 km^2, surrounded by forests and farmland amounting to 30 km^2 (Dip et al. 2001). Most animals (about 75%) were shot by local game wardens, the remaining animals were killed during road or traffic accidents. The carcasses were wrapped in plastic bags and stored at –20°C until necropsy. Tissues were carefully examined for postmortem degradation and for the presence of shots or shot injuries and, if present, such samples were eliminated from further analysis. The age of each animal was determined by counting annuli in the cementum of a canine tooth of the lower jaw (Harris 1978; Kappeler 1985).

Sample analysis

Organochlorine concentrations were assessed in samples of homogenized kidney fat as described by Corsolini et al. (2000) with the following modifications. Samples were extracted in the presence of a mixture of n-hexane and dichloromethane at a ratio of 4 : 1. The apolar phase was processed through two consecutive Florisil columns eluted with n-hexane/dichloromethane at ratios of 4 : 1 on the first column and 9 : 1 on the second column. Analyses were performed with a HRGC 5160 gas chromatograph (Carlo Erba) equipped with 63Ni electron capture detector. A fused silica capillary column (60 m x 0.25 mm x 0.25 µm) was employed (MSP-Friedli). The carrier gas was hydrogen at 2 ml/min with a splitting ratio of 15:1. The temperatures of the injector and detector were 260˚C and 315˚C, respectively. The oven was kept at 100˚C, then increased to 160˚C at 10˚C/min, then to 265˚C at 3˚C/min and finally set at 295˚C (with an increase of 20˚C/min). Pure reference standards (Dr. Ehrenstorfer) were used for recovery determination and quantification. Each series of analysis included a blank, a standard calibration curve, and spiked specimens. Recovery of organochlorines with spiked samples ranged from 80% to 100%. In the case of dieldrin and endrin, recovery was reduced to about 40%. All results are given in mg/kg on a wet weight basis and represent arithmetic means ± standard error of the mean (S.E.). The coefficient of variation on replicate probes was < 7%. The limit of detection in tissue samples was 0.005 mg/kg.

Statistics

PCB, dieldrin and dichlorodiphenyltrichloroethane (DDT) concentrations between different areas, age groups and sexes were compared by the Mann-Whitney *U*-test and the Kruskal-Wallis non-parametric analysis of the variance using the Graphpad Instat version 3.0a software. The Kruskal-Wallis post test for multiple comparisons according to Dunn was applied to determine *P* values, and differences were considered significant at $P < 0.05$.

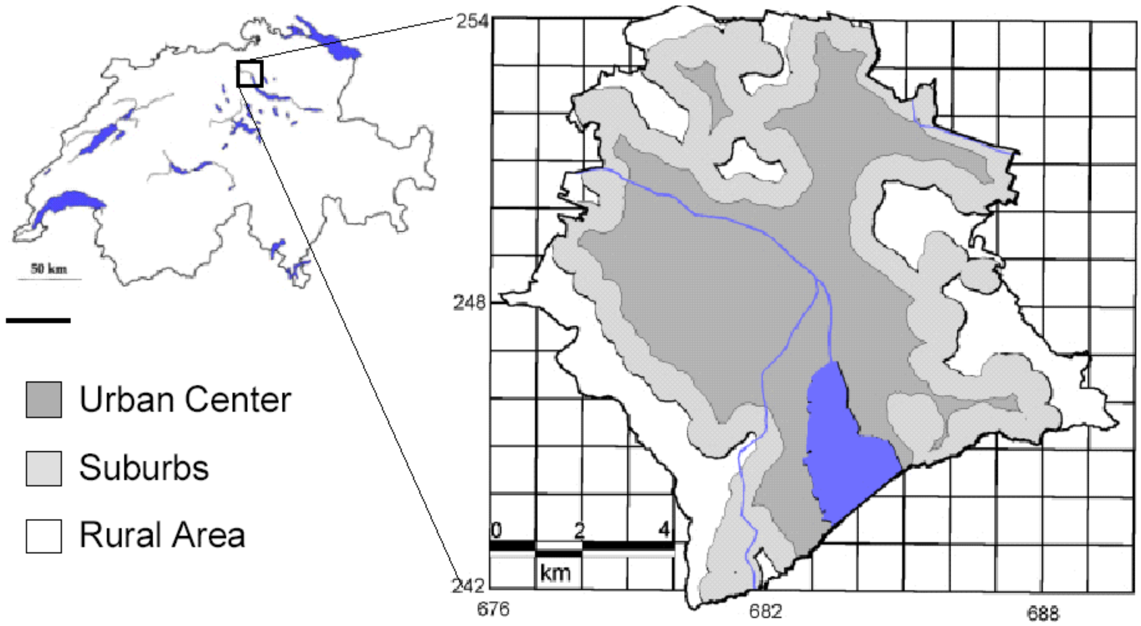


Fig. 1. Study area. The varying distances between neighbouring buildings were used to divide the municipality of Zürich into a rural (distances > 100 m), suburban and urban compartments (distances < 100 m). The suburban area constitutes a transition zone of 500 m between the rural and urban compartments. White: rural area; light gray: suburban area; dark gray: urban area; blue: lake and rivers.

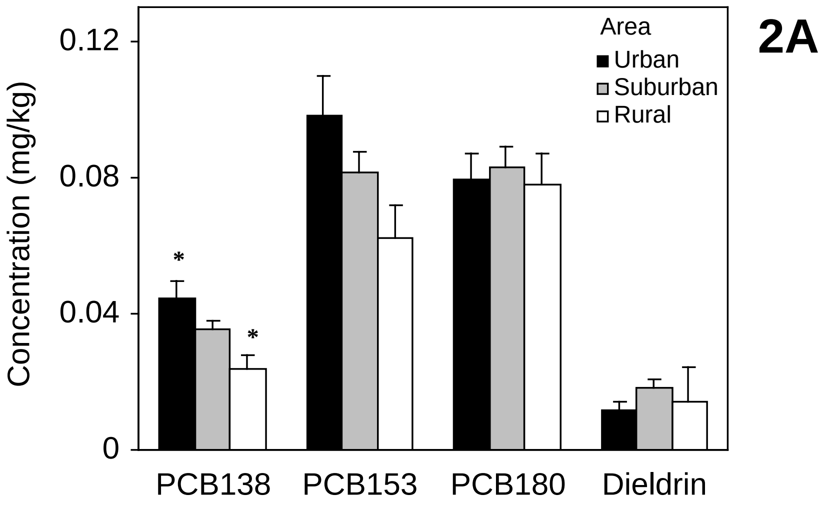
Results

Composition of Sample Population

A sample of perirenal adipose tissue was obtained from a total of 190 red foxes collected between January 1999 and February 2000. Fifty-nine animals were from the urban center of the city of Zürich, 120 animals were collected in the suburban area and only 11 foxes were from the near rural surroundings (Fig. 1). Upon age determination, these animals were divided into three groups that included juvenile foxes with an age of 12 months or less (N = 107), young foxes that were between 13 and 24 months old (N = 36), and adult foxes with an age of more than 2 years (N = 47). The study population consisted of 47% females and 53% males.

Organochlorine Residues

A series of persistent organochlorine pollutants were determined by gas chromatography coupled to electron capture detection. The quantitatively most important residue fraction consisted of PCBs, a class of ubiquitous environmental pollutants comprising 209 possible congeners with different chlorine substitution patterns (Giesy and Kannan 1998). These individual congeners have different physicochemical properties that influence their bioavailability, metabolism and half-life such that, in most biological extracts, PCB138, PCB153 and PCB180 constitute the dominating components (Safe 1994; Cogliano 1998). These major PCB congeners were detected in the adipose tissue of all 190 foxes, although at relatively low levels. PCB 138 was present at concentrations ranging between 0.005 (the limit of detection) and 0.150 mg/kg. The lowest PCB153 and PCB180 levels were around 0.010 mg/kg. The highest concentrations observed for PCB153 and PCB180 were 0.485 and 0.357 mg/kg, respectively. In contrast to these major congeners 138, 153 and 181, which were detected in all animals, PCB28 was found above the limit of detection of 0.005 mg/kg only in two foxes. All foxes resulted negative for PCB52, but PCB101 was found in 17 animals at concentrations of 0.005-0.011 mg/kg. Similarly, detectable concentrations of organochlorine insecticides were encountered only in a fraction of the animals. For example, 77% of tissue samples were positive for dieldrin with concentrations of up to 0.154 mg/kg. Similarly, 36% of samples resulted positive for DDT with the highest concentration reaching 4.361 mg/kg. Only few animals contained trace levels of endosulfan, hexachlorobenzene or heptachlor epoxide in their adipose tissue.



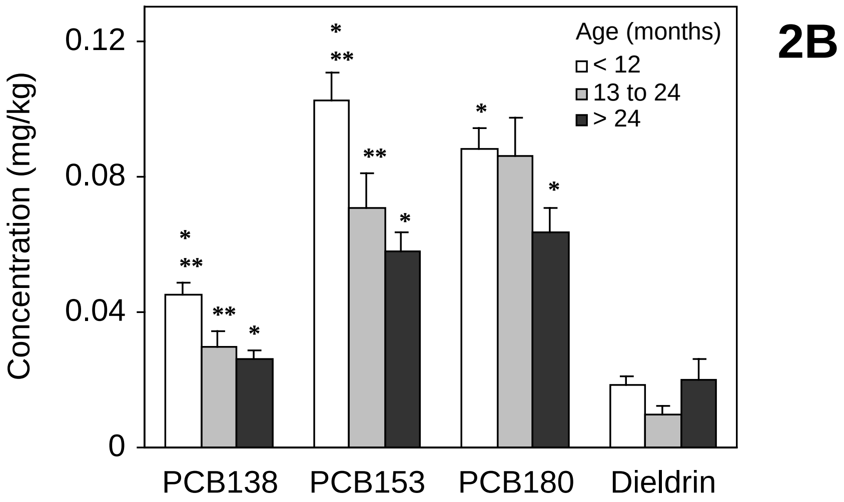


Fig. 2. Mean concentration (+ S.E.) of PCBs and dieldrin in the adipose tissue of foxes. The asterisks denote statistically significant differences between distinct areas or age groups. (A) Comparison between different environmental compartments; *, P < 0.05 between the values of urban and rural foxes. (B) Comparison between different age groups; *, P < 0.05 between the values of juvenile and adult animals; **, P < 0.05 between the values of juvenile and young foxes.

Comparison Between Foxes from Different Habitats

In a previous study with the same fox population (Dip *et al.*, 2001), we found that animals from different but adjacent environmental compartments contained distinctly different levels of heavy metals. Here, we observed that one of the PCB congeners (PCB138) was preferentially accumulated in the foxes of the urban center (Fig. 2A). The increased value for PCB138 in urban foxes relative to the rural animals was significant upon analysis by the Mann-Whitney *U*-test. An apparently similar but statistically not significant trend was observed for PCB153. No regional difference was detected in the level of congener PCB180 and the foxes of all three environmental compartments also contained, on the average, nearly identical levels of dieldrin (Fig. 2A) and DDT (not shown). This comparison suggests that the degree of exposure to persistent organochlorine pollutants is not dramatically increased in the urban center of the city relative to its suburban or rural surroundings.

Age-Dependent Distribution of Organochlorine Residues

The entire fox population, including the small rural fraction of only 11 animals collected at the city border, was further dissected according to age and sex. We calculated an additive PCB concentration (sum of PCB138, PCB153 and PCB180) of 0.227 ± 0.018 mg/kg (mean value ± S.E.) in juvenile foxes aged 12 months or less. Surprisingly, this total PCB concentration decreased to 0.151 ± 0.016 mg/kg in the adult animals with ages over 24 months. Notably, the absolutely highest PCB load (sum of PCBs amounting to nearly 1 mg/kg) was detected in a juvenile fox, while the absolutely lowest sum of PCBs (0.019 mg/kg) was found in an adult fox. The same general trend of reduced PCB burden with increasing age was observed with all individual congeners tested (Fig. 2B). In all these cases, the overall difference between juvenile and adult animals appeared significant upon data analysis by both the Mann-Whitney *U*-test and a non-parametric analysis of the variance (see Materials and Methods for details). No such general decrease could be detected for organochlorine insecticides, as there was a very similar dieldrin concentration in all three age groups (Fig. 2B). The content of DDT was not dissected by age because only few animals resulted positive for this insecticide. Nevertheless, it is remarkable that the two animals with highest concentrations of dieldrin (0.154 mg/kg) or DDT (4.361 mg/kg) both belonged to the category of juvenile foxes with an age of 12 months or less.

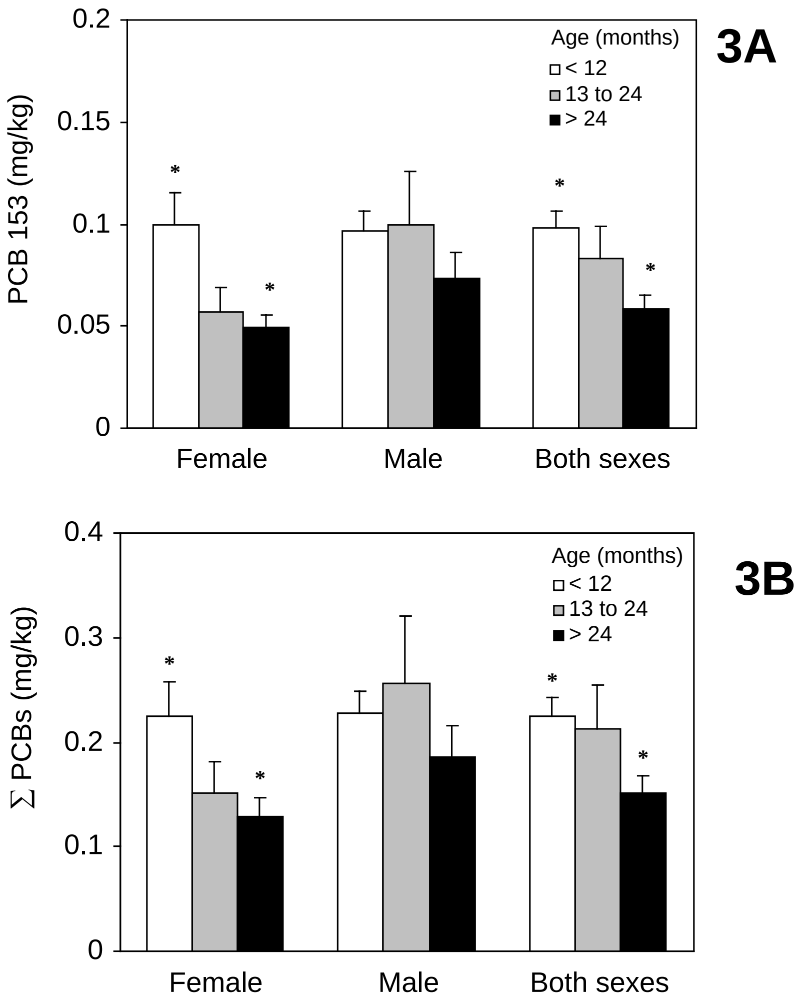


Fig. 3. Concentrations of PCBs (mean + S.E.) in the adipose tissue of foxes of different sex. (A) Congener PCB153. (B) Sum of the three major congeners (PCB138, PCB153, PCB180). The asterisks indicate statistically significant ($P < 0.05$) differences between juvenile and adult foxes.

Sex-Dependent Distribution of PCB residues

When the foxes were separated according to sex, we observed only slightly higher PCB levels in males than in females. However, a clear difference between the two sexes became apparent when the concentration in each group of animals was again plotted as a function of their age. In fact, a statistically significant (Mann-Whithey *U*-test and analysis of the variance) reduction of PCB concentration was found in the adipose tissue of female foxes, where the sum of PCBs decreased from 0.225 ± 0.032 mg/kg (mean value ± S.E.) in juvenile animals to 0.129 ± 0.018 in adults (Fig. 3A). In contrast, the male foxes maintained approximately the same PCB level in the fatty tissue through all stages of life (Fig. 3A). The age-dependent decrease of PCB burden in female animals was significant for all individual PCB congeners tested, but the difference between juvenile and old animals was particularly strong with PCB153 (Fig. 3B). In contrast, the PCB153 content of adult males was not significantly different from that of juvenile animals (Fig. 3B). The overall higher PCB concentration in juvenile foxes relative to adults, in combination with the selective drop of PCB levels in females, indicates that these compounds are transported from mothers to offspring during pregnancy or lactation. This elimination mechanism is absent in male foxes.

Discussion

The most unexpected finding of this study is that juvenile foxes aged 12 months or less display a higher burden of PCBs than adult foxes. PCBs have been largely used in industry, for example as heat transfer fluids, lubricants, dielectric fluids for transformers or flame retardants. However, most PCB applications have been restricted because of their environmental persistence and chronic toxicity and, due to these regulatory actions, the concentration of PCBs in environmental or biological matrices have been steadily declining in the last years (Dougherty et al. 2000). Consistent with this general reduction of PCB exposure, we found in our study conducted with samples obtained in the years 1999-2000 a considerably lower PCB content than in similar reports from neighboring countries (Germany and Italy) based on foxes collected during the years 1983-1993 (Brunn et al. 1991; Georgii et al. 1994; Corsolini et al. 1999; Corsolini et al. 2000).

The age-related drop of PCB levels found in urban foxes contrasts with the only comparable previous report. In fact, the PCB content increased with age in the study by Corsolini et al. (1999), who analyzed mainly rural foxes, indicating that the inverted distribution in our fox population may be characteristic to urban and suburban areas. A possible explanation for this inverted trend of PCB concentrations is provided by the finding that only females were able to reduce their PCB content with progressing age, while the males maintained a constant PCB burden throughout their life span. A similar sex difference has been observed before in different cetaceans (see for example Beckmen et al. 1999; Bernt et al. 1999; Severinsen et al. 2000) and is generally ascribed to the transfer of xenobiotics from mothers to the next generation through pregnancy and lactation. Indeed, Corsolini et al. (1999) already postulated that some organochlorine pollutants may be transferred from female foxes to the foetuses during pregnancy or to the cubs during lactation. Our present study shows, in this terrestrial indicator species, that such a transfer of toxic chemicals from females to the next generation may result in substantially higher levels of the contaminant in young animals relative to adults. Interestingly, this observation recapitulates similar findings from human studies showing that the concentration of polychlorinated xenobiotics in the blood of breast feeding mothers decreases during the first year after birth. This reduction of polychlorinated contaminants in the mothers was accompanied by a concurrent increase in the concentration of the same xenobiotic compounds in the newborn and, at the end of the first year, the infants' blood contained more polychlorinated pollutants than the respective mothers (Abraham et al. 1996; Abraham et al. 1998). Thus, an exceptional exposure to persistent organochlorine pollutants occurs in people during a critical stage of postnatal development and a similar pattern is observed in urban and suburban foxes. This comparison suggests that foxes sharing the same environment with the human population may be employed to monitor the distribution of persistent chemicals, particularly when studies on human volunteers are not practicable and the available information is therefore insufficient for a comprehensive risk assessment. For example, the analysis of urban and suburban fox populations may contribute to the identification of newly released critical chemicals that accumulate in children or other sensitive risk groups.

Acknowledgments

The authors thank all collaborators involved in the Integrated Fox Project. We especially thank C. Stauffer of the Green Department of the city of Zürich for his generous collaboration and for providing access to data of the game sanctuary of Zürich. We also thank the game wardens H. Aerne, S. Dräyer, E. Nüesch and B. Zweifel for collecting the foxes and C. Stieger, U. Müller and M. Ulrich for assistance during necropsy at the Swiss Rabies Center, Bern. The study was supported by the Swiss Federal Office of Veterinary Medicine.

References

Abraham K, Knoll A, Ende M, Päpke O, Helge H. 1996. Intake, fecal excretion, and body burden of polychlorinated dibenzo-p-dioxins and dibenzofurans in breast-fed and formula-fed infants. Pediatr Res 40:671-679.

Abraham K, Päpke O, Gross A, Kordonouri O, Wiegand S, Wahn U, Helge H. 1998. Time course of PCDD/PCDF/PCB concentrations in breast-feeding mothers and their infants. Chemosphere 37:1731-1741.

Ansorge H, Graeser K, Fink, H-G. 1993. Schwermetallrückstände beim Rotfuchs (*Vulpes vulpes*). Beiträge zur Jagd- und Wildforschung 18:79-82.

Beckmen KB, Ylitalo GM, Towell RG, Krahn MM, O'Hara TM, Blake JE. 1999. Factors affecting organochlorine contaminant concentrations in milk and blood of northern fur seal (*Callorhinus ursinus*) dams and pups from St. George Island, Alaska. Sci Total Environ 231:183-200.

Bernt KE, Hammill MO, Lebeuf M, Kovacs KM. 1999. Levels of PCBs and OC pesticides in harbour and grey seals from the St. Lawrence Estuary, Canada. Sci Total Environ 243-244:243-262.

Brunn H, Georgii S, Bachour G, Elmadfa I. 1991. Free-living animals as an indicator of environmental contamination. Tierärztl Umschau 46:549-553.

Bukovjan K. 1997. Concentration of selected foreign substances in the tissues of fox *Vulpes vulpes* L. Folia Venatoria 26/27:107-112.

Cogliano, VJ. 1998. Assessing the cancer risk from environmental PCBs. Environ Health Perspect 106:317-323.

Colborn T, vom Saal FS, Soto AM. 1993. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. Environ Health Perspect 101:378-384.

Corsolini S, Focardi S, Leonzio C, Lovari S, Monaci F, Romeo G. 1999. Heavy metals and chlorinated hydrocarbon concentrations in the red fox in relation to some biological parameters. Environ Monit Assessm 54:87-100.

Corsolini S, Burrini L, Focardi S, Lovari S. 2000. How can we use the red fox as a bioindicator of organochlorines? Arch Environ Contam Toxicol 39:547-556.

Deplazes P, Gloor S, Stieger C, Hegglin D. 2002. Urban transmission of Echinococcus multilocularis. In: Cestode Zoonoses: Echinococcosis and Cysticercosis (Craig P, Pawlowski Z, eds). Amsterdam:IOS Press, 287-297.

Dip R, Stieger C, Deplazes P, Hegglin D, Müller U, Dafflon O, Koch H, Naegeli H. 2001. Comparison of heavy metal concentrations in tissues of red foxes from adjacent urban, suburban and rural areas. Arch Environ Contam Toxicol 40:551-556.

Doganoc DZ, Gacnik KS. 1995. Lead and cadmium in meat and organs in Slovenia. Arch Environ Contam Toxicol 54:166-170.

Doncaster CP, Macdonald DW. 1991. Ecology and ranging behaviour of red foxes in the city of Oxford. Hystrix 3:11-20.

Dougherty CP, Holtz SH, Reinert JC, Panyacosit L, Axelrad DA, Woodruff TJ. 2000. Dietary exposures to food contaminants across the United States. Environ Res A 84:170-185.

Eaton DL, Klaassen CD. 1996. Principles of Toxicology. In: Casarett & Doull's Toxicology (Klaassen CD, ed) New York:McGraw-Hill, 13-33.

Ecobichon DG. 1996. Toxic effects of pesticides. In: Casarett & Doull's Toxicology (Klaassen CD, ed) New York:McGraw-Hill, 643-689.

Frøslie A, Haugen A, Holt G, Norheim G. 1986. Levels of cadmium in liver and kidneys from Norwegian cervides. Bull Environ Contam Toxicol 37:453-460.

Fry DM, Toone CK. 1981. DDT-induced feminization of gull embryos. Science 213:922-924.

Georgii S, Bachour G, Failing K, Eskens U, Elmadfa I, Brunn H. 1994. Polychlorinated biphenyl congeners in foxes in Germany from 1983 to 1991. Arch Environ Contam Toxicol 26:1-6.

Giesy JP, Kannan K. 1998. Dioxin-like and non-dioxin-like toxic effects of polychlorinated biphenyls (PCBs): implications for risk assessment. Crit Rev Toxicol 28:511-569.

Gloor S, Bontadina F, Hegglin D, Deplazes P, Breitenmoser U. 2001. The rise of urban fox populations in Switzerland. Mamm Biol 66:155-164.

Golden RJ, Noller KL, Titus-Ernstoff L, Kaufman RH, Mittendorf R, Stillman R, Reese EA. 1998. Environmental endocrine modulators and human health: an assessment of the biological evidence. Crit Rev Toxicol 28:109-227.

Guillette LJ, Pickford DB, Crain DA, Rooney AA, Percival HF. 1996. Reduction in penis size and plasma testosterone concentrations in juvenile alligators living in a contaminated environment. Gen Comp Endocrinol 101:32-42.

Harris S. 1977. Distribution, habitat utilization and age structure of a suburban fox (Vulpes vulpes) population. Mammal Rev 7:25-39.

Harris S. 1978. Age determination in the red fox (Vulpes vulpes) – an evaluation of technique efficiency as applied to a sample of suburban foxes. J Zool 184:91-117.

Harris S, Trewhella WJ. 1988. An analysis of some of the factors affecting dispersal in an urban fox (*Vulpes vulpes*) population. J Appl Ecol 25:409-422.

Hill EF. 1999. Wildlife toxicology. In: General and Applied Toxicology (Ballantyne B, Marrs T, Syversen T, eds) New York:Grove's Dictionaries Inc, 1327-1363.

Hofer S, Gloor S, Müller U, Mathis A, Hegglin D, Deplazes P. 2000. Urban cycle of Echinococcus multilocularis in the city of Zürich, Switzerland. Parasitol 120:135-142.

Hunter DJ, Hankinson SE, Laden F, Colditz GA, Manson JE, Willett WC, Speizer FE, Wolff MS. 1997. Plasma organochlorine levels and the risk of breast cancer. N Engl J Med 337:1253-1258.

Hutton M. 1982. The role of wildlife species in the assessment of biological impact from chronic exposure to persistent chemicals. Ecotoxicol Environ Safety 6:471-478.

Jorgenson JL. 2001. Aldrin and dieldrin: a review of research on their production, environmental deposition and fate, bioaccumulation, toxicology, and epidemiology in the United States. Environ Health Perspect 109 Suppl 1:113-139.

Kappeler A .1985. Untersuchung zur Altersbestimmung und zur Altersstruktur verschiedener Stichproben aus Rotfuchs-Populationen (Vulpes vulpes L.) in der Schweiz [Diploma thesis] Bern, University of Bern.

Kendall RJ, Bens CM, Cobb GP, Dickerson RL, Dixon KR, et al. 1996. Aquatic and terrestrial ecotoxicology. In: Casarett & Doull's Toxicology (Klaassen CD ed) New York:McGraw-Hill, 883-905.

Kimbrough RD, Doemland ML, Krouskas CA. 2001. Analysis of research studying the effects of polychlorinated biphenyls and related chemicals on neurobehavioural development in children. Vet Human Toxicol 43:220-228.

Kottferová J, Koréneková B. 1998. Distribution of Cd and Pb in the tissues and organs of free-living animals in the territory of Slovakia. Bull Environ Contam Toxicol 60:171-176.

Krieger N, Wolff MS, Hiatt RA, River M, Vogelman J, Orentreich N. 1994. Breast cancer and serum organochlorines: a prospective study among white, black and Asian women. J Natl Cancer Inst 86:589-599.

Loizeau V, Abarnou A, Gugier P, Jaouen-Madoulet A, Le Guellec A-M, Menesguen A. 2001. A model of PCB bioaccumulation in the Sea Bass food web from the Seine Estuary (Eastern English Channel). Marine Poll Bull 43:7-12.

Macdonald SW, Newdick, MT (1982) The distribution and ecology of foxes, *Vulpes vulpes* (L.), in urban areas. In: Proceedings of the 2nd European Ecological Symposium (Bornkamm R, Lee JA, Seeward MR, eds) Oxford: Blackwell, 123-135.

MacKay D. 1991. Multimedia environmental models: the fugacity approach. Chelsea: Lewis.

Markov G. 1996. Roe deer (*Capreolus capreolus* L., 1758), a zoomonitor for the estimation of the natural environment quality in Bulgaria. In: Proceedings of the International Union of Game Biologists (IUGB) XXII Congress (Botev N, ed), 444-447.

Nowak RM. 1991. Mammals of the world. Baltimore:John Hopkins University Press.

Pocock SJ, Smith M, Baghurst P. 1994. Environmental lead and children's intelligence: a systematic review of the epidemiological evidence. Br Med J 309:1189-1197.

Poole KG, Elkin BT, Bethke RW. 1998. Organochlorine and heavy metal contamination in wild mink in Western Northwest Territories, Canada. Arch Environ Contam Toxicol 34:406-413.

Safe, S.H. 1994. Polychlorinated biphenyls (PCBs): environmental impact, biochemical and toxic responses, and implications for risk assessment. Crit Rev Toxicol 24:87-149.

Santiago D, Motas-Guzman M, Reja A, Maria-Mojica P, Rodero B, Garcia-Fernández AJ. 1998. Lead and cadmium in red deer and wild boar from Sierra Morena Mountains (Andalusia, Spania). Bull Environ Contam Toxicol 61:730-737.

Schöffel I, Schein E, Wittstadt U, Hentsche J. 1991. Zur Parasitenfauna des Rotfuchses in Berlin (West). Berl Münch Tierärztlich Wochenschrift 104:153-157.

Seegal RF. 1994. The neurochemical effects of PCB exposure are age-dependent. Arch Toxicol Suppl 16:128-137.

Severinsen T, Skaare JU, Lydersen C. 2000. Spatial distribution of persistent organochlorines in ringed seal (Phoca hispida) blubber. Marine Environ Res 49:291-302.

Thibodeaux LJ. 1979. Chemodynamics: environmental movement of chemicals in air, water, and soil. New York:Wiley.

Tyler CR, Jobling S, Sumpter JP. 1998. Endocrine disruption in wildlife: a critical review of the evidence. Crit Rev Toxicol 28:319-361.

Vreugdenhil HJ, Lanting CI, Mulder PG, Boersma ER, Weisglas-Kuperus N. 2002. Effects of prenatal PCB and dioxin background exposure on cognitive and motor abilities in Dutch children at school age. J Pediatr 140:48-56.

Wells PG. 1999. Aquatic toxicology. In: General and Applied Toxicology (Ballantyne B, Marrs T, Syversen T, eds) New York:Grove’s Dictionaries Inc, 1309-1325.

Willingham AL, Ockens NW, Kapel, CM, Monrad J. 1996. A helminthological survey of wild red foxes (Vulpes vulpes) from the metropolitan area of Copenhagen. J Helminth 70:259-263.

Winneke G, Bucholski A, Heinzow B, Kramer U, Schmidt E, Walkowiak J, Wiener JA, Steingruber HJ. 1998. Developmental neurotoxicity of polychlorinated biphenyls (PCBs): cognitive and psychomotor functions in 7-month old children. Toxicol Lett 102-103:423-428.

Anhang III (proceedings of a conference): Information on foxes in Zurich's backyards: the INFOX programme

Fabio Bontadina[1], Daniel Hegglin[1], Sandra Gloor[1], Therese Hotz[1] and Christian Stauffer[2]

[1] SWILD – Urban ecology & wildlife research, Zurich Switzerland
[2] Grün Stadt Zürich, Zurich, Switzerland

Bontadina F, Hegglin D, Gloor S, Hotz T, Stauffer Ch. (1998): Information on foxes in Zurich's backyards: the INFOX programme. In: Workshop on Human Dimension in Large Carnivore Conservation, KORA Jahresbericht 1998.3;13-19.

Abstract

In Switzerland the dramatic growth of the red fox population is most prominent in urban areas. This has a number of ecological and epidemiological implications. The Integrated Fox Project includes scientific research and an information campaign - named INFOX - to enhance public comprehension about urban foxes. Based on the public attitudes toward urban foxes we describe objectives and target groups of the INFOX programme. In a preliminary overview we show methods and materials used in the first year of the campaign and try to evaluate the effect of the efforts.

The Integrated Fox Project: Interdisziplinary research on Fox Ecology and Epidemiology in Switzerland

The red fox (Vulpes vulpes) is the most widespread and abundant predator on earth, living in almost all habitats of the Northern Hemisphere such as woodlands, mountains, deserts or even suburban and urban environment. Moreover the red fox is the main carrier and vector species of the two most important endemic zoonoses rabies and fox tapeworm. This makes the fox a highly controversial and emotional species with a great potential public involvement and of fundamental importance as far as management questions are concerned.

Over the past ten years there has been a four-time increase in the red fox population in Switzerland. This growth was most prominent in suburban and urban areas. In 1996 we started an integrated research and education project on the dynamics of the red fox population in Switzerland, involving basic ecological and epidemiological research, monitoring and surveillance procedures for epizootics, applied management, and a public information programme called INFOX. Scientists and specialists of wildlife research, veterinary medicine, social science and public relation are involved in the project.

Integrated Fox Project

The Integrated Fox Project IFP includes five modules, each working on different aspects (Fig. 1). The modules are tightly connected by a strategic frame, shared infrastructure and the exchange of material, data and results.

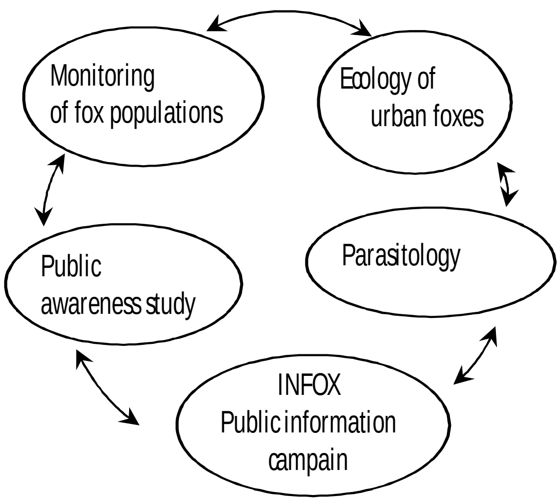


Fig. 1. Organisation of the project.

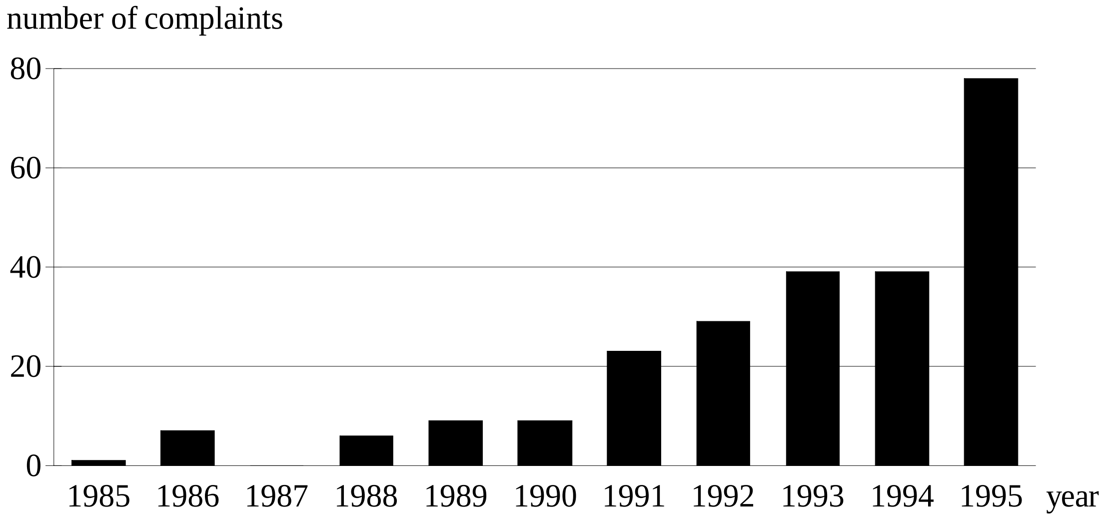


Fig. 2: In Zurich the growth of the urban fox population can be shown by the increase of sightings and complaints of inhabitants reported by one of the three urban game wardens.

Three major problems: echinococcosis, wildlife management and public opinion

In Switzerland rabies was a major problem from the late sixties until the early eighties. In 1978 a vaccination campain of the fox population was started. Since then it was possible to get rabies under control. Today no wild animal with rabies has been found for a year.

Alveolar echinococcosis: The fox tapeworm *Echinococcus multilocularis* is a fox parasite. Human beings can be infected by the eggs of the tapeworm and fall ill with alveolar echinococcosis. The risk of infection is extremely small (8 to 10 persons are affected in Switzerland each year). However the illness is most serious and can not be cured, although it can be treated by surgery and/or chemotherapy. There is no high-risk group known although people living in the countryside tend to fall ill on echinococcosis more often. Despite the dramatic increase of fox populations in the last two decades, the infection rate has been constant for thirty years. Nevertheless the increase of foxes in suburban and urban areas could promote the spread of fox tapeworm in these areas and may increase the risk for human beings in the future.

Fox control and management problems: Foxes are believed to be increasingly responsible for damages to livestock or pets, or on crops, gardens and buildings by digging dens. In Zurich and other Swiss cities there has been a long-standing policy of fox control, usually in response to specific complaints from the local residents. Despite of the intensive control efforts the fox population is growing. Moreover the control activities often result in considerable public debate.

Public opinion problems: There is a wide spectrum of public attitude to the presence of foxes. Some people treat foxes like pets and feed them, while others are worried about the presence of an unknown, wild predator in their vicinity. This fear is often related to zoonoses associated with foxes.

Human attitudes toward urban foxes

We evaluated the spectrum of public attitudes toward urban foxes in a non-representative way by personal contacts with inhabitants during biological field studies, by public calls for fox sightings in news papers and on radio and TV and by the Fox phone, where anybody can phone for information or to report sightings or complain about foxes. Public attitudes toward urban foxes are half positive (41%), half negative (38%), the rest neutral requests for information (n=162).

Tab. 1: Main cause of negativ attitudes toward foxes (n = 62).

Fox tapeworm	31%
Disorder in garden	25%
Afraid, div. problems	18%
Concerned about pets	18%
Request of shooting foxes	8%

Objectives of INFOX:

Ways to the coexistence of inhabitants of cities and urban foxes

Foxes are „neighbours“, but no pets

A lot of people like foxes maybe because they look so similar to dogs, maybe because of their beautiful fur or their image of cleverness.

- INFOX wants to inform about this wild animal species by making it possible to observe it or its traces in town. INFOX tries by information to show people the difference of wild animals and pets.

Communication of the results of the study

We frequently experience, that people often know more about foxes out of fairytales and stories than out of their own experience. Therefore we believe that a lot of conflicts between people and foxes are based on insufficient knowledge about foxes.

- By keeping the public informed about the current study on urban foxes, about methods and preliminary results the INFOX campaign wants to improve and correct the knowledge of people about foxes.

Possibilities of an adapted management of urban foxes

A lot of people think that it would be possible to control fox population by hunting. Because foxes can be the source of rabies and echinococcosis some people call for severe control efforts.

- INFOX wants to inform about rabies and echinococcosis and how we can act to minimize the risk of being infected. INFOX also informs about the possibilities and the limits of fox management.

Foxes as a symbol of urban nature

A lot of people are fascinated by the fact of foxes living in cities. More than any other urban species foxes are identified as a part of real wildlife. Therefore foxes can be perceived as a symbol of urban nature.

- The INFOX-information about the life of urban foxes wants to give the possibility to people in town to experience nature in their immediate vicinity.

Target groups

- All inhabitants of urban areas specifically in Zurich
- multipliers (teachers, children, doctors, veterinarian)
- people, who feel afraid of or have problems with foxes (Fox phone).

Information materials and procedures

- Fox phone: open to the public for questions, sightings etc., „communication centre“.
- leaflet with short information about the current project and fox biology, addresses and phone numbers for more information
- Information on the Swiss television: the TV program „Menschen-Technik-Wissenschaft“ (men - technique - natural science) informs six times about the Integrated Fox Project in 1997/98. Afterwards a book and a video cassette are planned.
- Scientific publications and information for doctors and veterinarians.
- Schools survey and drawing competition: to obtain a picture of the relative abundance of foxes throughout Zurich about 100 schoolclasses were asked to record all sightings of foxes between May and July 1997. Teachers are asked to

make urban foxes a subject in school. We offer teaching materials. A drawing competition takes place for all children in town.

- Foxes in culture: as a co-production of the theatre group M.A.R.I.A. and the Integrated Fox Project the peace „Woman in Fox“ by David Garnett is performed. A exhibition about urban foxes and with the drawings of the competition is shown.

First evaluation of the effect

In Tab. 2 we present our estimation of the effect of the different communication channels. This evaluation is based on personal experience made during the INFOX campaign, not on quantitative data. It is thought to be a background for further discussions. The criteria on which we evaluated the effect of different media are the following:

Television. Television makes it possible to reach almost every inhabitant of Switzerland. The Swiss television programme on urban foxes of Zurich was very successful and led to top viewing figures. On the other hand the contributions about foxes were quite short (6 to 14 min.). Therefore the information was rather superficial. In our experience most people who saw the urban fox programme remember only some pictures which were very emotional.

Print media. Provides the articles were long enough it was possible to communicate more complex contents, too. It is possible to adapt the information level and language chosen to the distinctive readers of each newspaper.

School children. They like and remember mostly emotional contents. Children are multipliers of information because they talk about their experience at home in their families, too.

Personal contact. This is the most time consuming way to communicate about urban foxes and one reaches only few people. Nevertheless it is very often the only way to solve problems individually. Very often it was possible to find suitable solutions for the problems of people who are afraid of foxes or of zoonosis connected with or feel angry about foxes.

Tab. 2: Our personal evaluation on the effects of different information „chanals" of the INFOX-campaign.

medium	**television**	**print medias**	**school children / other multipliers**	**cultural events**	**pers. contact**
Foxes are „neighbours", but no pets	●	●	◐	●	●
Communication of the results of the study	◐	●	◐	○	●
Possibilities of an adapted management of urban foxes	○	●	○	○	●
Foxes as a symbol of urban nature	●	◐	●	●	●
audience					
# of contributions	7	>50	3	3	500
reached persons (total, only Switzerland)	4.7 Mio	>3.3 Mio	1000	1500	500

● strong effect ◐ medium effect ○ weak effect

Acknowledgements.

We are grateful to all members of the Integrated Fox Project for their contributions to INFOX. For the financial support on INFOX we thank: Waldamt der Stadt Zürich, Zürcher Tierschutz, Beitrag aus dem Reinerlös von 10 Prozent des Verkaufszuschlages auf den Pro Patria-Marken 1996, Familien-Vontobel-Stiftung, Schweizerische Akademie der Naturwissenschaften SANW, WWF Zürich, WWF Schweiz, Helen-Bieber Fonds, Zürcher Hochschul-Verein, Ernst Göhner Stiftung, Präsidialdepartement der Stadt Zürich, Genossenschaft Migros Zürich, Ella & J. Paul Schnorf Stiftung, Henry Ford European Conservation Awards 1997.
This is contribution nr. 1 of the Integrated Fox Project IFP.

Anhang IV (Forest Snow and Landscape Research): INFOX – Kommunikation für ein konfliktarmes Zusammenleben von Menschen und Stadtfüchsen

Fabio Bontadina[1], Sandra Gloor[1], Daniel Hegglin[1], Therese Hotz[1] and Christian Stauffer[2]

[1] SWILD – Urban ecology & wildlife research, Zurich Switzerland
[2] Grün Stadt Zürich, Zurich, Switzerland

Bontadina F, Gloor S, Hegglin D, Hotz T, Stauffer Ch. (2001): INFOX – Kommunikation für ein konfliktarmes Zusammenleben von Menschen und Stadtfüchsen. Forest Snow and Landscape Research 2001;76:267-284.

Summary

Fox populations in Switzerland have undergone a drastic increase since the mid-1980s. Parallel to the growth in rural areas, foxes have emerged in urban areas. Today, foxes live already in all Swiss cities. In 1995 the Integrated Fox Project IFP, a research and communication project, was started to study and inform about the amazing dynamic of this medium-sized carnivore. INFOX, the communication campaign of the IFP, was simultaneously planned with the scientific research program. The aim of the campaign was a friendly coexistence of people and foxes. Therefore the public was currently informed about the preliminary results of the project and people had the opportunity to give feed backs about their attitudes towards and problems with foxes. The campaign was continuously adjusted to the needs of the public. It included several communiqués for the media, a TV series, an exhibition, a drawing contest about urban foxes for school children, leaflets, a telephone information line and more. Beside the biological phenomenon, people were actively informed about negative aspects connected with urban fox populations like rabies or the fox tape worm *Echinococcus multilocularis* in order to enable the public to achieve realistic risk perception and to prevent overreaction or panic as well as carelessness when dealing with foxes.

Zusammenfassung

Die Fuchspopulationen der Schweiz haben in den letzten 15 Jahren um das Vierfache zugenommen. Im Zuge der erfolgreichen Bekämpfung der Tollwut mittels oraler Impfung von Füchsen war ab Mitte der 1980er-Jahre ein markanter Anstieg ländlicher Fuchsbestände zu verzeichnen. Parallel dazu wurden vermehrt auch Füchse in Städten wie Zürich und Genf beobachtet. Die erstaunliche Dynamik dieses mittelgrossen Raubtiers war 1995 Anlass, das Integrierte Fuchsprojekt IFP als Forschungs- und Kommunikationsprojekt ins Leben zu rufen.

INFOX, die Informationskampagne des IFP, wurde von Beginn weg zusammen mit den Forschungsprojekten konzipiert, band die Bevölkerung in das Projekt ein, informierte laufend über neuste Resultate des Projektes, und thematisierte neben dem biologischen Phänomen auch sensible Bereiche wie die übertragbaren Krankheiten (Zoonosen). Übergeordnetes Ziel von INFOX war ein konfliktarmes Zusammenleben von Menschen und Füchsen zu ermöglichen. Mittel von INFOX waren auf nationaler Ebene eine sechsteilige Serie am Fernsehen, Radiosendungen und Pressemitteilungen, auf regionaler Ebene in Zürich u.a. die Anlaufstelle „Fuchstelefon“, ein Zeichnungswettbewerb und Unterrichtsmaterialien zu Siedlungsfüchsen für Schülerinnen und Schüler, eine Ausstellung über Stadtfüchse sowie Medienmitteilungen. Im Zentrum von INFOX stand die rollende Entwicklung der Kampagne: Anregungen und Bedürfnisse aus der Bevölkerung wurden in verschiedenen Phasen in die Kampagne integriert und diese neu darauf ausgerichtet. Ein weiterer wichtiger Punkt war die aktive und offensive Information auch über sensible Bereiche. Es gelang, zum Beispiel über Zoonosen und speziell das Thema Fuchsbandwurm frühzeitig zu informieren, Risiken offen anzusprechen und mögliche Massnahmen aufzuzeigen. Damit wurde zu einer sachlichen Diskussion beigetragen und konnte einer Überreaktion in der Bevölkerung, wie das im Ausland geschehen ist, entgegengewirkt werden. Wir ziehen Schlussfolgerungen und diskutieren Empfehlungen für Kampagnen zur Förderung der Akzeptanz von Wildtieren.

Einleitung

Rotfüchse erobern die Siedlungsgebiete

Die BewohnerInnen der meisten Siedlungsgebiete in der Schweiz sehen sich Ende der 1990er-Jahre mit einer neuen Situation konfrontiert: In ihrer nächsten Nachbarschaft leben Füchse, welche keineswegs nur nachts in Stadtrandgebieten nach Nahrung suchen, sondern mitten im Siedlungsraum den Tag verschlafen und hier auch Junge grossziehen, eigentliche Siedlungsfüchse also. Seit Mitte der 1980er-Jahre haben die Fuchsbestände der Schweiz, u.a. als Folge der erfolgreichen Bekämpfung der Tollwut, in ländlichen Gebieten stark zugenommen (Breitenmoser et al. 2000, Breitenmoser et al., in diesem Band). Parallel dazu kam es zu einer sprunghaften Besiedlung von Dörfern, Agglomerationen und Städten durch Füchse (Gloor et al. 2001).

Diese Entwicklung wurde von der Bevölkerung zu Beginn kaum bemerkt, da Füchse ein verstecktes Leben führen und die Bestandesdichten anfänglich gering waren. Obwohl immer mehr Leute Füchsen in Wohngebieten begegneten, wurden solche Beobachtungen sowohl von der Bevölkerung als auch von den Jagdverantwortlichen lange als Ausnahmeereignisse bewertet, denn für viele Menschen sind Füchse typische Waldtiere. Ein Fuchs mitten im Siedlungsgebiet wird deshalb häufig als etwas Unnatürliches wahrgenommen. Auch Ängste im Zusammenhang mit der Tollwut prägen die Haltung vieler Leute gegenüber dem Rotfuchs, obwohl diese Tierseuche in ganz Westeuropa erfolgreich bekämpft werden konnte und die Schweiz seit 1999 tollwutfrei ist (Zanoni et al. 1999).

Wildtierforschung und Kommunikation im Integrierten Fuchsprojekt

Die enorme Dynamik der Fuchspopulationen der letzten 15 Jahre und die damit zusammenhängenden Fragen und Probleme waren 1995 Anlass, das Integrierte Fuchsprojekt IFP ins Leben zu rufen. Das Ziel war, in einem interdisziplinären Forschungsprojekt die verschiedenen Aspekte der zunehmenden Fuchsbestände zu untersuchen. Von Anfang an war das Kommunikationsmodul INFOX wichtiger Bestandteil des IFP und wurde eng verknüpft mit den wildbiologischen, parasitologischen und sozialwissenschaftlichen Projektteilen im Siedlungsgebiet.

Ein Grund dafür war, dass Forschungsarbeiten im urbanen Raum, anders als Arbeiten in abgelegenen Gebieten, stark dem öffentlichen Interesse ausgesetzt sind, um so mehr als das Fuchsprojekt in Zusammenhang mit den Zoonosen Tollwut und Alveoläre Echinokokkose (Kleiner Fuchsbandwurm) sehr sensible Bereiche

bearbeitete. Ein weiterer wichtiger Grund war, dass wir die Bevölkerung als eine unverzichtbare Informationsquelle des Siedlungsraumes ins Projekt einbinden wollten.
Im vorliegenden Beitrag möchten wir aufzeigen, welche Gedanken und Motivationen der Kommunikationskampagne INFOX zu Grunde lagen und wie deren Konzeption und Durchführung schrittweise realisiert wurde. Der Abschluss des ersten Teils der Informationskampagne im Frühling 1999 gibt uns die Gelegenheit, die angestrebten Ziele, die eingesetzten Mittel und den Erfolg von INFOX zu diskutieren.

Das Thema „Kommunikation rund um Wildtiere“ bleibt aktuell. Das Fuchsweibchen mit seinen Welpen im Familiengarten, Wölfe auf Schafweiden, aber auch Zwergfledermäuse in einem Rollladenkasten machen deutlich: Wildtiere leben in unserer nächsten Nachbarschaft und es gilt, Wege für ein möglichst konfliktarmes Zusammenleben zu finden.
Indem wir unsere Erfahrungen mit der INFOX-Kampagne diskutieren und mögliche Konsequenzen für solche Projekte formulieren, möchten wir zu einer erfolgreichen Kommunikationsarbeit im Bereich Menschen und Wildtiere beitragen.

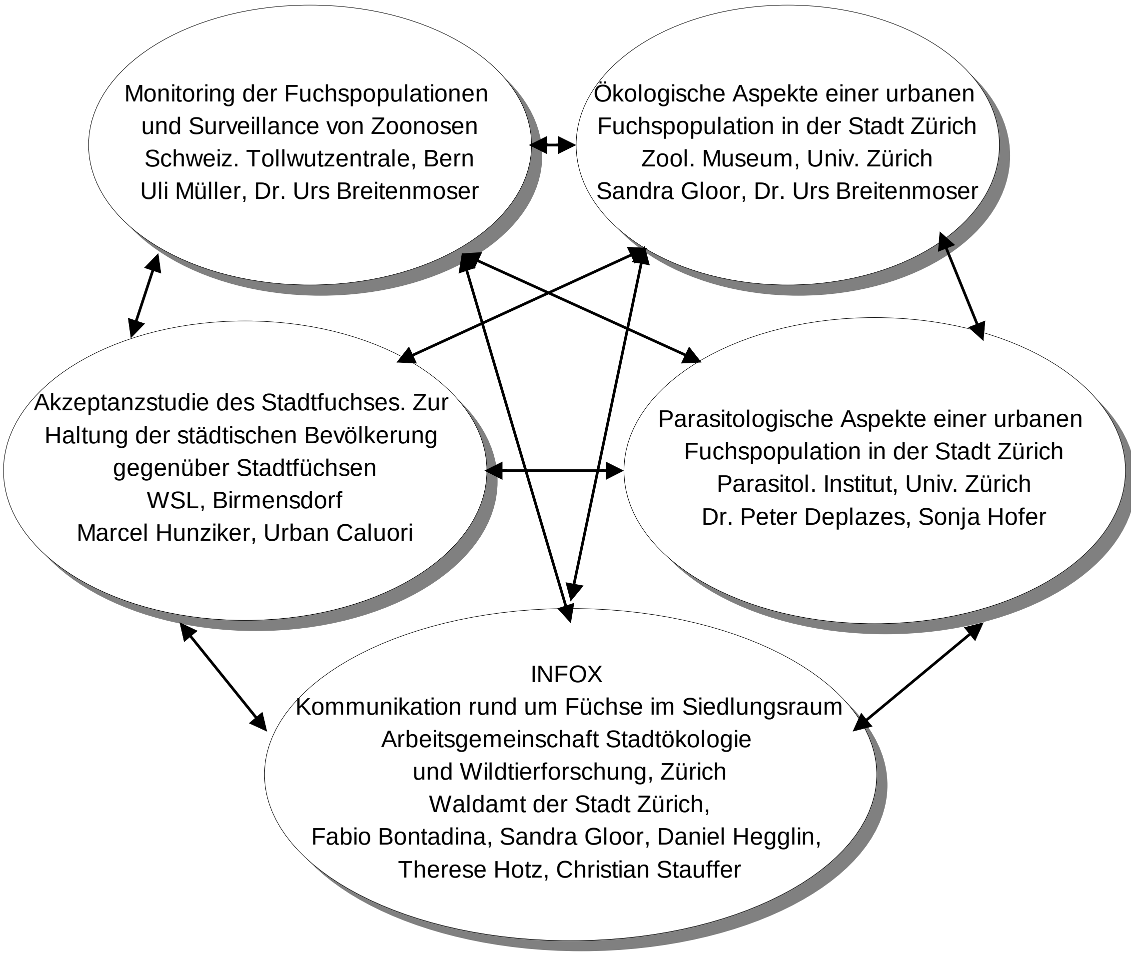


Abb. 1: Die fünf Module des Integrierten Fuchsprojektes und die verantwortlichen Institutionen und Personen.

Entstehung und Ziele von Infox

Das Integrierte Fuchsprojekt IFP und INFOX

1995 erarbeitete die Arbeitsgemeinschaft Stadtökologie und Wildtierforschung (neu: SWILD) im Auftrag der Fachstelle Naturschutz des Gartenbauamtes der Stadt Zürich eine erste Bestandesaufnahme zu Füchsen im Siedlungsraum in Zürich und anderen europäischen Städten (Hotz et al. 1995). Diese Vorstudie führte zu einer ersten Kontaktnahme mit den verschiedenen zuständigen Stellen. Im Anschluss wurde von VertreterInnen der Schweizerischen Tollwutzentrale in Bern, des Institutes für Parasitologie der Universität Zürich, des Waldamtes der Stadt Zürich (neu: Grün Stadt Zürich) und der Arbeitsgemeinschaft Stadtökologie und Wildtierforschung (SWILD) das Integrierte Fuchsprojekt IFP ins Leben gerufen. Während der Planungsphase stiess für die sozialwissenschaftliche Studie die

Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft WSL zum Projektteam. Im Rahmen des IFP wurden in fünf Modulen verschiedene Aspekte der zunehmenden Fuchsbestände bearbeitet (Abb. 1). Je nach Fragestellung waren die Module eng miteinander verknüpft und profitierten gegenseitig von der gemeinsamen Benutzung der erfassten Daten und der Infrastruktur, von den Erfahrungen, dem Know-how der unterschiedlichen Wissenschaftsdisziplinen und dem regelmässigen Informationsaustausch.

Das Modul INFOX wurde von der Arbeitsgemeinschaft Stadtökologie und Wildtierforschung Zürich (SWILD) in Zusammenarbeit mit allen am IFP beteiligten Personen konzipiert und durchgeführt.

Eine wichtige Rahmenbedingung für INFOX in der Stadt Zürich bildete der Umstand, dass das Gemeindegebiet der Stadt Zürich seit 1929 ein Wildschonrevier ist. Drei vollamtliche Schonrevieraufseher (Wildhüter) sind seither ermächtigt, auf dem Stadtgebiet Hegeabschüsse vorzunehmen. Bis zu Beginn des Fuchsprojektes war es im Wildschonrevier gängige Praxis, bei Reklamationen aus der Bevölkerung Füchse in Wohngebieten zu schiessen. Trotz hohen Abschusszahlen nahm die Fuchspopulation aber ständig zu. Im Rahmen des IFP sollte deshalb untersucht werden, welchen Einfluss Reduktionsmassnahmen auf städtische Fuchspopulationen haben. In der einen Hälfte der Stadt wurde die bisherige Abschusspraxis beibehalten, während in der anderen Stadthälfte nur noch sehr zurückhaltend eingegriffen wurde. Mit dem unterschiedlichen Vorgehen sollten Erfahrungen gesammelt und der Effekt auf die beiden Teilpopulationen der Stadtfüchse untersucht werden.

Die Ziele von INFOX

Voraussetzung für INFOX war die Kenntnis, dass Füchse das Siedlungsgebiet als Lebensraum erobert haben und es im Rahmen der heutigen Jagd- und Tierschutzgesetzgebung in der Schweiz selbst mit intensivsten jagdlichen Eingriffen nicht möglich ist, diese Entwicklung rückgängig zu machen.

Das übergeordnete Ziel von INFOX war:
Ein konfliktarmes Zusammenleben von Menschen und Füchsen im Siedlungsraum.

Mit folgende Teilzielen sollte das übergeordnete Ziel erreicht werden:

- Wecken des Interesses für das Wildtier Fuchs im Siedlungsgebiet und positive Positionierung des Fuchses.

- Abklärung der Bedürfnisse der Bevölkerung.
- Eingrenzung konkreter Konfliktbereiche in Zusammenarbeit mit der Bevölkerung.
- Aktive und transparente Information über Gefahren und Risiken im Zusammenhang mit Zoonosen.
- Entwicklung und Umsetzung von Konzepten für die Lösung der konkreten Konflikte.
- Einbindung der Bevölkerung in die Forschungsarbeiten.

Durch die laufende Information über die aktuellen Forschungsergebnisse sollte das Interesse für diesen neuen Mitbewohner geweckt werden. Durch sachliche und aktive Information über mögliche Gefahren und Risiken im Zusammenhang mit Zoonosen sollten einerseits Panikreaktionen verhindert und andererseits der Tendenz zur Verhaustierlichung von Füchsen (Füttern und Zähmen) entgegengewirkt werden.

INFOX wurde auf nationaler Ebene mit einem Schwergewicht für die deutschsprachige Schweiz und auf regionaler Ebene für die Stadt Zürich – wo sehr hohe Fuchsdichten mitten im Siedlungsgebiet verzeichnet und die ökologischen und parasitologischen Forschungsarbeiten durchgeführt wurden - und deren Umgebung konzipiert, wobei jeweils unterschiedliche Methoden und Mittel zum Einsatz kamen.

Realisierung

Mittel und Wege von INFOX und Teilziele der einzelnen Kommunikationsschritte
INFOX wurde als Informations-Drehscheibe geplant, wobei im Mittelpunkt der kontinuierliche und gegenseitige Austausch von Information, Bedürfnissen und Problemen ein wichtiges Ziel war. PartnerInnen von INFOX waren neben den WissenschaftlerInnen des Fuchsprojektes die Bevölkerung (z.B. Kinder und ihre Eltern, LehrerInnen, GartenbesitzerInnen), für Wildtiere verantwortliche Amtsstellen, die Jägerschaft und die Medien.
INFOX wurde von Anfang an in Etappen entwickelt. Die Bevölkerung sollte in die Kampagne einbezogen und beteiligt werden, was es ihr ermöglichte, ihre Fragen und Bedürfnisse selber einzubringen. Dies erlaubte eine Eingrenzung von verschiedenen Konfliktkreisen, auf die mit den jeweils adäquaten Informationsmethoden reagiert werden konnte.

Integriertes Fuchsprojekt IFP

Abb. 2: Projektlogo

Um die Wirkung und Verbreitung der Informationen zu verstärken, wurden für verschiedene Projektteile die Zielgruppen Kinder und LehrerInnen ausgewählt, die als MultiplikatorInnen wirken konnten.

Projektlogo und einheitliche Gestaltung aller Informationsauftritte

Der einheitliche Auftritt mit einem Projektlogo (Abb. 2) und professioneller Gestaltung aller Projektunterlagen durch eine visuelle Gestalterin sollte den Effekt des Wiedererkennens verstärken und somit die Kampagne als Ganzes und nicht nur als Einzelereignisse erkennbar machen.

Mittel für die deutsche Schweiz

- Fuchstelefon für Fragen rund um Füchse

Das Fuchstelefon war von Anfang an ein wichtiger Pulsnehmer für INFOX. Es diente als Anlaufstelle für alle Fragen und Probleme aus der Bevölkerung rund um Füchse. Mitarbeitende des Fuchsprojektes nahmen die Telefone persönlich entgegen, Probleme wurden im direkten Gespräch gelöst oder an weitere Fachstellen (Wildhüter, Institut für Parasitologie der Universitäten Zürich und Bern) weitergeleitet. Wegen der beschränkten finanziellen Mittel wurde das Fuchstelefon für die deutschsprachige Schweiz nur zu bestimmten Zeiten, z.B. nach einer Medieninformation, geführt. Während der übrigen Zeit blieb es mehrheitlich auf die Stadt Zürich beschränkt.

Ziele: Anlaufstelle für Fragen und Probleme aus der Bevölkerung, Anlaufstelle für dringende Fragen nach Medienberichten, Pulsnehmer für Bedürfnisse der Bevölkerung.

Beteiligung: Von Januar 1997 bis August 1999 war das Fuchstelefon national ca. 12 Wochen in Betrieb. Es wurden ca. 130 Anrufe aus der ganzen Schweiz (ohne Zürich) beantwortet.

- 5-teilige Serie von Beiträgen im Rahmen des Magazins „Menschen-Technik-Wissenschaft“ des Schweizer Fernsehens DRS

Während eines Jahres (Feb. ’97 bis Jan. ’98) wurden in sechs Beiträgen der Sendung MTW in 5 bis 15 Minuten Beiträgen das Phänomen Stadtfuchs und das Integrierte Fuchsprojekt mit seinen fünf Modulen vorgestellt und laufend über vorläufige Resultate berichtet.
Ziele: Positive Positionierung des Fuchses, Aufzeigen des Phänomens von Stadtfüchsen, Information zu Zoonosen, welche vom Fuchs übertragen werden, Verhaltensregeln zum Umgang mit Siedlungsfüchsen.
Beteiligung: Die Beiträge wurden gemäss Erhebungen des Schweizer Fernsehens von je bis zu 600'000 Personen gesehen. Bei drei Beiträgen wurden vorangehend Kurzbeiträge in den Hauptnachrichten der „Tagesschau“ gesendet.

- 6-teilige Medienkampagne

Teilweise verbunden mit den Fernsehbeiträgen wurden in sechs Medienaktionen die folgenden Schwerpunktthemen verbreitet: 1) Phänomen Stadtfüchse, IFP, 2) Jungfüchse in der Stadt: Faszination und Probleme, Jungfuchsmarkierungen in der Stadt Zürich, 3) Fuchsbandwurm bei Zürcher Füchsen: Erste Forschungsresultate, Präventionsmassnahmen, 4) Ein Monat im Zeichen des Fuchses: Kulturelle Aspekte, mit Theater, Ausstellung und Matinee, 5) Faszination/Probleme Stadtfüchse: Aussergewöhnliche Bilder von Schlafplätzen von Füchsen in der Stadt, Füchse nicht füttern!, 6) Vorstellung des Ratgebers: Lösungen bei Problemen mit Füchsen.
Ziele: Positive Positionierung des Fuchses, Aufzeigen des Phänomens von Stadtfüchsen, Information zu Problemen und Zoonosen, Aufzeigen von Verhaltensregeln zum Umgang mit Stadtfüchsen und von Lösungswegen bei Problemen.
Beteiligung: Es wurden dutzende Medienleute beraten und viele Interviews gegeben. Insgesamt sind über 130 Zeitungsartikel erschienen (nur von uns erfasste Artikel, ohne professionelle Medienkontrolle), ca. 10 Radiobeiträge und 3 Regionalfernsehbeiträge ausgestrahlt worden.

- Ratgeber mit konkreten Lösungsvorschlägen für die wichtigsten Probleme mit Füchsen im Siedlungsraum.

Der Ratgeber „Füchse im Siedlungsraum - Leben mit einem Wildtier“ wurde auf Grund der Erfahrungen am Fuchstelefon der Stadt Zürich und unzähligen Gesprächen während der Feldarbeiten und an Veranstaltungen entwickelt. Die Broschüre wendet sich an die Bevölkerung von Siedlungsgebieten und ist so konzipiert, dass in einem Kernteil die am häufigsten gestellten Fragen beantwortet

und/oder konkrete Lösungsvorschläge geliefert werden. Der Ratgeber wurde in Zusammenarbeit mit einer verantwortlichen Behörde produziert und enthält einen lokalen Teil, der einen persönlichen Bezug zu den verantwortlichen Personen und den lokalen Verhältnissen schafft.
Ziele: Information zu den wichtigsten Fragen zu Füchsen im Siedlungsraum, Unterstützung der Jagd- und Wildtierverantwortlichen bei ihrer Informationsarbeit, konkrete Tipps und Tricks zur Lösung von Problemen mit Stadtfüchsen.
Beteiligung: Die 50-seitige Broschüre wurde bisher für die Stadt Zürich, Stadt und Kanton Schaffhausen und den Kanton Bern in einer Gesamtauflage von 7'700 Exemplaren produziert. Im Jahr 2001 werden Neuauflagen geplant.

Mittel auf regionaler und lokaler Ebene: Stadt und Kanton Zürich

- Informationsblatt zu Füchsen in der Stadt Zürich

Das Faltblatt enthält Kurzinformationen zu Füchsen in der Stadt (Biologie, Zoonosen, Verhaltensempfehlungen) und die wichtigsten Telefonnummern für weitere Informationen. Es wurde während den Feldarbeiten und nach Beratungsgesprächen an Interessierte abgegeben.
Ziele: Bekräftigung der mündlichen Informationen, Bekanntmachung der Anlaufstelle Fuchstelefon und weiterer Kontaktadressen.
Beteiligung: Das Informationsblatt wurde in zwei Auflagen zu je 5000 Exemplaren gedruckt und an Interessierte verteilt.

- Zürcher Fuchstelefon für Fragen rund um Füchse

Das Fuchstelefon für die Stadt Zürich war eine wichtige Drehscheibe für Informationen rund um Füchse. Neben den Beratungsgesprächen war das Fuchstelefon das beliebteste Mittel, um Fuchsbeobachtungen und Baustandorte zu melden. Während der Arbeiten mit Schulen der Stadt Zürich konnte Unterrichtsmaterial bestellt werden.
Regional wurde das Fuchstelefon in Zusammenarbeit mit dem Waldamt der Stadt Zürich geführt. Informationen zu Fuchsbeobachtungen wurden jedoch vertraulich behandelt, um zu garantieren, dass Füchse nicht auf Grund von Beobachtungsmeldungen geschossen wurden, was die Zusammenarbeit mit der Bevölkerung erschwert hätte.
Die GesprächspartnerInnen am Fuchstelefon wurden jeweils gefragt, ob sie an Interviews im Rahmen einer sozialwissenschaftlichen Studie teilnehmen würden.
Ziele: Anlaufstelle bei Fragen und Problemen, Meldung von Fuchsbeobachtungen, Materialbestellungen, persönliche Beratung, Entlastung der Wildhüter, Auswahl

von potentiellen InterviewpartnerInnen für die sozialwissenschaftliche Befragung des IFP (Hunziker 1998, Caluori 1999).
Beteiligung: Von Januar 1997 bis August 1999 (32 Monate) wurden 344 Anrufe aus der Stadt Zürich entgegengenommen.

■ Informationsveranstaltungen und Infoversände für Jäger im Raum Zürich

Bei Projektbeginn wurden in Zusammenarbeit mit dem Waldamt der Stadt Zürich und den Zürcher Wildhütern zwei Informationsveranstaltungen für die an Zürich angrenzenden Jagdreviere durchgeführt. Die Veranstaltungen boten die Gelegenheit, das Projekt vorzustellen und mit der Jägerschaft zu diskutieren. Gleichzeitig wurden die Jäger aufgerufen, die in Zürich markierten Füchse zu melden, falls diese in ihrem Jagdrevier gefunden wurden. In zwei Versänden an die Jäger des Zürcher Jagdschutzvereins wurden im Abstand von je einem Jahr vorläufige Resultate des Projektes mitgeteilt und nochmals zur Meldung von markierten Füchsen aufgerufen.
Ziele: Kontakte zur Jägerschaft, Diskussion und Kritik des IFP, Rückmeldungen markierter Füchse.
Beteiligung: In zwei abendlichen Informationsveranstaltungen konnten alle 14 benachbarten Jagdgesellschaften von Zürich persönlich über das Projekt informiert werden. In zwei Versänden an die Mitglieder des Zürcher Jagdschutzvereins wurden je ca. 1000 Informationsblätter verteilt.

■ Aufrufe an die Bevölkerung, Fuchsbeobachtungen im Siedlungsraum zu melden

Die Bevölkerung der Stadt Zürich wurde über diverse Medien (Tagespresse, Quartierpresse, Lokalradios) aufgerufen, Fuchsbeobachtungen zu melden. Im Hauptuntersuchungsgebiet der wildbiologischen Untersuchungen in Zürich Wiedikon wurden zudem in 23'000 Haushaltungen Flugblätter mit einem Kurzbeschrieb des Fuchsprojektes und einem Meldeaufruf verteilt. Die Meldungen erreichten uns per Post oder über das Fuchstelefon.
Ziele: Einbezug der Bevölkerung in das Projekt, Bekanntmachen des Stadtfuchs-Phänomens, Bekanntmachen des IFP, Kenntnis über Baustandorte und Jungenaufzuchtorte auf Privatgrundstücken, Grundlagen für eine möglichst genaue Bestandesschätzung in Zürich Wiedikon.
Beteiligung: Auf dem Fuchstelefon gingen nach den Aufrufen im Mai 1997 85 Meldungen ein, über den Postweg erreichten uns aus dem Hauptuntersuchungsgebiet Zürich Wiedikon 133 Meldungen.

■ Begehungen und Aussprachen mit Familiengarten- und Quartiervereinen

Die breite Thematisierung der Füchse im Siedlungsraum führte bei verschiedenen Bevölkerungsgruppen zu einer grossen Verunsicherung. Viele GartenbesitzerInnen und Familien mit Kindern fühlten sich durch die Anwesenheit der Füchse belästigt und im Zusammenhang mit den Zoonosen (Kleiner Fuchsbandwurm, Tollwut) bedroht. In zahlreichen Informationsveranstaltungen bei Familiengarten- und Quartiervereinen und bei Begehungen v.a. in Schrebergartenarealen wurde das direkte Gespräch mit den Betroffenen gesucht und gleichzeitig Informationen vermittelt. An den Veranstaltungen und den Begehungen waren jeweils Vertreter des Waldamtes und des Institutes für Parasitologie beteiligt. Weitere unzählige Gespräche und Begehungen führten die drei Wildhüter der Stadt Zürich durch.
Ziele: Direkte Kommunikation mit besonders betroffenen Bevölkerungsgruppen, Entschärfung und Versachlichung der oft sehr emotionalen Situation.

- Umfrage bei Schulkindern zu Fuchsbeobachtungen

In Grossbritannien wurde eine Methode zur Bestandesschätzung entwickelt, welche erfolgreich in vielen britischen Städten zur Anwendung kam (Harris & Rayner 1986). Wir führten in Zürich einen Test dieser Methode durch. Hierbei wurden über die Stadtzürcher Schulen Kinder und Jugendliche aufgerufen, eigene Fuchsbeobachtungen und solche von Verwandten und Bekannten zu melden. Durch genaue Fuchszählungen in einem Testgebiet in Zürich Wiedikon wurden anschliessend die Anzahl Füchse pro Anzahl Fuchsbeobachtungen eruiert und auf die einzelnen Stadtgebiete hochgerechnet. Die Ergebnisse aller Schulkind-Fuchsbeobachtungen wurden im Rahmen der Fuchsausstellung (Beschreibung unten) vorgestellt.
Ziele: Bewusstsein für die Anwesenheit des Wildtieres Fuchs mitten in der Stadt vermitteln, Motivation für eine Auseinandersetzung mit dem Thema wecken, Nutzung des Multiplikatoreffekts durch Einbindung von Verwandten und Bekannten, Daten für eine Bestandesschätzung erheben, Beteiligung an Kulturmonat und anderen Aktionen erhöhen.
Beteiligung: In 51 Schulhäusern beteiligten sich 72 Schulklassen und meldeten 255 Fuchsbeobachtungen.

- Unterrichtshilfe für LehrerInnen

Eine Unterrichtshilfe über Füchse im Siedlungsgebiet sollte LehrerInnen motivieren, das Thema im Unterricht zu behandeln und die Kinder für Füchse in ihrer Nachbarschaft zu sensibilisieren. Damit sollten die Kinder auch motiviert werden, an den Fuchsbeobachtungen und am Zeichnungswettbewerb teilzunehmen.

Ziele: Informationsvermittlung, Motivation von Schulkindern, sich mit dem Thema zu beschäftigen, Beteiligung an den Fuchsbeobachtungen, Beteiligung am Zeichnungswettbewerb (Beschreibung unten).
Beteiligung: Es wurden 150 Unterrichtshilfen verteilt.

- Zeichnungswettbewerb „Füchse in der Stadt"

Der Zeichnungswettbewerb, an welchem alle Schulkinder der Stadt Zürich mit Einzel- oder Klassenarbeiten teilnehmen konnten, sollte einen weiteren, weniger intellektuellen Zugang zu Thema ermöglichen. Die Kinder sollten motiviert werden, sich mit Füchsen im Siedlungsraum auseinanderzusetzen und ihre eigenen Ideen und Vorstellungen auszudrücken. Jedes Bild wurde an einer grossen Ausstellung gezeigt und jedes Kind erhielt einen Preis.
Ziele: Motivation von Schulkindern, sich mit dem Thema zu beschäftigen, positives Erlebnis im Zusammenhang mit Stadtfüchsen, Beteiligung an den Fuchsbeobachtungen, Motivation, den Kulturmonat (nachfolgend beschrieben) zu besuchen.
Beteiligung: Es beteiligten sich 41 Schulklassen mit Einzel- oder Gruppenarbeiten, insgesamt über 400 Kinder mit 264 Arbeiten am Wettbewerb.

- Kulturmonat im Zeichen des Fuchses: Ausstellung „Lueged nume, de Fuchs gaat ume …", Theater „Frau in Füchsin", Matinee „Fuchs, du hast die Stadt gestohlen"

In einer grossen Ausstellung wurden zum einen alle Arbeiten des Zeichnungswettbewerbes gezeigt, zum andern führte ein vielfältig gestalteter Informationsteil durch die Welt der Zürcher Stadtfüchse. Die Kinder wirkten dabei als MultiplikatorInnen, indem sie die Ausstellung zusammen mit ihren SchulkollegInnen, FreundInnen und Familien besuchten.
Im Rahmen des Kulturmonates wurde die Theatergruppe Freies Theater M.A.R.I.A., Baden, für fünf Aufführungen des Theaters „Frau in Füchsin" nach Zürich eingeladen. Zusammen mit MitarbeiterInnen des Fuchsprojektes entwickelte die Theatergruppe zudem eine Matinee, welche auf spielerische Art Biologisches, Mythisches und Fabelhaftes zu Füchsen im Siedlungsgebiet vermittelte. Die Matinee wurde zweimal in der Fuchsausstellung durchgeführt.
Ziele: Sichtbar- und Bewusstmachen der Anwesenheit der Stadtfüchse, Aufzeigen kultureller Aspekte des Themas (Geschichten, Märchen, Mythen), nachhaltiges Erlebnis des Stadtfuchs-Phänomens mit allen Sinnen, Informationsvermittlung.
Beteiligung: Die Ausstellung dauerte drei Wochen und wurde von über 1000 Personen besucht. Die fünf Theaterabende wurden von 260 Personen, die Matinees von 153 Personen besucht.

Tab. 1: Ereignisse rund um Stadtfüchse, das IFP und INFOX in zeitlicher Abfolge

Zeit	Ereignisse in der Stadt Zürich und im IFP	Ereignisse von INFOX auf nationaler Ebene	Ereignisse von INFOX auf regionaler/lokaler Ebene
1989	■ Im Wildschonrevier der Stadt Zürich wird der Winterbestand der Rotfüchse erstmals auf mehr als 200 Individuen geschätzt, die Fuchspopulation Zürichs nimmt weiter zu.		
1994/1995	■ Vorstudie im Auftrag des Gartenbauamtes der Stadt Zürich, Fachstelle Naturschutz, und anschliessende Gründung des IFP	■ In der deutschsprachigen Presse erscheinen erste Zeitungsartikel (z.B. Tages Anzeiger, 5. Sept. 94, Sonntags-Blick, 13. Nov. 94)	■ In Stadt und Region Zürich erscheinen erste Zeitungsartikel über Füchse im Siedlungsraum (z.B. Tagblatt der Stadt Zürich, 20. April '94, Züri Woche, 12. April '94).
Frühling 1996	■ Start des IFP in fünf Module ■ Gestaltungskonzept und Projektlogo	■ Konzeption von INFOX	
Oktober 1996	■ Start des Nationalfonds-Projektes „Füchse im Siedlungsraum" in der Stadt Zürich	■ Vorbereitung der MTW-Serie, Planung der Medienkampagne	■ Informationsblatt zu Füchsen in der Stadt Zürich ■ Start der Finanzierungsgesuche für INFOX bei Stiftungen, Institutionen, Vereinen, Organisationen, privaten Sponsoren
Dezember 1996	■ Beginn der Feldarbeiten in der Stadt Zürich ■ 1. Fang eines Altfuchses, Start der Telemetrie		■ Informationsveranstaltungen für Jäger im Raum Zürich
Januar 1997	■ Start von INFOX ■ Intensive Telemetriearbeiten bis Juni 1999	■ Erste Medieninformation: Füchse in Siedlungsgebieten und das Interdisziplinäre Forschungsprojekt ■ 1. Teil der MTW-Serie über das IFP ■ Reportage auf DRS 2	■ Start des Fuchstelefons ■ in unregelmässigen Abständen Veranstaltungen und Begehungen mit Familiengarten- und Quartiervereinen über den gesamten Zeitraum des IFP ■ diverse Vorträge
Frühling 1997	■ 1. Jungfuchsmarkierungen in der Stadt Zürich	■ 2. Teil der MTW-Serie zum Thema „Jungfüchse" ■ Medieninformation Jungfüchse	■ Beiträge in den lokalen Medien ■ Aufruf, Fuchsbeobachtungen zu melden in Zürich Wiedikon
Sommer 1997		■ 3. Teil der MTW-Serie: Monitoring, Ernährung Stadtfüchse	■ Schulumfrage, Unterrichtshilfe, Zeichnungswettbewerb ■ Informationsversand an die Zürcher Jäger
Herbst 1997	■ Erste Resultate der Fuchsbandwurm-Untersuchungen	■ 4. MTW-Serie: Fuchsbandwurm im Siedlungsraum ■ Medieninformation zu Fuchsbandwurm, Resultate des IFP	■ Medieninformation zu Fuchsbandwurm, Resultate des IFP in den Quartierzeitungen, lokale Medien
Januar 1998		■ 5. MTW-Serie: INFOX, Kulturmonat im Zeichen des Fuchses in Zürich, Kinder befassen sich mit Stadtfüchsen	■ Kulturmonat im Zeichen des Fuchses: ■ Ausstellung, Theaterabende, Matinees ■ Medieninformation rund um den Kulturmonat
Frühling/ Herbst 1998	■ 2. Jungfuchsmarkierungen in der Stadt Zürich		■ Informationsblatt an die Zürcher Jäger mit Aufruf, Beobachtungen von markierten Füchsen zu melden ■ Medieninformation: Füchse nicht füttern, zahme Füchse werden geschossen
Frühling 99		■ Ratgeber für Stadt und Kt. SH u. Kt. BE, Medieninform.	■ Ratgeber für die Stadt Zürich, Medieninformation

Diskussion

Füchse im Siedlungsraum waren bis 1996 kaum ein Thema in der Schweizer Öffentlichkeit und auch in der Stadt Zürich wurde das Phänomen nicht allgemein wahrgenommen. Dies ermöglichte es uns, den Zeitplan für die Kommunikationskampagne weitgehend selber zu bestimmen und aktiv und ohne öffentlichen Druck schwierige Themen wie die Risiken rund um Zoonosen aufzugreifen.
Allerdings musste der anfängliche Plan, den nationalen Start von INFOX auf das zweite Forschungsjahr zu legen, schon bald verworfen werden. Erste Kontakte mit Medienvertretern machten klar, dass ein grosses Interesse für das Thema vorhanden war und die Medien (insbesondere das Fernsehen) nicht bereit waren, mit „Primeur"-Beiträgen über das Phänomen Stadtfüchse zuzuwarten. Um die Inhalte und den zeitlichen Ablauf der Medieninformationen von unserer Seite her steuern zu können, mussten wir den Kommunikationsteil gemeinsam mit den Forschungsarbeiten starten, auch wenn aus konzeptioneller Sicht ein späterer Zeitpunkt für den Beginn sinnvoller gewesen wäre.

Als übergeordnetes Ziel von INFOX haben wir das konfliktarme Zusammenleben von Menschen und Füchsen im Siedlungsraum angeführt. Dieses hoch angesetzte Ziel kann durch zeitlich begrenzte Öffentlichkeitsarbeit nicht erreicht werden, sondern muss in Dauerarbeit angestrebt werden. Trotz aller Bemühungen wird immer ein Teil der Bevölkerung eine negative Einstellung Wildtieren gegenüber beibehalten. Wichtig ist es jedoch, die allgemeine Bevölkerung für eine positive Haltung zu gewinnen. Öffentlichkeitsarbeit über Wildtiere darf deshalb nicht in erster Linie auf problematische Aspekte fokussieren. Da in einer ersten Phase durch die Öffentlichkeitsarbeit mehr Menschen den Konflikt erkennen, ist es wichtig, dass durch klare Empfehlungen Sicherheit im Umgang mit Wildtieren vermittelt wird.

Die nationale Kampagne, insbesondere die Sendungen im Fernsehen, erreichte eine grosse Breitenwirkung. Die Einschaltquoten erreichten sehr hohe Werte und schlagartig waren sehr viele Leute über das Vorhandensein von Füchsen im Siedlungsraum und das laufende Fuchsprojekt informiert. Dies unterstützte die Feldarbeiten, die regionalen Aufrufe, Füchse zu melden und die Beteiligung an anderen Aktionen im Rahmen von INFOX. Allerdings wurde in den Beiträgen nicht immer der von INFOX gewünschte Schwerpunkt gesetzt (z.B. zu lange Sequenz von zahmen Füchsen, vgl. unten). Am Fuchstelefon und während der Feldarbeiten erhielten wir zudem den Eindruck, dass über die Fernsehbeiträge nur sehr wenige

Informationen bleibend vermittelt werden konnten und ZuschauerInnen sich vor allem an einzelne, stark emotionale Bilder erinnerten. So blieben etwa Bilder von zutraulichen Füchsen, die gefüttert wurden, als starker Eindruck haften, während der kritische Kommentar zu solchen Bildern oft sehr schnell vergessen wurde.
Differenziertere Informationen konnten eher in den Printmedien vermittelt werden. Da die Artikel meist im Anschluss an die Fernsehbeiträge erschienen, wurde hier eine Synergie erreicht, indem das eine Medium das Interesse weckte und das andere die Information vertiefte.

Das schwierigste Thema wurde mit der Zoonose des Kleinen Fuchsbandwurms behandelt. Das sehr kleine, aber doch existente Risiko einer Erkrankung für den Menschen (Eckert & Deplazes 1999) und die wegen der langen Inkubationszeit unklaren Übertragungswege sind geradezu prädestiniert, diffuse Ängste zu wecken. Im Vordergrund stand für INFOX die offensive, transparente und sachliche Information der Bevölkerung und damit das Verhindern einer Überreaktion auf Forschungsarbeiten und mögliche Ergebnisse.
Auf regionaler Ebene spielte dabei eine wichtige Rolle, dass zum Zeitpunkt der Medieninformation über den Kleinen Fuchsbandwurm und über erste Forschungsergebnisse die betroffene Bevölkerung die Anlaufstellen für Fragen bereits kannte (Fuchstelefon, Waldamt, städtische Wildhüter, Institut für Parasitologie) und dass diese Stellen auf die Anfragen vorbereitet waren und eng miteinander zusammenarbeiteten. In den direkten Gesprächen mit Ratsuchenden konnten Fragen besprochen, Lösungen von Problemen gesucht und Anregungen entgegengenommen werden. Je nach Bedarf konnten Ratsuchende auch an eine weitere Stelle verwiesen werden. Die kompetente Beratung rund um die Krankheit Alveoläre Echinokokkose schaffte Vertrauen und zeigte den Betroffenen, dass ihre Ängste ernst genommen wurden und die zuständigen Ämter und das Integrierte Fuchsprojekt sich aktiv um das Thema bemühten. Je nach Situation konnten auch weitere Schritte eingeleitet werden, wie Begehungen in Schrebergärten, Vorträge an Jahresversammlungen von Familiengartenvereinen, Veranstaltungen bei Quartiervereinen und kostenlose medizinische Abklärungen von SchrebergärtnerInnen.
Neben den Ängsten rund um Zoonosen kristallisierten sich im Verlaufe von INFOX zwei weitere Problemkreise heraus: (1) Schäden, welche Füchse in Gärten verursachten und (2) Füchse, die von Anwohnerinnen oder Anwohnern mit Futter angelockt und gezähmt wurden.
Zahme und halbzahme Füchse führten und führen immer wieder zu Anrufen von verängstigten oder verärgerten Anwohnern beim Fuchstelefon oder bei den

Wildhütern. Diese Füchse kennen kaum Scheu vor dem Menschen, sitzen z.B. beim Barbecue im Garten neben dem Grill oder dringen gar in Wohnungen vor. Füchse sind im allgemeinen nicht aggressiv und greifen den Menschen nicht an. Trotzdem ist ein solch nahes Aufeinandertreffen von Mensch und Fuchs wegen der Gefahr übertragbarer Krankheiten auf keinen Fall sinnvoll. Auf die Information, dass Füchse und andere Wildtiere nicht zu füttern oder gar zu zähmen sind, wurde deshalb grossen Wert gelegt. Zudem kann so eine zusätzliche Förderung der Füchse im Siedlungsgebiet durch ein zusätzliches Nahrungsangebot gebremst werden. Das Waldamt der Stadt Zürich und das Integrierte Fuchsprojekt wiesen in einer gemeinsamen Medieninformation darauf hin, dass zahme und halbzahme Füchse geschossen werden und Füchse nicht gefüttert werden dürfen.

Trotz allen Bemühungen von Seiten des Projektes und der zuständigen Stadtbehörden und Wildhüter, waren und sind nicht alle Konflikte lösbar. So nehmen die Reklamationen aus der Bevölkerung weiter zu, am stärksten in jenem Stadtteil mit der zurückhaltenden Abschusspraxis. Die Fallwildzahlen (tot aufgefundene Tiere) zeigen zwar die stärksten Zuwachsraten in jenem Stadtteil, in dem anteilsmässig die meisten Abschüsse von Füchsen erfolgen. Die Reklamationen jedoch bewegten sich in diesem Stadtteil in den letzten Jahren etwa im gleichen Rahmen. Die Abschüsse dürften, nach vorläufiger Einschätzung des IFP, nicht zu einer Stabilisierung oder Reduktion der Fuchspopulation geführt haben, bei der betroffenen Bevölkerung hinterliessen sie jedoch den Eindruck des aktiven Handelns durch die zuständigen Behörden. Umgekehrt waren verschiedene GartenbesitzerInnen von Schrebergärten und Einfamilienhausgärten in der Stadthälfte mit zurückhaltender Hegeabschusspraxis über die Präsenz der Füchse sehr verärgert und äusserten die Meinung, dass von Seiten der Stadt zu wenig gegen die Störenfriede unternommen werde. Vereinzelt wurde mit Selbsthilfemassnahmen gedroht und in einem Fall wurde ein Fuchs in einem Gartenareal vergiftet aufgefunden. Das Waldamt entschied sich deshalb, in solchen Fällen auch in diesem Stadtteil vermehrt Hegeabschüsse vorzunehmen, um die Situation zu beruhigen.

Allgemein erhielten wir den Eindruck, dass bei akuten Konflikten oder Ängsten der Bevölkerung der direkte Kontakt von den zuständigen Stellen mit den Betroffenen der einzige Weg ist, um Lösungen zu finden. Oft werden erst im direkten Gespräch die genauen Probleme und deren Hintergründe klar und es können gemeinsam individuelle Lösungswege diskutiert oder Massnahmen ergriffen werden. Wertvolle Informationen für diese Gespräche lieferte die soziologische Studie zu den grundsätzlichen Haltungen der Einwohnerinnen und Einwohner der Stadt Zürich

gegenüber Stadtfüchsen (Caluori 1999), welche im Rahmen des IFP durchgeführt wurde.
Bei der Information von grösseren Gruppierungen ist es wichtig, dass das Gespräch mit den verschiedenen Interessen- bzw. Bevölkerungskreisen gesondert gesucht wird (z. B. GartenbesitzerInnen von Schrebergärten oder lokal Betroffene mit kontroversen Meinungen), damit die bestehenden Schwierigkeiten gezielt angegangen werden können. Es wird geschätzt und stiftet Vertrauen, wenn die Betroffenen bei der Problemlösung einbezogen werden, was allerdings eine vorangegangene, kompetente Information voraussetzt. Ähnliche Empfehlungen werden für Öffentlichkeitsarbeit im Zusammenhang mit grossen Beutetieren wie Wolf und Bär gegeben (Bath 1989 und 2000, Kellert et al. 1996).
Eine grundsätzlich negative Haltung gegenüber Wildtieren mit Information ändern zu können, scheint allerdings schwierig zu sein. Immerhin werden dem Fuchs als äusserlich attraktivem und wenig Angst einflössenden Wildtier grössere Sympathien entgegengebracht als beispielsweise dem Wolf und negative Extrempositionen werden seltener eingenommen. Diese Haltung zeigt sich auch in unseren Mythen. Die positive Beeinflussung einer neutralen oder unentschiedenen Einstellung ist dagegen eher möglich (Bath 1989 und 2000).
Menschen mit positiver Einstellung Wildtieren gegenüber sind eher bereit, Kompromisse einzugehen als Menschen mit negativer Haltung und beispielsweise zu befürworten, dass Problemfälle, d. h. Schaden stiftende Individuen abgeschossen werden, wie dies auch das Waldamt Zürich (neu: Grün Stadt Zürich) für Füchse und das Bundesamt für Umwelt, Wald und Landschaft BUWAL beispielsweise für Luchse und Wölfe entschieden hat.

Obwohl wir überzeugt sind, mit INFOX für anstehende Probleme mit Füchsen einiges beigetragen zu haben, können wir nicht mit Zahlen belegen, wie effektiv, breit und nachhaltig die Wirkung von INFOX war und ist. Eine Erfolgskontrolle, wie sie z. B. von Bath (1996) vorgeschlagen wird und über Wölfe im Gange ist (Bath 2000), wäre Gegenstand eines eigenen Forschungsprojektes.

Folgerungen

Folgerungen aus INFOX für die weiteren Arbeiten des Integrierten Fuchsprojektes

1. Anlaufstellen für kompetente Beratung müssen vorhanden und bekannt sein. Vor allem stark betroffene Bevölkerungsgruppen müssen die Möglichkeit für eine Beratung im direkten Gespräch haben. In der Stadt Zürich ist dies mit dem

Waldamt (neu: Grün Stadt Zürich), den drei Wildhütern, dem Fuchstelefon und dem Institut für Parasitologie an der Universität Zürich weiter gewährleistet.

2. Die Konzeption von weiteren Kommunikationsschritten soll auf Grund der quantitativen Studie zur Akzeptanz der Füchse im Siedlungsraum, welche zur Zeit durchgeführt wird (Hunziker 1998), vorgenommen werden.
3. Zahme und halbzahme Füchse, sowie Füchse, welche gefüttert werden, führen zu Konflikten: Medieninformationen zum Abschuss von gezähmten Füchsen, Füchse sollen nicht gefüttert werden.
4. Dank der engen Zusammenarbeit von Forschung und INFOX wurde der Forschungsbedarf zu folgenden Themen deutlich:
   - Der Fuchsbandwurm-Zyklus im urbanen Raum, Risikoabklärungen
   - Handlungsszenarien bei Infektionsrisiko Fuchsbandwurm im urbanen Gebiet
   - Handlungsszenarien bei Tollwutfällen im urbanen Gebiet

Folgerungen für die Kommunikationsarbeit im Bereich Mensch und Wildtier

1. Nur aktive Information ist planbar: Problemkreise sollten aktiv und offensiv kommuniziert werden. Dabei empfiehlt es sich, die verschiedenen Interessen- oder Lokalgruppen getrennt zu informieren.
2. Es empfiehlt sich, ein Wildtier oder ein Phänomen zuerst positiv zu positionieren (in den ersten Medienberichten standen schöne und faszinierende Bilder und Berichte im Vordergrund), damit die Meinung der allgemeinen Bevölkerung nicht negativ beeinflusst wird. Erst in einem zweiten Schritt sollen die problematischen Seiten thematisiert werden.
3. Kommunikationsarbeit sollte dynamisch entwickelt werden und sich an den Bedürfnissen und Problemen der betroffenen Bevölkerung orientieren. Dazu braucht es Instrumente zur Wahrnehmung der Probleme (z.B. Anlaufstelle wie Fuchstelefon, Kontaktpersonen wie Wildhüter, ProjektmitarbeiterInnen des Fuchsprojektes).
4. Für die Medienarbeit wurde ein Medienverantwortlicher als alleiniger bzw. erster Ansprechpartner für die Medien bestimmt, der alle Informationen und Interviews koordinierte. Dies garantierte eine einheitliche Informationspolitik während des gesamten Projektes. Die Medieninformationen umfassten vorbereitete Texte und Bildmaterial. Vor allem kleinere Zeitungen übernahmen die Texte oft im Wortlaut. Bei Anfragen von MedienvertreterInnen wurde auf der Abmachung bestanden, dass Interviewtexte und Inhalte gegengelesen werden können (nur fachlich, nicht formal).
5. Direkte Kontaktnahme und persönliche Gespräche bei Konflikten mit Betroffenen und zuständigen Amtsstellen sind unverzichtbar.

6. Praxisorientierte und ansprechend gestaltete schriftliche Unterlagen (z.B. konkreter Ratgeber zu Fragen und Problemen rund um Füchse) bilden eine wichtige Unterstützung bei Beratungen.
7. Forschung macht den Untersuchungsgegenstand zum Thema. Bei medienattraktiven oder konfliktträchtigen Forschungsthemen ist deshalb aktive Öffentlichkeitsarbeit unumgänglich.
8. Forschung im Siedlungsgebiet braucht wegen der erhöhten Aufmerksamkeit der Bevölkerung begleitende Öffentlichkeitsarbeit.

INFOX: Geld für die Füchse?

Professionelle Öffentlichkeitsarbeit kann nicht nebenbei erledigt werden. Soll sie ein Forschungsprojekt begleiten und unterstützen, muss sie frühzeitig und zusammen mit den Forschungsarbeiten geplant und in enger Zusammenarbeit mit allen Beteiligten durchgeführt werden. Öffentlichkeitsarbeit ist phasenweise sehr zeitintensiv, weshalb genügend freie Arbeitskapazität vorhanden sein muss, um alle nötigen Schritte zu planen, durchzuführen und die Beteiligten zu koordinieren. Die in den Forschungsarbeiten involvierten WissenschaftlerInnen kommen deshalb nur begrenzt für die Durchführung der Öffentlichkeitsarbeit in Frage und der Beizug von weiteren Kommunikations-Mitarbeitenden ist zu empfehlen. Auch die projektinterne Kommunikation spielt eine wichtige Rolle. Die Beteiligten müssen über die einzelnen Informationsschritte im Detail informiert und mit deren Aussagen und Form einverstanden sein.
Es liegt auf der Hand, dass für qualifizierte Kommunikation sowohl intern als auch extern genügende finanzielle Mittel zur Verfügung stehen müssen. Für INFOX wurde deshalb ein eigener, von den Forschungsarbeiten unabhängiger Budget- und Finanzierungsplan erstellt, wobei an der Finanzierung eine grosse Zahl von Ämtern, öffentlicher Institutionen, Tier- und Naturschutzorganisiationen und privater Stiftungen beteiligt waren. Das Sponsoring über Firmen oder Privatpersonen erwies sich sowohl im grösseren Rahmen als auch im Raum Zürich als sehr aufwändig und wenig erfolgreich.

Allgemeine Folgerungen

Nach einer Publikumsbefragung des Sendegefässes „Menschen-Technik-Wissenschaft MTW“ des Schweizer Fernsehens (MTWmail 1996) stehen Themen über Natur und Tiere bei allen Altersklassen an erster Stelle des Interesses. Die Voraussetzung, Wildtiere mit ihren sympathischen und problematischen Seiten zum Thema zu machen, stehen also gut und mit der Beteiligung der Medien kann gerechnet werden. Die Erfahrungen mit INFOX haben gezeigt, dass geeignet aufbereitete Medieninformationen speziell zusammen mit ansprechendem Bildmaterial (Fotos, Videosequenzen) bei den Medien meist auf ein grosses Echo stossen.

Kommunikationsarbeit in Zusammenhang mit Forschungsprojekten wird häufig vernachlässigt und bei Geld- und Auftraggebern von Forschungsprojekten fehlt nicht selten die Einsicht, dass neben den Forschungsarbeiten die Kommunikation fester Bestandteil von Projekten sein sollte. So sind die personellen und finanziellen Mittel oft nicht vorhanden, Öffentlichkeitsarbeit zu planen und gezielt durchzuführen. Gerade anwendungsorientierte und interdisziplinäre Forschung ist jedoch auf die Kommunikation mit der Bevölkerung angewiesen. Zudem schafft frühzeitige, aktive und transparente Kommunikation rund um Forschungsarbeiten Vertrauen und kann zu einem Zeitpunkt einsetzen, in welchem sachliche Diskussionen und Lösungen für Probleme oder Konflikte noch möglich sind.

Dank

Wir danken allen Mitarbeiterinnen und Mitarbeitern des Integrierten Fuchsprojektes für die gute Zusammenarbeit. Insbesondere danken wir den Wildhütern der Stadt Zürich Hermann Aerne, Stefan Dräyer, Erwin Nüesch und Bruno Zweifel.
Für die finanzielle Unterstützung von INFOX danken wir dem Waldamt der Stadt Zürich (neu: Grün Stadt Zürich), dem Zürcher Tierschutz, für den Beitrag aus dem Reinerlös der Pro Patria-Marken 1996, der Familien Vontobel-Stiftung, der Schweizerischen Akademie der Naturwissenschaften SANW, dem WWF Zürich, dem WWF Schweiz, dem Helen-Bieber Fonds, dem Zürcher Hochschul-Verein, der Ernst Göhner Stiftung, der Präsidialabteilung der Stadt Zürich, der Genossenschaft Migros Zürich, der Ella & Paul Schnorf Stiftung.
INFOX wurde mit folgenden Preisen ausgezeichnet: 1. Preis bei den Henry Ford European Conservation Awards 1997, Switzerland, für „INFOX - Wege für das Zusammenleben von Menschen und Stadtfüchsen“, Anerkennungpreis 1998 des Prix Media der Schweizerischen Akademie der Naturwissenschaften SANW, Nomination durch die Schweizerische Gesellschaft für Wildtierbiologie SGW.

Literatur

Bath, A. J. (1989): The Public and Wolf Reintroduction in Yellowstone National Parc. Society and Natural Resources, Vol. 2: 297-306.

Bath, A. J. (1996): Increasing the Applicability of Human Dimensions Research to Large Predators. Journal of Wildlife Research, 1(2): 215-220.

Bath, A. J. (2000): Human Dimension in Wolf Management in Savoie and Des Alpes Maritimes, France. A Large Carnivore Initiative for Europe (LCI). p. 166.

Bontadina, F., Hegglin D., Gloor, S., Hotz, T., Stauffer, C. (1998): Information on Foxes in Zurich's Backyards: the INFOX Programme. KORA-rapport 3, workshop on human dimension in large carnivore conservation, 56 pp, www.kora.ch, p. 15-20.

Breitenmoser U., Müller U., Kappeler A., Zanoni R.G. (2000): Die Endphase der Tollwut in der Schweiz. Schweizer Archiv der Tierheilkunde 147, 447-453.

Caluori, U. (1999): Füchse in der Stadt - missliebige und geliebte Nachbarn. Eine Studie zu den grundsätzlichen Haltungen der Einwohnerinnen und Einwohner der Stadt Zürich gegenüber Stadtfüchsen. Eidg. Forschungsanstalt für Wald, Schnee und Landschaft (WSL), Birmensdorf. Interner Bericht, 57 S.

Eckert, J. & Deplazes, P. (1999): Alveolar Echinococcosis in Humans: The Current Situation in Central Europe and the Need for Countermeasures. Parasitol. Today, vol. 15, no. 8, 315-319.

Gloor S., Bontadina F., Hegglin D., Deplazes P., Breitenmoser U. (2001): The rise of urban fox populations in Switzerland. Mammalian Biology. 66, 155-164.

Harris, S. & Rayner, J. M. V. (1986): Urban fox (Vulpes vulpes) population estimates and habitat requirements in several British cities. Journal of Animal Ecology, 55: 575-591.

Hotz, T., Bontadina, F. & Gloor, S. (1995): Füchse - wilde Tiere in der Stadt? Abklärungen zum Rotfuchs (Vulpes vulpes) in Zürich und europäischen Städten. Interner Bericht der Fachstelle Naturschutz des Gartenbau- und Landwirtschaftsamtes der Stadt Zürich, 37 S.

Hunziker, M., Egli, E. & Wallner, A. (1998): Return of Predators: Reasons for Existance or Lack of Public Acceptance. KORA-rapport 3, workshop on human dimension in large carnivore conservation with A. J. Bath, 56 pp, www.kora.ch, p. 25-30.

Kellert, S. R., Black, M., Rush, C. R., Bath, A. J. (1996): Human Culture and Large Carnivore Conversation in North America. Conservation Biology, 10/4: 977-990.

MTWmail (1996): Informationsblatt der Sendung MTW-Menschen-Technik-Wissenschaft, Schweizer Fernsehen DRS, 1/96, 4 p.

Zanoni, R. G., U. Breitenmoser, A. Kappeler, U. Müller, C. Müller, Wandeler, A. I. (2000): Tollwutfreiheit der Schweiz nach 30 Jahren Fuchstollwut. Schweizer Archiv für Tierheilkunde 147: 423-429.

Curriculum vitae

Name:	Daniel Hegglin
Geboren am	20. Januar 1967, in Zug
Heimatort:	Menzingen / ZG
Eltern:	Pirmin und Margrith Hegglin-Meyer

1973 – 1981	Primar- und Sekundarschule in Menzingen
1981 – 1986	Kantonsschule in Zug / Matura Typ B
1987 – 1995	Studium der Zoologie an der Universität Zürich, Hauptfach Zoologie, Nebenfach Umweltlehre. Diplomarbeit am Zoologischen Institut der Univ. Zürich, unter der Leitung von Prof. H. Kummer und Dr. B. Wechsler: „Das Verhalten von Muttersauen und das Erdrücken von Ferkeln beim Hausschwein (*Sus scrofa*)".
1995	Auszeichnung der Philosophischen Fakultät II der Universität Zürich und Schweisfurth-Forschungspreis für artgemässe Nutztierhaltung für die Diplomarbeit „Das Verhalten von Muttersauen und das Erdrücken von Ferkeln beim Hausschwein (*Sus scrofa*)".
seit 1995	Monitoring juveniler Bartgeier für die Stiftung pro Bartgeier
seit 1996	Mitarbeit in der Arbeitsgemeinschaft SWILD, Stadtökologie, Wildtierforschung, Kommunikation, Zürich.
1997 und 1998	1. Preis der Henry Ford European Conservation Awards Switzerland und 2. Preis des PRIX MEDIA der SANW für die Informationskampagne INFOX des Integrierten Fuchsprojekts zusammen mit Fabio Bontadina und Sandra Gloor
1999	Lehrauftrag an der Philosophisch–Naturwissenschaftlichen Fakultät der Universität Basel „Wild lebende Säugetiere in der Stadt – Erfassung und ökologische Bedeutung"
seit 1999	Mitglied der Fachkommission der Stiftung pro Bartgeier
1999 – 2003	Dissertation am Institut für Parasitologie und am Zoologischen Museum der Univ. Zürich, unter der Leitung von und Prof. Dr. P. Deplazes und Prof. Dr. Paul I. Ward: „The Fox Tapeworm (*Echinococcus multilocularis*) and the Red Fox (*Vulpes vulpes*) in the Urban Habitat: Ecological and Epidemiological Aspects and an Evaluation of an Intervention Strategy"

Im Verlaufe meines Studiums besuchte ich Vorlesungen folgender DozentInnen:

Bächli G, Bachofen R, Briegel H, Chanson R, Christen Ch, Cook CDK, Dorn-Mühlebach S, Dübendorfer A, Dubler E, Dürst A, Eichenberger M, Eller B, Endress P. K, Eugster CH, Fisch J, Fischer H, Fitze P, Flühler H, Fölsch DW, Graf B, Gresch P, Gutte B, Häsler R, Hegelbach J, Heimgartner H, Henz HR, Hertz J, Hohl H-R, Holzhey H, Honegger T, Kägi J, Keller H, Klötzli F, Kohl J, Kramer CU, Kubli E, Kummer H, Landolt E, Leuthold-Glinz W, Martin RD, Matile Ph, Müller H, Nievergelt B, Noll M, Nöthiger R, Oswald HR, Paul H, Rast D, Reyer H-U, Ribi G, Rieber H, Rössel R, Rüedi P, Rutishauser R, Sauter W, Schanz H, Schelbert-Syfrig H, Schmid O, Schmid P, Schneider K, Schneller J, Sticher H, Storrer HH, Tardent P, Turner DC, Waldner F, Walter P, Walter Th-A, Ward P, Wechsler B, Wehner R, Woggon W-D, Wolters G, Ziswiler V.

List of publications

- Wechsler, B.; **Hegglin, D.** (1997): Individual differences in sow behaviour and crushing of piglets. Applied Animal Behaviour Science 51 (1997) 39-49

- **Hegglin, D.**; Gajdon, G.; Good, T.; Getenet, A.; Gebremedhin, B.; Imfeld, S.; Lustenberger, J.; Niederberger, J. (1998): Larger mamals and birds in the Lowlands and on the Plateau of the Park. A survey on the Flora and Fauna of the Simen Mountains National Park. Walia; special issue. Pano-Verlag, Zürich, Switzerland. 52-63.

- **Hegglin, D.**; Bontadina, F.; Gloor, S. (1998): From the alpine to the urban fox - adaptive behaviour of the red fox (*Vulpes vulpes*). Advances in Ethology 33: 119, Supplements to Ethology. Abstract.

- Wechsler, B.; and **Hegglin, D.** (1998): Crushing of piglets in relation to the behaviour of the sow at the nest-site. Book of Abstracts of the 49th Annual Meeting of the European Association for Animal Production (1998) 124

- Bontadina, F.; **Hegglin, D.**; Gloor, S.; Hotz, T.; Stauffer, Ch. (1998): Information on foxes in Zurich's backyards: the INFOX programme. In: Workshop on Human Dimension in Large Carnivore Conservation, KORA Jahresbericht Nr. 3: 13-19.

- Hofer, S.; Gloor, S.; Müller, U.; Mathis, A.; **Hegglin, D.**; Deplazes, P. (2000): Urban cycle of *Echinococcus multilocularis* in the city of Zurich, Switzerland. Parasitology 120, 135-142.

- Gloor, S.; Bontadino, F.; **Hegglin, D.**; Hotz, T. (2001): Füchse im Siedlungsraum. Wildbiologie in der Schweiz 6(32):23pp.

- Gloor, S.; Bontadina, F.; **Hegglin, D.**; Deplazes, P.; Breitenmoser, U. (2001): The rise of urban fox populations in Switzerland. Mammalian Biology. 66: 155-164.

- Dip, R.; Stieger, C.; Deplazes, P.; **Hegglin, D**.; Müller, U.; Dafflon, O.; Koch, H.; Naegeli, H. (2001): Comparison of heavy metal concentrations in tissues of red foxes from adjacent urban, suburban and rural areas. Arch. Environ. Contam. Toxicol. 40, 551-556.

- Bontadina, F.; Gloor, S.; **Hegglin, D.**; Hotz, T.; Stauffer, Ch. (2001): INFOX – Kommunikation für ein konfliktarmes Zusammenleben von Menschen und Stadtfüchsen. For. Snow Landsc. Res. 76: 267-284.
- Stieger, C.; **Hegglin, D**.; Schwarzenbach, G.; Mathis, A.; Deplazes, P. (2002): Spatial and temporal aspects of urban transmission of *Echinococcus multilocularis*. Parasitology 124:631–640.
- Deplazes, P.; Gloor, S.; Stieger, C.; **Hegglin, D.** (2002): Urban transmission of *Echinococcus multilocularis*. In: Craig, P. and Z. Pawlowski (Eds.): Cestode Zoonoses: Echinococcosis and Cystercosis. IOS Press: 287-297.
- **Hegglin, D.**; Bontadina, F.; Gloor, S.; Romer, J.; Müller, U.; Breitenmoser, U.; Deplazes, P.: Baiting red foxes in urban area: a camera trap study. (Submitted)
- **Hegglin, D.**; Ward, P. I.; Deplazes, P.: *Echinococcus multilocularis* in urban areas: An intervention study. (Submitted)
- Contesse, P.; **Hegglin, D.**; Gloor, S.; Bontadina, F.; Breitenmoser, U.; Deplazes, P.: The diet of urban foxes (*Vulpes vulpes*) and the availability of anthropogenic food in the city of Zurich, Switzerland. Mammalian Biology. (Accepted)
- Dip, R.; **Hegglin, D.**; Deplazes, P.; Dafflon, O.; Koch, H.; Naegeli, H.: Age- and sex-dependent distribution of persistent organochlorine pollutants in urban foxes. (submitted)
- Schwarzenbach, G.; **Hegglin, D.**; Stieger, C.; Deplazes, P.; Ward, P. I.: An experimental field approach to parasitism and immune defence in voles. (in prep.)