

Conservation ecology in the horseshoe bats
Rhinolophus ferrumequinum* and *Rhinolophus hipposideros

Inauguraldissertation
der Philosophisch–naturwissenschaftlichen Fakultät
der Universität Bern

vorgelegt von
Fabio Bontadina
von Ponto Valentino / TI

Begutachtet von:
Prof. Dr. Raphaël Arlettaz, Abteilung Conservation Biology,
Zoologisches Institut der Universität Bern

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Der Dekan
Prof. Dr. G. Jäger

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Part I Analysing spatial data of different accuracy: the case of greater horseshoe bats foraging

Part II Foraging range use by a colony of greater horseshoe bats *Rhinolophus ferrumequinum* in the Swiss Alps: implications for landscape planning

Part III Jagt die Grosse Hufeisennase *Rhinolophus ferrumequinum* im Wald? - Grundlagen zum Schutz von Jagdgebieten der letzten grösseren Kolonie in der Schweiz

Part IV Schutz von Jagdgebieten von *Rhinolophus ferrumequinum*. Umsetzung der Ergebnisse einer Telemetrie-Studie in einem Alpental der Schweiz.

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Zusammenfassung

Eine entscheidende Voraussetzung für den Schutz von bedrohten Arten sind Kenntnisse über deren grundsätzliche ökologische Ansprüche, auf deren Grundlage der Bedarf nach artspezifischen Schutzmassnahmen abgeklärt werden kann. Die Grosse Hufeisennase (*Rhinolophus ferrum-equinum*) und die Kleine Hufeisennase (*Rhinolophus hipposideros*) sind heute in der Schweiz nach einem dramatischen Bestandseinbruch in der zweiten Hälfte des letzten Jahrhunderts "vom Aussterben bedroht". Mit der Zielsetzung, raumspezifische Angaben zur Nutzung der Ressourcen zu erheben, wurden Hufeisennasenkolonien in der Schweiz, in Italien und in Wales (UK) mit radiotelemetrischen Methoden untersucht, eine angepasste Methode zur Auswertung der Raumdaten entwickelt, konkrete, raumspezifische Vorschläge zur Umsetzung der Resultate in Schutz- und Fördermassnahmen formuliert und in einem Konzept die Prioritäten der weiteren Forschungsarbeiten aufgezeigt.

Bei der radio-telemetrischen Untersuchung einer sehr mobilen Art schwankt die Genauigkeit der erreichbaren Ortungen abhängig vom Gelände und dem Verhalten des Tieres. Es wird eine Methode vorgeschlagen, wie Ortungen geringer Genauigkeit nicht - wie allgemein empfohlen - aus den Analysen ausgeschlossen werden müssen und deren Informationen damit verloren gehen, sondern wie diese zusammen mit ihrem Fehler in die Berechnung der Aufenthaltsdichten einbezogen werden können, ohne dass dabei die hohe räumliche Auflösung von genauen Ortungen verloren geht.

Beide Hufeisennasenarten zeigen eine Selektion für Waldgebiete, wobei die Kleine Hufeisennase streng an Waldgebiete gebunden ist, während dies für die Grosse Hufeisennase nur im Frühling zutrifft. Die Hypothese, wonach der grossräumige Populationsrückgang in der zweiten Hälfte des letzten Jahrhunderts auf einen Verlust der Jagdlebensräume zurückgeht, kann für die Kleine Hufeisennase verworfen werden, da Waldgebiete in derselben Zeit an Fläche zunahmen.

Das Muster der Raumnutzung beider Arten ist stark vom Reproduktionsquartier geprägt. Hufeisennasen nutzen ihre unmittelbare Umgebung der Kolonie im Umkreis von 2.5 bis 3.5 km für die Nahrungs suche, je weiter Jagdgebiete von der Kolonie entfernt sind, desto geringer

ist die Nutzungsdichte. Dieses Raumverhalten wird im Zusammenhang mit einer Begrenzung durch die Flügelmorphologie gesehen, die für lange Flüge nicht geeignet ist, den Hufeisennasen umgekehrt jedoch ermöglicht, mit wendigem Flug in dichter Vegetation Insekten zu jagen. Aufgrund dieser Resultate wird postuliert, dass räumlich explizite Arten-schutzmassnahmen in der Umgebung des Reproduktionsquartiers am wirkungsvollsten sind. Es werden drei Perimeter für die Umsetzung der Resultate im Umfeld von Reproduktionskolonien mit zunehmender Grösse und mit abnehmender Schutzpriorität vorgeschlagen: Kernjagd-gebiete mit den höchsten Nutzungsdichten, das gesamte Aktivitätsgebiet der Kolonie und das Verbreitungsgebiet der Art in einer Region. Die aufgrund der Forschungsresultate abgeleiteten konkreten Massnahmen sind als Hypothesen zu verstehen, deren Wirksamkeit zu kontrollieren ist.

Aufgrund einer Erfassung der Restvorkommen der Kleinen Hufeisennase in der Schweiz und einer Evaluation der Ursachen, die zum Aussterben geführt haben, werden Prioritäten für weitergehende Forschungsarbeiten festgelegt.

Übersicht

Ökologische Daten als Grundlage von Schutzkonzepten

Eine entscheidende Voraussetzung für den Schutz und das Management von bedrohten Arten sind Kenntnisse über deren grundsätzliche ökologische Ansprüche, ihre "natural history", sowie Informationen über die dynamischen Prozesse, welche die Grösse von Populationen und ihre Verbreitung bestimmen (Hunter 1996, Primack 1998). In der Conservation Biology dienen deshalb ökologische Daten zur Verbreitung, zur Populationsentwicklung, zur Morphologie, Physiologie, Genetik und zum Verhalten, zur Ressourcennutzung sowie über interspezifische Interaktionen dazu, den Gefährdungsgrad von Populationen zu erfassen und die Mechanismen und Ursachen der Gefährdung zu verstehen (Soulé 1986). Dies ist eine Voraussetzung, um auf der Basis von wissenschaftlichen Resultaten effektive Schutzmassnahmen ableiten zu können (Suter 1998).

Artenschutz oder Biotopschutz ?

Es wird kontrovers diskutiert, ob Schutzkonzepte auf einzelne Arten ausgerichtet sein sollen oder ob sie sich auf gesamte Ökosysteme – oder gar ganze Landschaften – beziehen sollen (Simberloff 1998). Das Konzept eines Schutzes von Ökosystemen wurde vor allem in den USA entwickelt und geht von der Idee aus, dass mit dem Schutz des Lebensraumes (Biotopschutz) gleichzeitig alle Lebewesen in ihm geschützt werden (Grumbine 1994, Morrissey 1994 in Simberloff 1998), was Schutzmassnahmen, die auf einzelne Arten ausgerichtet sind (Artenschutz), erübrigen würde.

Die unterschiedlichen Standpunkte haben auch in der Europäischen Naturschutzpraxis zu unterschiedlichen Prioritäten geführt (z. B. Schulte 2000, BUWAL 2000), wo die Schutzanstrengungen gerne auf den Biotopschutz beschränkt werden. Bei dieser Kontroverse wird jedoch häufig ausser Acht gelassen, dass je nach Art unterschiedliche räumliche Skalen (Wiens 1993) betroffen sind. So können für Insekten einzelne kleine Flecken eines Habitattypes als Lebensraum von Populationen genügen (Murphy, Freas & Weiss 1990), während für grössere Wirbeltiere

häufig Lebensräume nötig sind, die sich aus verschiedenen Habitattypen zusammensetzen oder die gar aus verschiedenen Landschaftseinheiten bestehen (Breitenmoser 1998). Für deren Schutz wäre demzufolge die Unterschutzstellung riesiger Gebiete nötig, was in Nordamerika, Kanada oder Australien denkbar scheint, im durch den Menschen dichtbesiedelten Europa jedoch kaum möglich ist. Gerade im Westen Europas sind kaum mehr grössere, vom Menschen nicht stark beeinflusste Flächen zu finden, womit der integrale Schutz von ganzen Ökosystemen kaum je in Frage kommt.

Neben latenten oder periodischen Einflüssen durch den Menschen hat speziell die Fragmentierung von Lebensräumen grosse Auswirkungen auf Tiergemeinschaften (Primack 1998, Debinski & Holt 2000). Sie führt zur Aufteilung von Landschaften in kleine Habitatinseln (MacArthur & Wilson 1967, Wilcox 1980), die durch andere Habitattypen oder Barrieren in unterschiedlichem Ausmass voneinander getrennt sind (Mader 1984). Der Einfluss von Barrieren ist um so grösser, je beschränkter die Mobilität einer Art ist (Soulé & Wilcox 1980). Diese durch den Menschen verursachten massiven Veränderungen in der Qualität der Habitate und der Struktur der Landschaft werden als wichtige Ursache für die Bedrohung vieler Arten angesehen (Primack 1998). Um für eine Art eine erfolgreiche Schutzstrategie festlegen zu können, muss deren Resourcennutzung in Verbindung mit ihren räumlichen Ansprüchen bekannt sein und es müssen die Konflikte mit der menschlichen Landnutzung identifiziert sein. Nur so kann eine Lösung gefunden werden, bei der entweder mit der integralen Erhaltung einer Fläche oder mit artspezifischen Schutzmassnahmen im räumlichen Verbund die Erhaltung und Förderung einer Art erreicht werden können.

Mehrstufige Selektion von Ressourcen

Die Fähigkeit zur aktiven Fortbewegung erlaubt Tieren das Aufsuchen von günstigen Orten zur Erschliessung der benötigten Ressourcen. Diese Habitatselektion kann als hierarchischer räumlicher Prozess aufgefasst werden: in einer ersten Stufe erfolgt die Wahl des Verbreitungsgebietes, innerhalb diesem dann die Selektion eines Gebietes als Homerange, innerhalb dieses Wohngebietes werden wiederum Flächen und Habitat-

strukturen (Habitatelemente) gewählt (Owens 1972, Johnson 1980). Als vierte Stufe kann die Selektion von Nahrung innerhalb von aufgesuchten Habitat elementen verstanden werden (Johnson 1980).

Die vorliegende Arbeit orientiert sich an diesem grundlegenden Konzept aus der Landscape Ecology (Wiens 1973), indem die Habitatnutzung von unterschiedlichen räumlichen Skalen untersucht wird. Bei der Habitat selektion wird die Qualität und Struktur der genutzten Habitate im Vergleich zu deren Angebot gestellt. In jeder Raumskala können unterschiedliche Habitate oder Strukturen selektiert werden (z. B. Rolstad, Loken & Rolstad 2000). Die zurückgelegten Distanzen geben Hinweise auf den Aufwand zur Erreichung der Ressourcen.

Zwei stark gefährdete Fledermausarten als Untersuchungstiere

Die vorliegenden Untersuchungen wurden an der Grossen Hufeisennase (*Rhinolophus ferrumequinum*, Schreber 1774) und der Kleinen Hufeisennase (*Rhinolophus hipposideros*, Bechstein 1800) durchgeführt. Beide Arten sind in der Schweiz "vom Aussterben bedroht" (Duelli 1994). Es sind nördlich der Alpen die einzigen beiden Vertreterinnen der Familie der Rhinolophiden, die weltweit ca. 70 Arten umfasst (Nowak 1994). Beide Arten galten in der Schweiz bis in die Mitte des zwanzigsten Jahrhunderts als weit verbreitet (Baumann 1949, Stutz & Haffner 1984). Während die Grossen Hufeisennase vermutlich nie in grosser Dichte vorgekommen ist, wird die Kleine Hufeisennase als Fledermausart beschrieben, die unter den dreissig einheimischen Fledermausarten als eine der häufigsten, wenn nicht sogar als häufigste angetroffen wurde. Diese Situation sieht heute grundsätzlich anders aus, nachdem die Populationen beider Arten in den 1950er, hauptsächlich aber in den 1960er und 1970er-Jahren einen dramatischen Bestandseinbruch erlitten haben: beiden Arten stehen heute kurz vor dem Aussterben. Massive Bestandesrückgänge und Arealverluste werden aus einer Mehrheit der Länder Nord-, West- und Zentraleuropas vermeldet (Übersicht zur Kleinen Hufeisennase in Bontadina et al. 2000), weshalb sie in einer Vielzahl europäischer Länder als "vom Aussterben bedroht" in den Roten Listen aufgeführt sind und in den Anhang der EC Habitat Directive aufge-

nommen worden sind (Ransome & Hutson 2000). Damit wird unterstrichen, dass prioritär Massnahmen zum Schutz von Quartieren und Lebensräumen nötig sind.

Von der Grossen Hufeisennase sind in der Schweiz nur noch etwa 300 Tiere in drei isolierten Kolonien übrig geblieben (Beck & Schelbert 1999), während der Bestand der Kleinen Hufeisennase auf etwa 2000 Tiere in 40 Reproduktionsquartieren geschätzt wird (Bontadina et al. 2000, A. Theiler, mündl. Mitteilung). Die beiden Arten kommen im Gegensatz zu früher in der Schweiz kaum mehr sympatrisch vor, weshalb auf einen direkten Vergleich der beiden Arten im selben Lebensraum verzichtet werden musste.

Die grösste der drei Kolonien der Grossen Hufeisennase liegt im Vorderrheintal und ist mit etwa 150 Weibchen, die zur Jungenaufzucht im Sommer im Estrich einer Kirche zusammenkommen, die grösste bekannte Reproduktionskolonie in ganz Mitteleuropa (Ohlendorf 1999). Solche Restkolonien, die aufgrund ihrer Grösse dennoch gute Überlebenschancen haben, verdienen eine spezielle Aufmerksamkeit bei Schutzanstrengungen, da sie neben der Erhaltung der existierenden Population auch als Ausgangspunkt für eine mögliche Expansion der Population und eine Wiederbesiedlung verlorengegangener Gebiete im ursprünglichen Verbreitungsgebiet dienen können (Bellamy 1996). Zudem bedeutet ihre Einzigartigkeit auch die letzte Gelegenheit, die lokalen artspezifischen Anforderungen studieren zu können.

Die Dringlichkeit der Erhaltung der Population im Vorderrheintal nahm zusätzlich an Bedeutung zu, als in der unmittelbaren Umgebung dieser Wochenstubenkolonie eine landwirtschaftliche Flurbereinigung (Melioration) geplant wurde. Es ist bekannt, dass eine solche Reorganisation des landwirtschaftlich genutzten Landes einen negativen Einfluss auf die Qualität von naturnahen Flächen und die Strukturvielfalt hat (Tanner & Zoller 1996, Vickery et al. 2001). Diese Kolonie war deshalb aus dringendem Anlass Gegenstand eines Schutz- und Förderungsprojektes, das eine Untersuchung der Raumnutzung und der Habitatwahl beinhaltete (Beck et al. 1994). Diese Untersuchung ist Grundlage meiner Arbeiten der Teile I bis IV.

In Teil V sind Resultate dargestellt, die in einer Referenz-Untersuchung an einer Kolonie der Grossen Hufeisennase in Italien erhoben wurden. In manchen Gebieten des Mittelmeerraumes ist die Grosse Hufeisennase noch häufig. Der Beitrag entstand bei einer Einladung an einen italienischen Kongress und hatte zum Ziel, anhand des Fallbeispieles dieser ökologischen Untersuchung die Möglichkeiten und Grenzen von radio-telemetrischen Forschungsarbeiten bei Fledermäusen aufzuzeigen.

Bei der Kleinen Hufeisennase wurde in der Schweiz nach ihrem drastischen Bestandesrückgang ebenfalls ein Bedarf nach schutzrelevanten Grundlagen manifest (Bontadina et al. 2000). Allerdings war noch vor wenigen Jahren eine radio-telemetrische Untersuchung der Jagdgebiete aus technischen Gründen nicht möglich, wie eigene Tests im Jahre 1991 gezeigt haben (Bontadina et al., unpubl. Daten). Erst die Entwicklung von Miniatursendern (Naef-Daenzer 1993) erlaubte diesen systematischen Zugang. Angesichts der geringen Populationsgrössen der Kleinen Hufeisennase in der Schweiz wurden die ersten umfassenden Feldarbeiten zur Habitatnutzung dieser Art in einem Gebiet in Wales, GB, durchgeführt, wo noch grössere Bestände der Kleinen Hufeisennasen vorkommen (Schofield 1996). Die Ergebnisse zur Ressourcenutzung dieser Art sind im Teil VI enthalten.

Der Wissenschaftliche Rat der Schweizerischen Koordinationsstelle für Fledermausschutz entschloss sich, eine schutzorientierte Forschungsarbeit für die Kleine Hufeisennase durchzuführen. Damit bestand der Bedarf nach einem umfassenden, auf wissenschaftlichen Grundlagen abgestützten Forschungskonzept. Für die ganze Schweiz wurden die Grundlagen zum aktuellen Status der Art zusammengetragen und mit ExpertInnen-Interviews und einer Evaluation von möglichen Ursachen wurden die wahrscheinlichsten Gefährdungsfaktoren identifiziert. Diese Grundlagen sind zusammen mit einem Forschungskonzept, das die Ausrichtung der Forschung in verschiedenen Schritten aufzeigt, im letzten Beitrag (Teil VII) zusammengestellt.

Zielsetzung der vorliegenden Arbeit

Um die ökologischen Ansprüche der beiden Arten zu verstehen und artspezifische Schutzmassnahmen empfehlen zu können, fehlten insbe-

sondere raumspezifische Angaben zur Nutzung ihrer Ressourcen. Es wurde deshalb für die Grosse Hufeisennase der nutzbare Raum für die gesamte Kolonie bestimmt und die Merkmale analysiert, welche die Ressourcennutzung einer Kolonie räumlich festlegen. Die öko-morphologische Voraussage, dass Grosse Hufeisennasen im Wald jagen, wurde überprüft. Bei der Kleinen Hufeisennase wurde mit einem unterschiedlichen Auswertungsansatz ebenfalls die Raumnutzung von Individuen aus einer Reproduktionskolonie untersucht, zusätzlich wurde die Habitatselektion innerhalb der Aktivitätsgebiete analysiert. Eine Voraussetzung für diese Untersuchungen war dabei, dass eine angepasste Methode für die Erfassung und Auswertung der Raumdaten dieser sehr mobilen Tiere entwickelt werden konnte.

Die gewonnenen ökologischen Daten werden als Basis verstanden, um Empfehlungen für den Schutz der gefährdeten Fledermauspopulationen formulieren zu können. Dabei sollten insbesondere räumlich explizite Schutzmassnahmen abgeleitet werden, die den regionalen Akteuren in der Umsetzung eine Antwort darauf geben, in welchem Perimeter die Schutzansprüche der Art prioritär berücksichtigt werden müssen und ob Schutzmassnahmen flächig im Rahmen des Biotopschutzes realisiert werden können, oder welche spezifischen Massnahmen des Arten- schutzes nötig sind. Für die Kleine Hufeisennase wird ein detailliertes Forschungskonzept präsentiert, das aufgrund einer Evaluation der Gefährdungsfaktoren die Prioritäten im Forschungsbedarf aufzeigt.

Teil I: Kombination von Ortungen unterschiedlicher Genauigkeit

Dieser Artikel behandelt die methodischen Probleme beim Studium einer schnell fliegenden, mobilen Tierart mittels Radiotelemetrie. Da besonders in schlecht zugänglichem Gelände – im dargestellten Beispiel in einem Alpental – ein sendermarkiertes Tier nicht eingekreist werden kann ("homing-in on the animal" White & Garrott (1990)), bieten nur Kreuzpeilungen die Möglichkeit für genaue Beobachtungen. Als Folge davon schwankt die Genauigkeit der Beobachtungen je nach Topographie oder Aktivität des Tieres, wobei nur ein Teil der Beobachtungen die gewünschte räumliche Auflösung (Genauigkeit) zeigt. Umgekehrt enthalten auch Ortungen mit geringerer Auflösung wichtige Information

über die Aufenthalte, besonders wenn sie schwer zugängliche Gebiete des Homerange betreffen. Anstelle der bisherigen Empfehlung, dass Ortungen geringer Genauigkeit aus den Analysen eliminiert werden sollen (Worton 1987), schlagen wir vor, dass diese Ortungen ebenfalls aufgenommen, zusätzlich jedoch eine Schätzung des Ortungsfehlers in die Datenaufnahme einfließen soll. Damit kann eine Verzerrung (bias) in den Raumnutzungsdaten vermieden werden. Mit simulierten Datenreihen und realen Daten aus der Feldstudie der Grossen Hufeisennase in den Schweizer Alpen konnten wir aufzeigen, dass das Fehlen von Ortungen hoher Genauigkeit durch eine grössere Anzahl an Ortungen geringer Genauigkeit kompensieren werden kann. Im Fallbeispiel waren grosse Teile des Untersuchungsgebietes nachts für die Beobachter nicht zugänglich. Entsprechend variierte die Genauigkeit der Ortungen stark abhängig vom Ort und der Aktivität der Fledermäuse. Durch die rechnerische Verbindung von Ortungen mit unterschiedlicher Genauigkeit in einer kernel estimation (Worton 1987) konnten wir auch unge nauen Ortungen aus unzugänglichen Gebieten in die Analysen einbe ziehen, ohne damit die hohe räumliche Auflösung in den übrigen Gebieten zu verlieren. Dies ist eine Voraussetzung, um unverzerrte Auf nahmen der Habitatnutzung erfassen zu können.

Teil II: Raumnutzung einer Kolonie der Grossen Hufeisennase

Um Nutzungskonflikte eingrenzen zu können, wurde die Raumnutzung der letzten grösseren Reproduktionskolonie der Grossen Hufeisennasen in der Schweiz aufgrund von zufällig ausgewählten Tieren aus der Kolonie erfasst. Die Jagdgebiete der Tiere aus der Kolonie überlagerten sich zu einem grossen Teil, so dass bereits 15 untersuchte Individuen die gesamte Fläche der Jagdgebiete der Kolonie nutzten. Der Raum wurde dabei selektiv entsprechend der Topografie genutzt. Die durch schnittliche Aufenthaltsdichte der Tiere aus der Kolonie ist dann hoch, wenn die Distanz zum Quartier klein und die Meereshöhe gering ist und korreliert positiv mit dem Waldanteil. Die durchschnittlichen Distanzen zu den Jagdgebieten sind im Frühling grösser, was darauf hinweist, dass in dieser Jahreszeit die Nahrungsressource limitierend sein könnte. Wir empfehlen, dass den Ansprüchen der Kolonie innerhalb einer Fläche mit

einem Radius von 4 km um das Reproduktionsquartier höchste Priorität eingeräumt wird. Dies betrifft die in der Studie ausgezeichneten Kernjagdgebiete, sowie Gebiete, die sich aus denselben Habitattypen zusammensetzten. Aufgrund der beobachteten Raumverteilung postulieren wir, dass Schutzmassnahmen einen grösseren Einfluss haben, wenn sie in der Nähe des Quartiers realisiert werden und Lebensräume enthalten, die im Frühling - der vermutlichen kritischen Jahreszeit - genutzt werden.

Teil III: Jagt die Grosse Hufeisennase im Wald?

Die auf der Struktur der Ultraschallrufe sowie der Flügelmorphologie basierende Hypothese, dass Grosse Hufeisennasen speziell angepasst sind, um in dichter Vegetation zu jagen, wird überprüft. Die Analyse der Habitatselektion zeigt, dass die Grosse Hufeisennase im Frühling mehrheitlich im Wald jagt, während im Sommer und Herbst keine Selektion von Wald im Vergleich zum Offenland nachweisbar ist. Das Ergebnis, dass die öko-morphologischen Voraussagen nur im Frühling zutreffen, wird als Hinweis dafür interpretiert, dass in dieser Jahreszeit ein starker Selektionsdruck wirkt. Es wird vorgeschlagen, darauf basierend die Prioritäten bei der Umsetzung von Schutzmassnahmen festzulegen.

Teil IV: Schutz von Jagdgebieten der Grossen Hufeisennase

Aufgrund der Ergebnisse einer Untersuchung von sendermarkierten Grossen Hufeisennasen werden konkrete Massnahmen zum Schutz von Jagdgebieten und Prioritäten bei der Umsetzung vorgeschlagen.

Für die Grossen Hufeisennasen müssen für den Schutz von Jagdgebieten Artenschutzmassnahmen durchgeführt werden: 1. Geeignete Lebensräume müssen über 30 % der Fläche im Umkreis von 3.5 km um das Wochenstubenquartier ausmachen. 2. Diese Gebiete müssen kleinräumig eine hohe Diversität an Lebensraumtypen und dadurch einen grossen Anteil an Grenzflächen aufweisen.

Wir definieren drei Umsetzungs-Perimeter. 1) Als Kernjagdgebiete werden die Gebiete mit der grössten Aufenthaltsdichte von jagenden Grossen Hufeisennasen bezeichnet. In der Fallstudie machen sie 1.6 km² aus. Sie sollen umfassend geschützt werden. 2) Das Aktivitätsgebiet um das Wochenstubenquartier beinhaltet die bekannten oder potentiellen Jagdgebiete. Diese sollen erhalten und aufgewertet werden. 3) Im regio-

nalen Verbreitungsgebiet sollen bei grösseren Landschaftsveränderungen die Ansprüche der Grossen Hufeisennasen berücksichtigt werden.

Die Erhaltung einer Population ist durch die Quartiertradition eng mit dem benützten Wochenstubenquartier verknüpft. Damit eine Wochenstubenkolonie erhalten bleibt, müssen beides, die mikroklimatischen Anforderungen an das Wochenstubenquartier wie auch die Ansprüche an die direkt umgebende Landschaft erfüllt sein. Die vorgeschlagenen Massnahmen sind Hypothesen, deren Wirkung zu kontrollieren ist.

Teil V: Telemetrie von Fledermäusen

In einer kleinen Übersicht werden die Möglichkeiten und Grenzen der Radiotelemetrie bei Fledermäusen anhand einer Feldstudie über die Grosse Hufeisennase in Italien aufgezeigt. Zuerst muss die genaue Fragestellung der Untersuchung festgelegt, dann ein passendes Forschungsdesign entwickelt werden. Das Gewicht der einsetzbaren Sender und das Empfangsmaterial setzen die technischen Grenzen. Mit Literaturhinweisen und Beispielen aus der Fallstudie werden Anwendungen bezüglich der Aktivität, der Selektion von Quartieren, der Nutzung von Jagdgebieten und der Habitatselektion sowie von Verhaltensbeobachtungen vorgestellt. Eine Ausführliche Liste an weiterführenden Referenzen und von Internet-links soll den Einstieg in die Methode der Radiotelemetrie erleichtern.

Teil VI: Mehrstufige Habitatselektion der Kleinen Hufeisennase

Dieser Artikel beschreibt die erste Untersuchung zur Habitatnutzung der Kleinen Hufeisennase mittels der Radiotelemetrie. Erst die Entwicklung des weltweit kleinsten aktiven Telemetrie-Senders an der Schweizerischen Vogelwarte ermöglichte die Anwendung dieser Methode bei dieser kleinen Fledermausart, die ein Gewicht von nur 4 bis 8 g aufweist. Im Rahmen einer Untersuchung in Wales, UK konnten Kleinstsender mit einem Gewicht von nur 0.35 g eingesetzt werden. Die 8 Untersuchungstiere jagten alle in kleiner Distanz zum Wochenstubenquartier, die Hälfte der Zeit blieben sie gar innerhalb von 600 m zum Quartier. Dies führt in der Nähe des Quartiers zu einer aussergewöhnlich hohen Dichte jagender Tiere und damit wahrscheinlich zu einer hohen intraspezifischen Konkurrenz. Obwohl das Untersuchungsgebiet viele

extensive Weiden enthielt, die als Jagdgebiete der Art vermutet wurden, jagten die Kleinen Hufeisennasen fast ausschliesslich in Waldgebieten, meist in Laubwäldern. In beiden Stufen der Habitatselektion wurde dieses Habitat mit höchster Präferenz genutzt sowie Jagdgebiete mit einer hohen Habitatdiversität aufgesucht. Wir empfehlen dementsprechend, dass sich Schutzmassnahmen innerhalb von 2.5 km zum Quartier und auf die Erhaltung und Förderung von Lebensräumen mit Laubwäldern und hoher Habitatdiversität konzentrieren sollen. Zudem sollte mit Untersuchungen in anderen Regionen überprüft werden, ob die vorgefundene Habitatselektion für die Art generell zutrifft.

Teil VII: Forschungskonzept Kleine Hufeisennase in der Schweiz

Mit dem Ziel, ein Forschungskonzept für den Schutz der Kleinen Hufeisennase in der Schweiz aufstellen zu können, wurde als Grundlage die Angaben über den aktuellen Stand und die jüngste Entwicklung der Restpopulationen in der Schweiz gesammelt und eine Bewertung der vermuteten Ursachen des Aussterbens aufgrund von qualitativen Experteninterviews vorgenommen. Daraus wurde ein Forschungskonzept entwickelt, das den Forschungsbedarf und seine Prioritäten aufzeigt.

Die Ergebnisse zeigen, dass im Jahr 2000 in der Schweiz nur noch 39 Reproduktionskolonien mit ca. 1700 im Quartier gezählten Individuen beobachtet werden konnten. Diese Kolonien waren in acht Kantonen, hauptsächlich im Voralpen- und Alpenraum zu finden. 95% der Tiere wurden in vier Gruppen von Kolonien gefunden, die isolierte Populationen darstellen könnten. Bei 55% der Kolonien war in den letzten 10 Jahren eine Zunahme zu verzeichnen, 27% blieben stabil, während bei 18% eine abnehmende Tendenz aufgezeigt werden konnte.

Gemäss einer Evaluation der Ursachen des Aussterbens und einer ExpertInnenbefragung haben sich der Einsatz von Pestiziden, Veränderungen in der Strukturierung der Landwirtschaft sowie die sich daraus ergebende Nahrungsverknappung als die wahrscheinlichsten Faktoren für das Aussterben einer Grosszahl von Kolonien ergeben. Es werden deshalb die Untersuchung der Ressourcennutzung und der Schadstoffbelastung mit höchster Forschungspriorität vorgeschlagen. Zur Kontrolle der weiteren Populationsentwicklung wird die Einführung

eines detaillierten, langfristigen Monitorings empfohlen. Nach einer Evaluation der ersten Resultate könnten in einer zweiten Forschungsphase Arbeiten zur Populationsdynamik, zum Mikroklima in den Quartieren sowie zu populationsgenetischen Fragen und zum Wiederbesiedlungspotential durchgeführt werden. Die Resultate der Forschungsarbeiten sollen so aufgearbeitet werden, dass praktische Schutzmassnahmen in den Regionen umgesetzt werden können.

Schlussfolgerungen

Im Rahmen der vorliegenden Arbeiten werden detaillierte Angaben zur Raum- und Habitatnutzung der beiden gefährdeten Hufeisennasenarten präsentiert. Durch den Einbezug des Peilfehlers konnten die Auswertungen optimal auf die radiotelemetrisch erhobenen Daten dieser schnell fliegenden, nachtaktiven Fledermausarten abgestützt werden. Die Vorteile sind auch bei der Analyse der Nutzungsdaten mit der Compositional Analysis, einer neueren Auswertungsmethode zur Rangierung der Habitatselektion (Aebischer et al. 1993), anwendbar. Umgekehrt müssen die Grenzen der Methode dort gesehen werden, wo räumliche Flächenmasse verglichen werden sollen. Da unterschiedliche Fehler von Ortungen einbezogen werden, sind Flächenberechnungen nicht mehr direkt vergleichbar. Vergleichbare Flächenangaben können jedoch weiterhin mit Standartparametern gerechnet werden (Harris et al. 1990).

Beide Hufeisennasenarten weisen eine Selektion für Waldgebiete auf. Dabei erweist sich die Kleine Hufeisennase - zumindest in Wales - als streng an diesen Lebensraum gebunden, während die Grosse Hufeisennase in der Schweiz nur im Frühling ausschliesslich Waldgebiete aufsucht (Beck et al. 1994, Bontadina et al. 1995). Dies entspricht auch im südlichen Lebensraum Norditaliens den Gewohnheiten der Art, wie unsere Vergleichsuntersuchung gezeigt hat (Bontadina et al. 1999, unpubl. Daten) und wird auch von den Studien aus Grossbritannien bestätigt (Duvergé & Jones 1995, Duvergé 1996). Damit wird die Hypothese, dass der grossräumige Populationsrückgang mit einer Reduktion des Flächenanteils von günstigen Jagdlebensräumen einhergegangen ist, unwahrscheinlich, da die Waldbestände in der Zeit des Bestandes-

rückganges der Hufeisennasen keine Reduktion erfahren haben, oder sich in manchen Teilen sogar ausgedehnt haben (Smout 1997). In denjenigen Gebieten, in denen die Kleine Hufeisennase in der Schweiz ausgestorben ist (z.B. Stutz & Haffner 1984) hat die Waldfläche in dieser Zeit ebenfalls tendenziell zugenommen (Schuler & Bürgi 1998).

Die Kombination der Ansprüche an ein geeignetes Reproduktionsquartier, das die mikroklimatischen Anforderungen erfüllt, und gleichzeitig an eine unmittelbare Umgebung, in der geeignete Habitate in genügendem Ausmass vorkommen, könnte eine Hauptursache sein, weshalb beide Arten – die mit einer deutlichen K-Selektion (Gaisler 1989) an einen stabilen Lebensraum angepasst sind – empfindlich auf Veränderungen in der Umwelt reagieren. Dies könnte ein Hinweis darauf sein, dass auch multifaktorielle Ursachen für das beobachtete Aussterben von Populationen verantwortlich sein könnten.

Bei beiden Fledermausarten fällt die sehr kleinräumige Raumnutzung auf. Im Vergleich mit anderen Fledermausarten liegen die Jagdgebiete der Hufeisennasen in fünf bis zehnfach kleinerer Distanz zum Quartier (Kronwitter 1988, Güttinger 1997, Arlettaz 1999). Dabei verhalten sie sich in ihrer Raumnutzung wie central-place foragers (MacArthur & Pianka 1966). Dies obwohl sie keine Beutestücke zum central place, der Kolonie zurück transportieren. Selbst die säugenden Weibchen, die manchmal während der Nacht mehrerer Male zum Wochenstubenquartier zurückkehren, um das Jungtier zu säugen, können das Raummuster nicht in diesem Umfang erklären. Jones et al. (1995) haben vorgeschlagen, dass artspezifische Grenzen aufgrund der Flügel-Morphologie die Flugdistanzen bestimmen. Dabei besteht für die Art ein trade-off zwischen den breiten Flügeln mit hoher wing-loading, die wenig geeignet sind um grössere Distanzen zu fliegen, umgekehrt den Hufeisennasen aber erlauben, sehr wendig und langsam in Luftraum mit vielen Hindernissen zu fliegen, also im Wald zu jagen.

Die beobachtete räumlich begrenzte Nutzung der näheren Umgebung eines Quartiers als Jagdraum hat direkte Auswirkungen auf die raumrelevanten Schutzmassnahmen. Gute Jagdgebiete müssen auf Grund der Resultate in der Nähe zum Quartier liegen. Aufgrund der beobachteten Raumnutzung können Distanzen vom Quartier abgeleitet werden,

innerhalb derer bei Nutzungskonflikten den Gebieten mit selektierten Habitaten höchste Priorität zugesprochen werden muss. Zusammen mit den Angaben zu den Habitaten in wichtigen Jagdgebieten können räumlich explizite Schutzkonzepte ausgearbeitet werden (Beck et al. 1994, Bontadina et al. 1996).

Untersuchungen in der Conservation Biology, die an Reliktpopulationen durchgeführt werden, beinhalten die Schwäche von Fallbeispielen: die Ergebnisse beruhen auf Korrelationen, es bestehen keine Replikate der Untersuchung und experimentelle Manipulationen sind im Falle einer vom Aussterben bedrohten Art meist nicht vertretbar. Die abgeleiteten Massnahmen und Schutzhaltvorschläge sollen deshalb als Hypothesen aufgefasst werden, die mindestens mit einem langfristigen Monitoring und zusätzlich mit Wirkungskontrollen der einzelnen Schutzmassnahmen überprüft werden sollten.

Mit dem Forschungskonzept für die Kleine Hufeisennase wird exemplarisch aufgezeigt, wie durch die Eingrenzung der möglichen Bedrohungursachen Forschungsprioritäten abgeleitet werden können. In einem stufenweisen Vorgehen sollen dann durch die Erforschung von Schlüsselfaktoren aus der Ressourcennutzung sowie aus der Populationsdynamik umsetzbare Forschungsresultate gesammelt werden, die zur Erhaltung und Förderung einer Art führen.

Analysing spatial data of different accuracy: the case of greater horseshoe bats foraging

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Abstract

Studying the habitat use of highly mobile, fast moving animal species by radio-tracking is particularly difficult. Often only a part of the locations reach the high spatial accuracy aimed for, especially where parts of the study area are not accessible to the observers, or if the accuracy of location is activity-dependent. As a result, excluding data of lower precision may result in biased information on home-range size and use.

We present a method to analyse sets of location data of different accuracy by kernel estimation. Each location is included into the estimation according to its class of accuracy.

For this purpose, the accuracy of locations has to be estimated in the field using an estimation of signal quality and topographic circumstances. In the given example three categories are defined on the base of test bearings with known position of the transmitter. Test-bearings are taken under conditions simulating those encountered during the field survey. The average deviation of the radiolocation from the real position is estimated for the three categories of data. In the kernel procedure, the smoothing parameter of each location is denoted by the standard deviation of the bearing error within each accuracy category. In this way the resulting density matrix accounts for differences in location accuracy.

Calculations are made with a module of the software GRID.

The option to join together data of different accuracy improves the results of home-range analyses. To include locations of low accuracy allows areas of high utilisation density to be detected if large samples are available. As an illustration of the method, we present an example from a radio-tracking study in greater horseshoe bats (*Rhinolophus ferrum-equinum*).

Introduction

Studying the range use of animals by radio-tracking is particularly difficult if the species is highly mobile and the observers cannot follow the tagged animal throughout the home-range. Very often homing-in on the signal (White & Garrott, 1990) to obtain visual observations is not possible. Thus the collection of data has to be based on the cross-triangulation of signal bearings. As a result the accuracy of locations may differ between parts of the study area (e.g. due to topographical features) or depending on the animal's behaviour (e.g. moving or resting). In topographically difficult areas, fixed stations for radio-tracking often give unreliable results. Therefore the locations have to be collected by two persons taking bearings from different places. Due to local conditions, the distance of the transmitter from the observers, and the behaviour of the animal, the estimated locations obtained by cross-triangulation often differ from the unknown true position of the tracked animal.

A measure of this error must be reported and included in the analysis, as pointed out by Saltz and White (1990) and Saltz (1995). Often, only parts of the spatial data reach the high level of accuracy aimed for. On the other hand additional data of lower accuracy may provide useful information. Up to now the usual way of dealing with data of different quality was to exclude locations exceeding a maximum tolerance, and to treat all remaining locations as if they were of the same quality. This procedure, however, has the disadvantage that a part of the information obtained from very accurate locations is reduced.

When radio-tracking greater horseshoe bats (*Rhinolophus ferrum-equinum*, Schreber 1774), these problems make it difficult to assess home range use and selection of foraging sites. We studied the species in an alpine valley where large parts of the study area were not accessible to observers (particularly at night). Therefore, the accuracy of locations varied largely depending on site and activity of the animals.

In order to make optimal use of the information contained in the data we developed a method to include data of different location accuracy into a

kernel estimation. Herein we discuss the advantages and limitations of this approach using simulations and field data.

Materials and Methods

Home-range estimators

The following method to analyse spatial data with different accuracy is based on a kernel estimation (Bowman 1985, Worton 1989). Kernel procedures allow patterns of locations to be transformed into a matrix of utilisation distribution. This utilisation distribution is a two-dimensional (relative) probability distribution of the estimated locations (overview in Silverman 1986, Worton 1989, Naef-Daenzer 1993a, b).

The transformation of a pattern of locations (points) into an utilisation density distribution (values) can be described as follows: For each intersection of a superimposed grid, the utilisation density is calculated on the base of the distance from the grid intersection to the locations. The kernel-function and the smoothing parameter h determine the extent to which a location at distance x contributes to the estimate. In the bivariate normal kernel estimation, locations are weighed according to a normal distribution of defined variance. In a three-dimensional graph of the density matrix, one single location is represented as a small Gauss-bump, the width of which is determined by the smoothing parameter (Silverman 1986, Worton 1989, 1995). The final utilisation distribution can be considered as the 'sum' of the bumps of all locations.

Based on the kernel density estimations, contour lines which include a percentage of the total volume (e.g. 20%, 80%) are calculated and used to identify core areas and total home-range size. On one hand the result of home range estimations depends on the sample size. On the other hand the kernel algorithm and the smoothing parameter greatly affect the results of the estimation. In particular the estimate of the total home range is not independent of the selection of the kernel parameters.

Locational observations of different accuracy provide the same information unit, but the information is spread over a different area. The mean distance between estimated and actual position describes the accu-

racy of the observation (Saltz 1995). If there is evidence that the deviations from the 'true' location (of the tracked animal) vary randomly, the location error is expected to be bivariate normally distributed and is described by the standard deviation (SD) of the distribution.

In order to combine data of different accuracy we have to include the error measure of the estimated locations into the smoothing parameter. This adaptation takes into account that the distribution of each information unit is spread over different areas depending on the accuracy. As the information of one Gauss-bump always represents one observation of the animal, the maximum density (the top of the bump) of one location of low accuracy is lower than that of a location with high accuracy, whereas the volume covered by the different bumps is constant (fig. 1).

[fig. 1]

If the accuracy of each data point is known, a kernel algorithm can account for the different location accuracy by using the location error as a variable to adapt the smoothing parameter for each location within the process. The calculations are made with a module of the software GRID (Naef-Daenzer 1993a). Core areas and home range areas were computed as percentage of total density volume. The contour lines are isopleths and represent similar density of utilisation.

Study area and data collection

25 greater horseshoe bats (*Rhinolophus ferrumequinum*) were radio-tagged and tracked in an alpine valley in the Grisons, Switzerland, from May to October, 1993 (Bontadina et al. 1995, 1997, unpubl. data). Greater horseshoe bats emerge at dusk and forage for some hours before they return to night roosts. Flying rapidly, they reach their foraging areas at distances of up to 7 km from their day roost. The position sensing transmitters (Holohil Ltd, Canada) allowed us to determine whether bats were flying or hanging. When aerial hawking the bats moved rapidly from one place to another over a large area. However, when perch hunting, the bats stayed at the same place for longer periods.

We tracked the bats using TRX-1000S (Wildlife Materials, USA) and modified YEASU FT-290 receivers (adapted by Karl Wagener, Germany) with hand-held H-aerials. The location of the tagged bats were

recorded in 5 minute intervals throughout the night by triangulation of the signal direction. Two field workers co-ordinated their simultaneous bearings using trigger signals from Casio DB-31 watches. Hand-held FM-radios were used to remain in contact with one another.

A category of accuracy was assigned to each location. In a first step, three categories of accuracy, notably "high", "medium" or "low", were used to categorise the locations in the field. These represented situations where estimated locations were supposed to lie within 50, 100 and 250m respectively of their true location. This estimation was made on the basis of a evaluation of the transmitter signal, the intensity of the signal and the estimated distance from each observer to the animal, as well as taking into account the possible influences of environmental conditions. In parallel with the data collection a field test was carried out with a transmitter being moved around in a foraging area by a colleague. Transmitters of known position were located and the actual accuracy of the three categories of locations was estimated using these control data.

Results

If the accuracy of each data point is known, a kernel algorithm can account for the different location accuracy by using the location error as a variable to adapt the smoothing parameter for each location within the process.

Simulations

By using a simulated sample of data, figure 2 demonstrates that core areas may be obtained by using either a few locations of high accuracy or a large sample of locations of low accuracy. We used two samples of the same distribution. Firstly, a data pattern of 100 locations (fig. 2, A) was analysed by a kernel estimation with low and high smoothing parameters. The resulting contour lines (B, C) differ in respect to shape and core area. In B, the kernel estimation with smaller smoothing parameter (according to a higher accuracy of the locations) reveals a significantly pronounced resolution and includes a core area, in contrast to C. However, a large sample may partly compensate for the loss in profile, as

demonstrated with the doubled data sample (fig. 2, D). In that case, the contour lines reveal again a core area.

[fig. 2]

When defining contour lines it must be taken into account that one location of high accuracy does not result in the same density pattern as one of low accuracy. Outliers of low accuracy can be excluded from a home range estimate by appropriate selection of contour levels. If the lowest contour line is above the maximum density of a single location, isolated locations are excluded. On the other hand, several inaccurate locations at the same position give the same maximum density as one of high precision. In the example of figure 2 the lowest contour line is the line with relative density values of more than one (larger than the maximum of one location).

For the comparison of areas it is important to notice that the estimated areas differ when using data of different accuracy and therefore different smoothing factors. In our simulation, if a core area is defined at a level of 50% of total density, then the area is 1.7 units, analysed with a smoothing factor of 50. If data of, for example half the accuracy is used and therefore the smoothing factor is set twice as large at 100, the area estimate is only 0.7 (fig. 3). Inversely, if the total home range area is estimated by 95% of total density, the kernel analysis with data of low accuracy (smoothing factor 100) reveals an area of 10.2 in distinction to 6.3 when using the same data but with smoothing factor of 50 (high accuracy).

[fig. 3]

The simulation shows, that areas of high location density are underestimated when using data of lower accuracy. In contrast, total home range size - represented by a contour line of low location density- is overestimated if the proportion of inaccurate locations is high. Therefore estimates of home range or activity areas increase when using data with lower accuracy because the information spreads over a larger area (fig. 3).

Field data

A total of 148 test bearings were available to analyse the accuracy of the three categories of locations, denoted „high“, „medium“ or „low“, respectively. They had their center not significantly different from the “true” center, the standard deviations of the normally distributed location errors were 44, 86 and 162 meters, respectively. The deviation was approximately normally distributed around the actual location with a mean not significantly different from the “true” center.

In the field study of foraging greater horseshoe bats 1331 locations were collected. Of these data only 28% reached the accuracy of the 50m category, another 31% reached an estimated accuracy of 100m and the last 41% were found within the 250m accuracy class.

37% of the locations of bats which were perch hunting, and therefore stayed at one place for a longer period, could be assigned to the highest accuracy category. But only 20% of the locations of individuals aerial hawking could be classified as such ($\text{Chi}^2=45.8$, $p<0.001$). This demonstrates how the accuracy of bearings can depend on behaviour.

In addition, the reached accuracy may depend also on the topographic situation in the field. The distribution of the pooled locations of 7 greater horseshoe bats in figure 4A shows a clear spatial aggregation. The locations at point G are situated in a steep gorge, which was not accessible to the observers. Therefore only locations with low accuracy (grey or white dots) could be taken. In other areas, it was possible to track the bat very accurately, because it did not move much (black dots).

Three core areas result from the calculations, if only the 38 locations of high accuracy are included (fig. 4B). Another core area in the gorge appears, if all 148 locations are analysed according to the lowest accuracy class (fig. 4C), but one former core area disappears. The resolution is lowered as much that the two core areas merge. The resulting larger areas include also areas with low observed utilisation by foraging bats.

As a solution we include all data according to their accuracy in the kernel analysis. This procedure preserves the three former core areas based on the locations with high accuracy. But it also contains the core area in the gorge (point G), including many locations of low accuracy. Despite the fact that more core areas are present, their total area is

smaller than without including the different accuracies in the calculations.

By including all data at the appropriate level of accuracy, the results of the kernel estimation could be improved to a great extent. As a consequence, the spatial result would be biased, if data of lower accuracy is refused.

[fig. 4]

Discussion

The option to include locations of different accuracy into a kernel estimation has the advantage that full information of all gathered locations is used without a loss in detail where accurate locations were possible. Excluding data of lower precision can influence the results substantially as shown in the examples above, especially, when radio-tracked animals stay in topographically difficult areas and the observers of a radio-tracking team cannot approach the animal close enough. Ignoring the data of low quality (the 250m class) would result in a highly incorrect representation of the activity range of horseshoe bats. This in turn might potentially lead to the wrong conclusions in respect of the behavioural and conservation ecology of the species.

Furthermore areas where a particular behaviour is dominant may be underestimated, e.g. it is generally not possible to obtain accurate locations along travelling routes, where the animals move very fast from one place to another. The inclusion of data of low accuracy makes it possible to detect and retain areas over which animals move rapidly.

Certainly, no statistical method can correct for an estimation error inherent in the data set. For this reason the resolution of the data cannot be enhanced. At least, the present method avoids a loss of information when data of high precision must be combined with data of lower accuracy. With regard to the detection of core areas of activity, the proportion of locations which reach a given level of accuracy is of great importance. Low accuracy of single locations lead to a increased variance in their spatial distribution. Thus, aggregations of points appear only if the sample size is large enough. Therefore, in order to represent core areas in

the data set, an increase in the bearing error should be compensated by a large sample size.

In our study the deviations from the true position of the transmitter were approximately normally distributed as seen in the test. This is not the case when locations are taken by triangulation data from fixed stations. In this case the bearing errors depend on the position of the transmitter relative to the antenna stations and are not analogous to a bivariate normal distribution (White and Garrott 1990). In such cases it would be possible to replace the bivariate kernel with another kernel shaped according to the error distribution, for example a polygon or an ellipse.

One problem which has to be solved when using locations of different accuracy is how to choose an adequate smoothing parameter for the kernel estimation. The smoothing parameter determines the shape of the density distribution. Several authors propose approaches to determine the parameter based on the statistical properties of the location set. Worton (1989) proposes a cross validation method and Sain et al. (1994) use a biased cross validation-method for choosing an appropriate smoothing parameter. Tufto et al. (1996) provide a solution to the problem of correcting discretisation errors for some cases where least square cross-validation otherwise would crash. All these methods define the smoothing parameter based on the variance of the points in x and y direction. In the case of an extensive data sample or if the locational error is very small, the cross-validation procedure may propose a smoothing parameter smaller than the achieved SD of the bearings. In this cases the resolution of the analysis can be improved by using the value for the class of bearings with the lowest accuracy. The other classes must than be proportionally fitted.

Depending on the purposes of a study, e.g. the analysis of core areas or the estimation of home ranges, different smoothing parameters may give the best results (Wray et al. 1992). Therefore there does not appear to be a single best way of determining the smoothing parameter (see discussion in Silverman 1986). Although some objectivity in choosing the value of the parameters would be desirable, the best estimation is that which gives the most convincing information on the biological system. Optimal selection of the parameters of a kernel estimation still depends on the aims

of the study. To allow comparisons of area estimates we recommend to use additionally standard parameters.

Acknowledgements

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Fig. 1: Three locations of different accuracy are shown in the density matrix. The information of the location of highest accuracy is concentrated on a small area and the maximum density reaches the highest value. The more inaccurate the location is, the larger the area is where an animal could possibly have been present, and the lower is the density it contributes to the analysis.

Fig. 2: The same generated distribution: A) pattern of 100 locations, B) these locations are analysed as having an accuracy of 50 units, C) the same locations analysed as having a low accuracy of 100 units and D) twice as much locations from the same distribution analysed as having a low accuracy. The side of one square equals 1000 units.

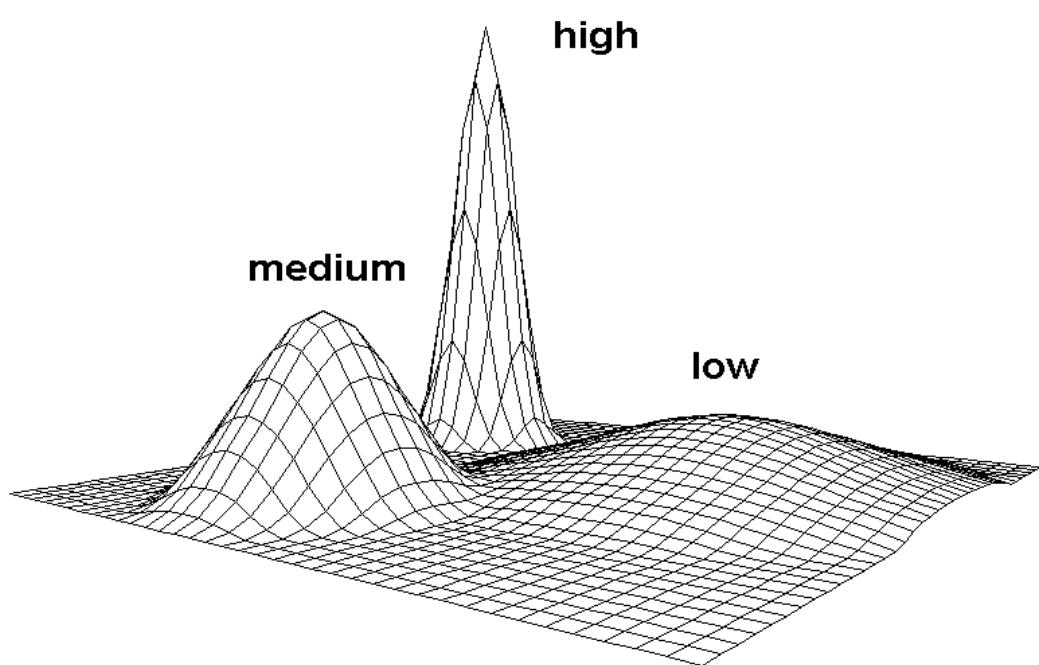
More locations of lower accuracy can compensate for peak areas. However the estimated areas become larger when using data with lower accuracy.

Fig. 3: Influence of accuracy on range estimates. Based on 200 generated points from a normal distribution with standard deviation (SD) of 1 unit, areas were calculated according to be of “high” and “low” accuracy (0.05 and 0.1 unit, respectively). Locations of the accuracy class „high“ reveal larger core areas and smaller home range estimates than locations of “low” accuracy.

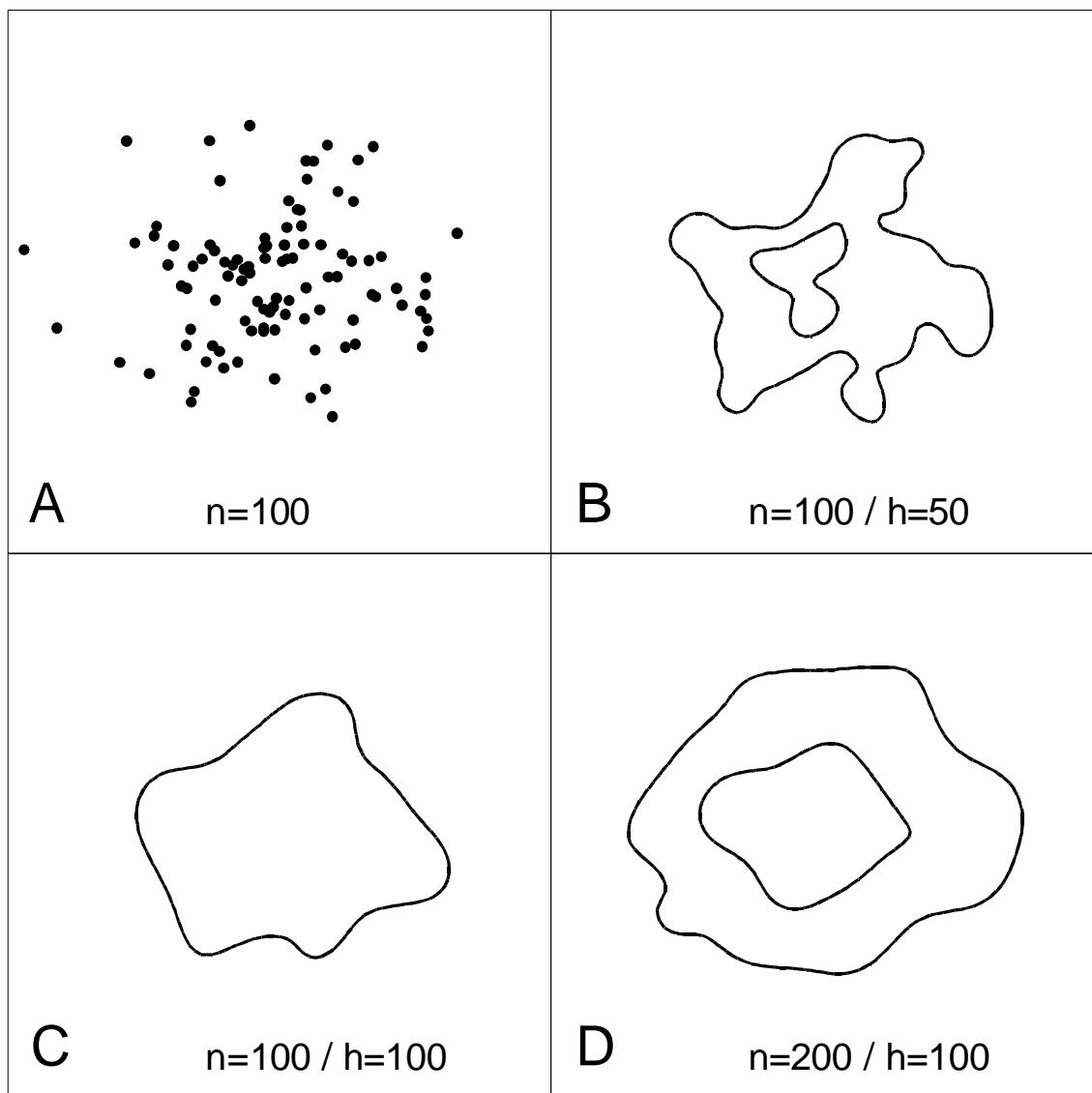
Fig. 4: Home range and core areas of seven greater horseshoe bats analysed by kernel estimations with locations of different accuracy. Contour lines are drawn at 80% and 30% density volume for home range and core areas, respectively. A) Distribution of the estimated locations of seven bats by radio-tracking. Locations estimated with „high“ accuracy are marked black, those with „medium“ or „low“ accuracy are grey and white, respectively. B) Only the 38 locations of the „high“ accuracy class are used for the kernel estimation. C) All 148 locations are used according to the lowest accuracy class. D) All locations were included in the kernel analysis according to

their accuracy. This result includes in high resolution all former areas with high utilisation density and the core area in the gorge (point G), where mainly data of low accuracy was available.

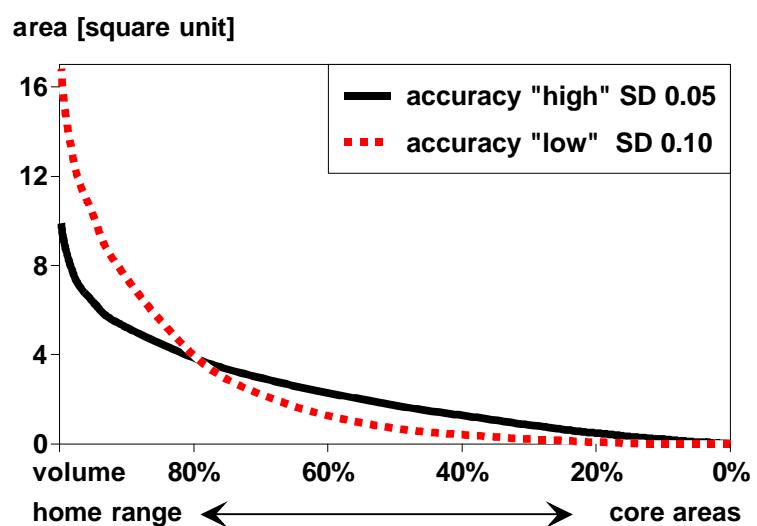
[fig. 1]



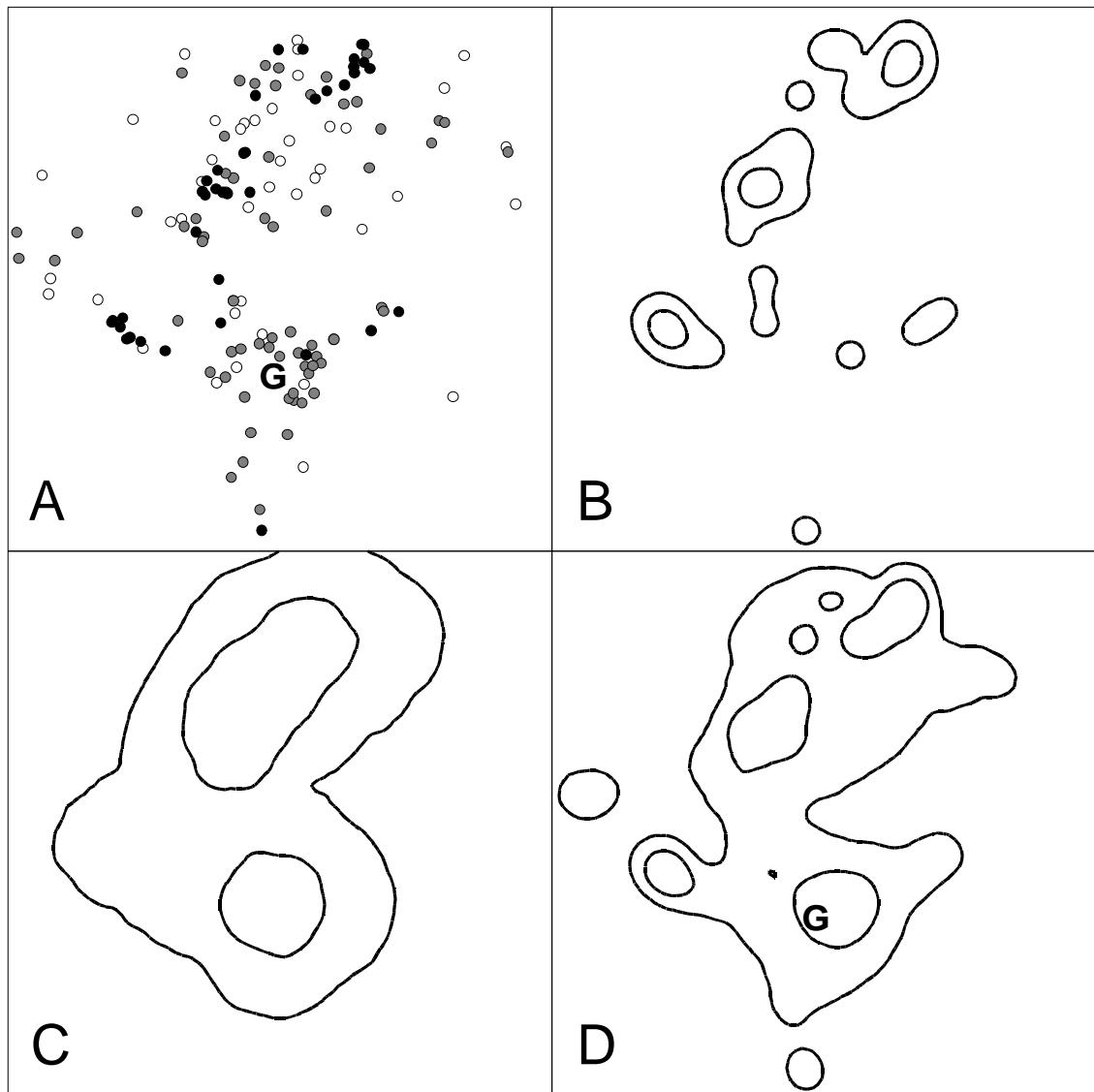
[fig. 2]



[fig. 3]



[fig. 4]



Foraging range use by a colony of greater horseshoe bats *Rhinolophus ferrumequinum* in the Swiss Alps: implications for landscape planning

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Key words: population decline, conservation, space use, kernel estimation, critical season, management.

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Abstract

After having suffered a dramatic population decline, the greater horseshoe bat has been classified as highly endangered in central and western Europe. We studied seasonal foraging range use of one large colony by radio-tracking so as to get founded arguments in the face of rising land use conflicts.

The individual bats used largely overlapping foraging ranges: on average 10 bats exploited more than 80 % of the colony range estimated to be 6.7 (± 0.34) km². Altitude above sea level and distance to the roost explained 30.5 % of the variation in utilisation density. Core foraging areas enclosed 74 % of the foraging activity of the bats within 30 % of colony home range. Foraging distances were larger in spring, which is probably the critical season for greater horseshoe bats.

We conclude that conservation of the colony must be given priority (1) within distances of up to 4 km from the nursery roost, (2) especially within core foraging areas; and we suggest that (3) management measures would be more effective if implemented near to the nursery colony and would contain habitats used in spring, the season suspected to be most critical.

Introduction

In temperate regions female bats associate in large numbers during the reproduction season to benefit from communal heating to raise their young (Lyman 1970). In general, the availability of a suitable and safe place for reproduction is a key resource (Begon et al. 1990). This is particularly true for bat colonies which choose their roosting places according to complex microclimatic and structural requirements and often use these locations in strict tradition over decades. Such roosts represent therefore a limiting factor: all reproducing females of the colony join at a unique place which determines the reproductive outcome of the year.

It is therefore not surprising that so far conservation measures for endangered bat populations often have concentrated mostly on the protection of the breeding roosts (Stutz & Haffner 1984, Beck & Schelbert 1999). However, the importance of the foraging areas connected to these maternity sites have often been neglected. The location of the roost further constraints the females in their choice to find foraging areas with abundant food. This is even more important in a maternity roost, as pregnant or lactating females have to fulfil extraordinary energetic demands (Speakman & Racey 1987, Ransome 1990).

In Switzerland we were challenged by a relict and isolated nursery colony of the greater horseshoe bat *Rhinolophus ferrumequinum* (Schreber, 1774). This originally cave dwelling bat tends, particularly in the northern part of its range, to roost in buildings during the summer. Females exhibit a strong philopatric behaviour and apparently reproduce mostly in the same nursery colony where they were born themselves (Ransome 1990). This may explain the observed traditional use of a singular reproduction roost.

The greater horseshoe bat was once widely distributed through western, central and southern Europe (Schober 1998). However it has suffered a significant decline in the northern extent of its range during the second half of the 20th century (Stebbins 1988, Ohlendorf 1996). Local population declines and the loss of colonies are well documented for most

countries north of the Alpine arch (Ohlendorf 1996). This dramatic decline led to the persistence of small remnant colonies at the northern border of the European distribution area, populations which are often isolated from each other. The species is classified as in danger of extinction in most central European countries and listed in the EC Habitat Directive (Ransome & Hutson 2000), which demands priority efforts in the protection of roosts and habitat.

Although in Switzerland many colonies of greater horseshoe bats have been documented once (Baumann 1949), today only three nursery roosts are known (Beck & Schelbert 1999). Whereas two of the nursery colonies are inhabited by only 10 and 50 bats, respectively, some 150 adult bats reproduce in the third roost, which is situated in the attic of a church in an isolated alpine valley. The latter, our study site, represents the largest nursery colony of this species known in central Europe (Ohlendorf 1996).

Such remnant colonies are of special concern in conservation biology of a species because they could be starting points for a later recolonisation of abandoned area (Bellamy 1996, Bontadina et al. 2000) and represent a last chance to understand the local species specific requirements (Carroll 1992).

The nursery roost was secured by a site agreement with local authorities (Lutz & Mühlenthaler 1996). However, in the direct surrounding of this vulnerable reproduction roost a reorganisation of agricultural land use and ownership was planned. This type of agricultural landscape planning is known to reduce the area of natural habitats and it often negatively affects their quality and biodiversity (Tanner & Zoller 1996, Vickery et al. 2001). Therefore the urgent need for a conservation study of this colony was given.

We investigated spatial requirements and resource exploitation of this colony in order to recognise potential utilisation conflicts, to suggest sound conservation recommendations going beyond roost protection,

and to propose the implementation of conservation measures in the re-organisation of future land use.

The detailed objectives of the study presented here, were 1) to designate the perimeter of potential land use conflict, 2) to identify representative core foraging areas and, 3) to examine whether spatial behaviour provides evidence for seasonal resource limitation.

Colony and study area

The nursery colony roosted in the attic of the church in the centre of the small village Castrisch, in the Upper Rhine Valley, Eastern Switzerland ($46^{\circ}51.31' N$, $8^{\circ}26.14' E$, 720 meters asl.). Counts of the number of animals leaving the roost in the evening, carried out since 1984, revealed constant colony size with a seasonal peak of about 150 emerging bats at the beginning of July (Lutz & Mühlethaler, unpubl. data). With "colony" we designate according to Gaisler (1963) all bats which constitute a reproductive community connected to the nursery roost. Usually only a small proportion of males join the summer group in the nursery roost. Including the males, we therefore estimate the colony to number about 200 individuals in total.

At the study site, annual precipitation is 950 mm, typical for an alpine-continental climate, with hot summers and relatively long, cold winters. The roost is situated in the river basin, 250 m from the Upper Rhine on a system of former gravel terraces only slightly higher than the river. The river valley rises on both sides steep up to 3000 m asl. There are several brooks from the sides entering the main river, which contribute with gorges and gravel deltas with treelines and bushes to a diversely structured relief.

The ground of the valley is shaped by the river with well expanded riparian vegetation. On the slopes predominate mixed broadleaf woodlands, whereas pine forests are less frequent. The productive ground in the plain is covered by intensively managed agricultural fields mostly devoted to hay production and pastures. The villages have retained some of the traditionally-managed orchards in their vicinity.

Methods

The study was conducted in 1993, one year before the landscape planning was completed. In order to compare the foraging behaviour during different seasons we studied the bats in the following three periods: spring (from 1st May to 9 June), summer (from 1st July to 6 August) and autumn (from 31st August to 12 October) corresponding to early pregnancy, lactation and post-lactation, respectively.

Radio-transmitters and tracking methods

To minimise the disturbance to the bats in the roost we caught the study animals in mist nets along flight lines when they left the roost at dusk or returned at dawn at eight different points between 10 and 500 m from the church. The bats caught were held in bags before having biometric data taken from them. Animals were sexed, the reproductive condition of the females was assessed and the individuals were banded using the official wing bands of the Museum of Geneva. Parous females were identified by the presence of large pelvic nipples (Gaisler 1963, Ransome 1990) and palpably pregnant animals were recorded. For the radio-tracking study we only tagged females as they are more bound to the maternity roost. Yet, in two cases males were radio-tracked. In order to study a representative sample of the colony we did no selection in the bats caught for tagging, except in that we omitted heavily gravid females for obvious reasons. Four individuals were tracked in two different seasons. This was due to the constraint by the limited colony size.

The bats were tagged with BD-2B transmitters from Holohil (Holohil Systems Ltd, 112 John Cavanagh Rd., Ontario KOA 1LO, Canada, www.holohil.com) with position sensors which allowed the discrimination between flying and hanging bats. The transmitters were attached to the back of the bats between the scapulae, the fur was trimmed and the tag was glued close to the skin using surgical cement (SkinBond, Smith & Nephew United Inc., Largo, Florida, USA). The transmitter batteries had a minimum lifespan between 10 to 21 days. We tracked the bats using TRX-1000 (Wildlife Materials, Inc., 1031 Autumn Ridge Road, Carbondale 62901, Illinois, USA, www.wildlifematerials.com) and

modified YEASU FT-290 receivers (adapted by Karl Wagener, Telemetrie-Material, Herwarthstrasse 22, D-5000 Köln 1, Germany) with hand-held H-aerials.

The location of the tagged bats were recorded in 15 minute intervals (interval sampling, Altmann 1974) throughout the night by triangulating the signal direction by two mobile persons. They co-ordinated their simultaneous bearings using trigger signals from Casio DB-31 watches and hand-held FM-radios were used to keep contact. If one person lost contact with the bat, the other tried to homing-in on the animal (White & Garrott, 1990). This was only possible with any reasonable accuracy when the animal was foraging in a small area. We assigned locations to one of three accuracy classes (50, 100 and 250 m) depending our confidence in the estimated location. The highest accuracy class could only be assigned when we were in close proximity to the bat, and using triangulation. The accuracy of these classes was determined during a field test at night with a transmitter being moved around in a foraging area by a colleague. A test of the deviation of the estimated locations from exactly known locations (location error method - Zimmermann & Powell, 1995) gave a location error with standard deviation (SD) of +/- 9.3 degrees with the estimated locations bivariately normally distributed around the "true" transmitter position. The locations of the estimated accuracy classes of 50, 100 and 250 meters had their centre not significantly different from the "true" centre, the standard deviations of the normally distributed location errors were 44, 85 and 162 meters, respectively (Bontadina & Naef-Daenzer, in press).

Time, location of observers, bearings of the bats, accuracy data and general observations were recorded in the field on a dictaphone and later transcribed onto data sheets. The positions of the bats in the field were subsequently calculated from the bearings and their estimated location digitised using a self-written program.

Habitat data, spatial calculations and statistical analysis

The studied bats used not exclusively the maternity roost but inhabited occasionally other day roosts (unpubl. data). For a better comparability,

the calculated flight line distances of the location do not always refer to the maternity roost but to the day roost used the preceding day. Foraging radius (= maximum distance) and median distance of locations (= distance, which includes 50% of locations) were calculated for each bat with all data of several nights. Bootstrap calculations for the colony foraging area were computed using a self-adapted program written in Turbo Pascal (Tufto et al. 1999). We investigated the influence of spatial features by regression analysis (Norusis 1986). Linear regressions performed better than exponential decay models. We used the geographical variables DIST and ALTITUDE and five parameters which describe land cover: BROADLEAF (amount of broadleaf woodland), CONIFER (amount of conifer woodland), REST (other open land as bare, gravel), GREEN (cover by meadows & pastures) and ARABLE (cover by arable land) (Beck et al. 1994).

The spatial model was calculated based on all locations included in a 98 % minimum convex polygon ($n = 1320$) to ensure, that some unique outliers do not inflate the foraging area. We defined individual core foraging areas by the 50 % kernel contour lines.

Because of the seasonal stratified range use in bats the foraging ranges we observed do not include all places relevant to a home range. We therefore use the term activity ranges for the areas used by individual bats during the relatively short study period of some days.

There is a problem to composite core foraging areas from several individuals (Wray et al. 1992). We computed utilisation density by kernel estimations (Worton 1989) according to the procedure described in Naef-Daenzer (1994) and Bontadina & Naef-Daenzer (in press). In order to weight all individuals equally, we calculated first a matrix of utilisation density for every bat, than the matrices of all bats of a season were combined and finally the matrices of the three seasons were joined. We delimited core foraging areas of the colony by those 30 percent of the total used area with the highest utilisation density of all radio-tracked bats.

Results

In 26 radio-tracking sessions we collected 1330 locations from 22 foraging greater horseshoe bats during 99 nights (Table 1). Data collection per session lasted for 3.8 ± 1.2 (mean \pm SD) nights. Four bats were radio-tracked in two seasons. In one of these cases the foraging ranges showed a minor overlap of 13%, in the other three cases no overlap at all, pointing to spatially seasonal foraging areas. For the spatial analysis we therefore treated all tracking sessions as samples of independent members of the colony. Accordingly we studied 8 bats in spring, 11 in summer and 7 in autumn.

[Table 1]

Foraging areas

The bats foraged every night within large individual foraging areas. Mean size of activity range, revealed by 90 % kernel density contour lines, was 50.8 ± 30.3 ha ($n = 26$, range 21.9 - 162.8 ha, Table 2). The overall range use by the colony was calculated by summing up all individual foraging areas. The recorded area increased progressively with the number of bats studied. In order to estimate the total foraging range of the colony we randomly added individual foraging ranges of radio-tracked bats and calculated the cumulative foraging area (Fig. 2). This was repeated for hundred calculations while the bats included were permuted (bootstrap sampling). The individual foraging ranges overlapped to a large extent with each other: 10 bats used already more than 80 % of the total recorded foraging area. The overall foraging range of all 26 bats was 6.13 km^2 . The regression curve of the bootstrapped range data approaches an asymptote at about 6.7 km^2 , but is nearly reached by the locational data of about 15 bats from different seasons. The extrapolated foraging range of the total colony lies with confidence of 95% between 6.4 and 7.0 km^2 .

[Figure 1]

Foraging intensity

The utilisation density within the foraging range of the colony was unevenly distributed. The observed foraging was distributed over a narrow band of altitude. The lowest grounds available were at 670 m asl and no foraging was observed in areas higher than 900 m asl. In the same foraging areas we found up to 16 bats (62 % of the sample studied) in the course of the year. The foraging bats showed a selective pattern of spatial use which reflected the topographical situation of the main valley and one side valley situated towards the south (Fig. 2).

The three factors ALTITUDE (meters above sea level), DIST (distance to the roost) and BROADLEAF (broadleaf woodland cover) were found to be significant predictors in linear regression which explained 24.9 % of the variability in the observed utilisation density (Table 3). The density of use decreased with distance to the roost and altitude (Fig. 3) and increased with broadleaf woodland cover.

[Figure 2]

[Table 3]

[Figure 3]

Fifty percent of the interval sampling locations (which is equivalent to 50% of time) we found the tracked bats within 1700 m of the maternity roost whereas the maximum foraging distance was 7.4 km. If the utilisation pattern is compared to a uniform distribution, foraging areas up to 4 km from the roost are used more than expected (Fig. 4). No areas above 900 meters asl. were used for foraging.

[Figure 4]

Core areas

The size of individual core foraging areas (50 % kernel) was 7.1 ± 4.0 ha and enclosed about an area of 7 % of the overall activity areas (Table 2). The individual core foraging areas overlapped only to a small extend, therefore the area curve increases at every step for nearly the area of the core area added (Fig. 2).

There were 15 spatially explicit core areas delimited (see Fig. 2, some of the smallest were omitted). They enclose an area of 2.1 km², according to the definition 30 % of the overall foraging area.

Indication for critical season

The body weight of 51 bats caught when emerging from the roost was 21.0 ± 2.8 g and showed no seasonal differences (ANOVA, $F_{2,48} = 1.40$, $p > 0.25$). The foraging distance of the bats differed in the three seasons (Median distance of individuals tested by season with Kruskall-Wallis test, $\text{Chi}^2 = 7.04$, $df = 2$, $p < 0.05$). In spring the bats foraged half of the time exterior to a distance of 2523 m from the roost. In summer, however, the distance was only 1524 m and decreased to 1005 m in autumn (Table 2). This difference in mean foraging distance was reflected by the amount of time they foraged in immediate vicinity of the roost. Whereas in spring the bats stayed for only 17.7 % of the time within 1.2 km of the roost but for 52.2 % further away than 2.4 km, this proportion was 66.1 % and 13.4 %, respectively, in autumn (Fig. 5).

[Figure 5]

The number of locations collected showed no influence on individual activity range size (linear regression, $n = 26$, $r = 0.04$, $p = 0.85$). We therefore compared seasonal activity ranges without correction for sample size. Mean activity ranges by 90 % kernel density estimates showed no significant seasonal differences (ANOVA, $F_{2,23} = 1.42$, $p = 0.26$) (Table 2).

Discussion

Foraging area of the colony

Greater horseshoe bats usually forage in short distance to their nursery roost, as the results of this study demonstrate. This finding could only be revealed by radio-tracking, as former attempts to find foraging areas by the use of an ultrasound detector in the field were only successful near to the nursery roost (Zahner 1997). Since the availability of transmitters, light enough to study greater horseshoe bats, there are several investigations which explored foraging behaviour in greater horseshoe bats in UK (Stebbins 1982, Jones & Morton 1992, Jones et al. 1996, Duverg   1996), in Luxembourg (Pir 1994), Germany (Geiger et al. 1993), Italy (Bontadina et al. 1999) and Switzerland (Beck et al. 1994, Bontadina et al. 1995, Lugon 1996).

Lugon (1996) found median foraging radii of 1 km in an Alpine Valley. Jones & Morton (1992) calculated mean foraging radii between 2 and 4 km, and Duverg   (1996) found values between 1.6 and 2.8 km in his extensive study. Our results are consistent with these findings and confirm that in different habitats and regions the mean distances used by greater horseshoe bats are very limited, mainly in the range of 1-4 km, although this sometimes may include foraging in peak distances of up to 7 km, as we observed in our study. The relatively small range used for foraging by greater horseshoe bats gets even more obvious when it is compared with ranges of other European bat species of similar size. Greater mouse eared bats *Myotis myotis* were observed to commute much larger distances of up to 25 km for foraging (G  ttinger 1997, Arlettaz 1999) and noctule bats *Nyctalus noctula* went at least 16 km (Kronwitter 1988).

An estimation of the foraging range of all members of the colony based on an extrapolation of spatially overlapping individual activity ranges revealed a foraging area of 7 km², an area significantly smaller than expected by the maximal ranges (at radius = 3.5 km: 39 km²). This was mainly contributed to a limitation by topography. Although this restriction, there was no indication for exceptionally enlarged foraging distances, if compared to other studies. This supports the hypothesis of Jones et al. (1995), which postulated that the foraging radius of a species is mainly limited by its wing morphology.

Identification of core foraging areas

Our results suggest that the cumulative foraging ranges of 15 bats from different seasons are sufficient to describe the overall foraging range of a colony as a whole. This is, however, not the case for the core foraging areas, those areas used most intensively for feeding and therefore judged to be the most important ones. The overlap of individual core areas was relatively small. Even the study of 26 bats, which represents about one sixth of the colony, could detect only a small amount of those core foraging ranges presumably used by all members of the colony. The steady increase of the core area curve depending on individuals included indicates, that colony core foraging areas, in difference to the small individual core ranges, are large and may even enclose a main part of the foraging area of the colony.

This pattern with small individual core foraging areas with minor overlaps with each other, and dispersed over a large area, could represent territorial defence of foraging areas or avoidance of interspecific competition. In accordance with Duverg   (1996) we had no indication of any territorial behaviour in the foraging area, except of two observations where a bat was chased away from a perch by another greater horseshoe bat.

Core areas are object of dispute in ecology (Wray et al. 1992), because their boundaries can not objectively be determined. In order to provide

priorities for conservation within the foraging area we stratified the colony area by the designation of those 30 % of the area with highest utilisation density (key feeding areas). This allowed the spatially explicit indication of areas of highest importance as required by landscape planning (e.g. Marzluff & Ewing 2001).

Factors explaining foraging intensity

Habitat selection may be examined at several spatial levels. After having identified a hierarchical order of selection processes, from selection of geographical range to selection of food items (Owen 1972), it is a fundamental concept to exercise resource exploitation studies at different scales (Wiens & Milne 1989). Thereby the components available depend upon the order of selection considered (Johnson 1980).

The differences in utilisation densities of the colony may partly be explained by altitude, broadleaf woodland cover and flight distance to the roost. Greater horseshoe bats forage mostly in areas of low altitude of their colony range. We suppose altitude represents the known dependency of nocturnal insect availability on temperature (Lewis & Taylor 1964, Duverg   1996). Duverg   (1996) found insect, especially moth, availability to increases about twofold by an increase of two degree of the initial nightly temperature within a range of 5 to 15 degree. On the other hand the temperature drops about 0.65 degree per 100 m as altitude increases (Pfister 2000). In particular in the alpine range greater horseshoe bats might benefit from this effect by looking for the lowest located suitable areas. In contrary they seemed to avoid altitudes more than 900 m asl. at all, although habitats did not change abruptly at this altitude. The second factor with influence on foraging was DISTANCE to the roost. The smaller the distance to the roost, the more bats were observed foraging. Therefore we suggest that the value of conservation measures increases with decreasing distance to the roost. This could be of particular interest for subadult bats, which only slowly enlarge their foraging ranges (Duverg   1996) and therefore are restricted to suitable habitats in the ultimate vicinity to their roost. The only factor of cover

which contributed to the model was cover of broadleaf woodland. However, only 25 % of the variability in utilisation density could be explained by spatial and geographical factors at the colony level. A first evaluation of the individual's selection of their activity ranges revealed a selective use of woodlands in spring (Bontadina et al. 1995). Other studies found specific habitat types selected for, too (Pir 1994, Duvergé 1996, Lugon 1996). We suppose therefore that habitat selection, carried out by individuals within their activity ranges, is responsible for a large part of the remaining variability in utilisation density.

Indication for critical season

In the circadian rhythm of hibernating bats, spring usually represents the season with their lowest weight of the year (Beasley et al. 1984). In captive pallid bats *Antrozous pallidus* peak levels of food intake occurred at times of the year when body weight was low (Beasley 1986). Ransome (1990) observed in greater horseshoe bats a body weight reduction of about one third during hibernation. The bats have to restore their condition after hibernation which signifies an increased energy demand. This is especially the case for female bats, which only shortly afterwards enter pregnancy and it is probably more severe in the continental climate of the Alps with long, cold winters. Moreover in early spring the insect abundance is very low (Ransome 1990, Duvergé 1996, own unpublished data) which requires an additional effort to replenish their resources. It was in spring, when we found larger foraging radii of female greater horseshoe bats. This means not only additional travel expenses, but also that the bats dispersed over more than twice the area used by the colony in summer (area with radius 1.5 km = 7 km² vs. 19.6 km² at radius of 2.5 km). We interpret the increase in foraging distance as an indication for food being a limiting resource in this season. This is in accordance with the findings from Ransome (1978), that reproduction success (in term of an early date of birth) was mostly related with the mean temperature, and hence insect availability, in spring. Racey & Swift (1985) found foraging areas contracting in lactating female Pipistrelle bats in summer, but Barclay (1989) found no correlation of foraging behaviour with sea-

son in pipistrelle bats *Pipistrellus pipistrellus*. Significant differences can be interpreted as a seasonal or reproductive effect (Duvergé 1996). This plays a minor role in our interpretation, as we use the result as indication of an increased effort necessary, independent whether this derives from increased energetic demand by the reproduction state and/or a seasonal shortage of food.

Species that have low fecundity but are long-lived, as this is the case in greater horseshoe bats (Ransome 1990), are most sensitive to seasonal resource bottlenecks (Payne & Wilson 1999). We therefore suggest to pay special attention to critical seasons in greater horseshoe bats. If the requirements of a highly endangered species has to be included into a conservation scheme in densely populated area, utilisation conflicts are inevitable. This is even more the case in synanthropic bat species which often have their roost within a human settlement and use large foraging areas in the vicinity. It was generally recognised in mammals, that viable populations often would require the preservation of areas of a size of some magnitudes larger than any existing natural reserves (Shaffer 1987). If therefore compromises between different utilisation interests are drawn, areas and habitats used in such a critical season should gain priority in a conservation scheme.

Implications for conservation

Mitchell-Jones (1995, 1999) outlined the importance of the identification of critical feeding areas around the breeding roosts. The spatial demands of this large relict colony of greater horseshoe bats, as revealed by radio-tracking, extends the perception of the conservation needs of this colony beyond the roost. For a successful conservation of the colony their spatial requirements for foraging must be considered (Bontadina et al. 1996). First, we suggest that with regard to possible utilisation conflicts the presence of greater horseshoe bats and their requirements must be considered within a distance of up to 10 km around all roosts used by several greater horseshoe bats. However, the requirements of greater horseshoe

bats must be given priority within a distances of 4 km to the nursery roost. **Second**, conservation of key feeding areas should earn highest priority. They concentrate a major amount of foraging activity of a significant proportion of the colony on a relatively small area. Further analysis should investigate fine grained habitat use within individual activity areas, in order to be able to extrapolated sufficiently the essential foraging areas. **Third**, we suggest that management measures are more effective, when they are implemented near to the nursery colony and enclose habitats used in spring, the season suspected to be critical.

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■ **Table 1:** Summery of 26 telemetry sessions of *Rhinolophus ferrumequinum* carried out in 1993: animal code with sex, wing band number, age and reproduction state, period of tracking session, number of nights with observations and number of sampling locations (five minutes intervals) are given and summarised for the three seasons spring, summer and autumn, which correspond to early pregnancy, lactation and post-lactation.

animal code (W = female, M = male)	wing band number	reprod. state, age class	date of tracking session	nights with observations	locations n
W1	H967	ad., 2	30.4.-2.5.	3	9
W7	H968	ad., 2	7.5.-12.5.	5	28
W17	H970	ad., 2	13.5.-17.5.	3	44
W27	H971	ad., 2	18.5.-25.5.	5	27
W8	H969	ad., 2	22.5.-30.5.	5	115
W9	H972	ad., 2	27.5.-3.6.	5	45
W18	H973	ad., 2	1.6.-6.6.	4	56
W19	H974	ad., 2	6.6.-11.6.	4	110
spring					34
					434
M8	H979	ad., 2	25.7.-31.7.	3	35
W37	I526	ad., 3	1.7.-2.7.	3	59
W47	H978	ad., 3	4.7.-7.7.	3	32
W57	H975	ad., 3	9.7.-12.7.	2	3
W28 (former W1)	H967	ad., 3	12.7.-22.7.	5	79
W29	H976	ad., 3	13.7.-24.7.	4	49
W3	I517	ad., 3	17.7.-26.7.	4	54
W11	H977	ad., 3	21.7.-30.7.	4	51
W2 (former W9)	H972	ad., 3	25.7.-31.7.	4	130
W13	H980	ad., 3	30.7.-1.8.	2	9
W23	H981	ad., 3	2.8.-?	4	104
summer					38
					570
M0	plastic ring #75	ad., 5	30.8.-24.9.	2	8
W3_h (former W3)	I517	ad., 2	30.8.-?	3	10
W22 (former W7)	H968	ad. (post lac.)	30.8.-21.9.	4	45
W38	H982	subad., 1	2.9.-?	4	67
W21	H983	ad., (non lac.)	1.9.-21.9.	4	63
W32	no ring	ad., 2	29.9.-?	4	58
W31	H986	ad., 1	29.9.-?	7	40
autumn					27
					283
year			26 sessions	99	1330

Table 2: Maximum foraging radius and Median distances (IQR = inter-quartile range) the bats went foraging from the roost.

animal code	maximum foraging radius	Median distance (IQR)	50 % kernel core area size [ha]	90 % kernel activity range size [ha]
W1	1917	1733 (1700 - 1785)	5	26.98
W17	2460	1950 (1589 - 2056)	10.3	61.04
W18	3262	2439 (627 - 2997)	6.1	56.85
W19	4174	3171 (2743 - 3608)	2.5	70.78
W27	7372	5941 (2347 - 6842)	4.4	48.12
W7	2333	1969 (1649 - 2069)	4.7	34.04
W8	4565	2448 (2295 - 2628)	5.4	27.39
W9	1702	535 (431 - 1143)	4.2	35.07
mean spring	3473	2523 (1672 - 2891)	5.3 ± 2.7	45.03 ± 16.59
W13	3457	536 (261 - 3332)	1.8	43.78
M8	3918	2928 (1982 - 2948)	5.2	23.76
W11	4744	1417 (1032 - 1527)	4.4	65.87
W2	4369	1876 (1763 - 3071)	4.2	35.51
W23	3789	1041 (951 - 1164)	5.6	40.97
W28	3251	1877 (1030 - 2151)	10	74.88
W29	2726	893 (258 - 1377)	7	59.87
W3	3448	1257 (951 - 1853)	18.7	162.80
W37	3290	2794 (2672 - 2995)	11.1	56.33
W47	2453	1010 (637 - 1575)	14.1	93.37
W57	2841	1129 (792 - 1985)	10.9	25.58
mean summer	3448	1524 (1121 - 2180)	8.5 ± 5.0	62.07 ± 39.53
M0	728	275 (205 - 544)	5.1	38.19
W21	5540	2411 (1175 - 2804)	5.1	27.35
W22	2118	1194 (950 - 1397)	5.4	28.05
W3_h	3282	617 (201 - 1519)	6.8	51.96
W31	1839	746 (456 - 1386)	13.9	83.64
W32	1235	787 (714 - 862)	4.9	21.87
W38	1472	1003 (685 - 1087)	10.8	27.02
mean autumn	1839	1005 (627 - 1371)	7.4 ± 3.5	39.73 ± 21.80
mean year	2743	1691	7.1 ± 1.6	50.81 ± 30.28

[Table 3]

Table 3. Utilisation density (UTILD) in the foraging area of the colony explained by the independent factors ALTITUDE (meters above sea level), DIST (distance to the colony), BROADLEAF (amount of broadleaf woodland cover), CONIFER (amount of conifer woodland cover), REST (other open land as bare, gravel), GREEN (meadows & pastures) and ARABLE (arable land) in linear regression ($n = 743$ ha squares with \geq one location). The dependent variable utilisation density was $\log_{10}(\text{UTILD}+1)$ transformed to achieve normality.

	std correlation coef.	T	p
constant	856	1.681	.093
ALTITUDE	-.174	-4.638	<0.001
DIST	-.257	-7.160	<0.001
BROADLEAF	.703	2.143	.032
CONIFER	.620	1.781	.075
REST	.595	1.449	.148
GREEN	.498	1.238	.216
ARABLE	.035	.235	.814

[Figure 1]

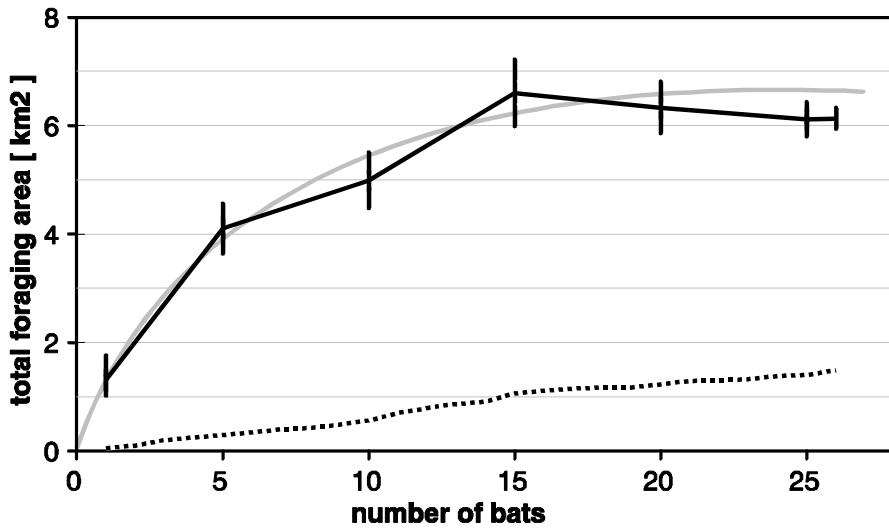


Fig. 1: Relation of area depending on number of individuals included.
Black line: 90 % kernel contour colony foraging area size computed as cumulated foraging areas of individual bats (mean +- 95 % confidence intervals of 100 bootstrap resamples). Grey curve: logistic regression line. Black dotted line: core area size computed as cumulated foraging areas of individual bats.

[Figure 2]

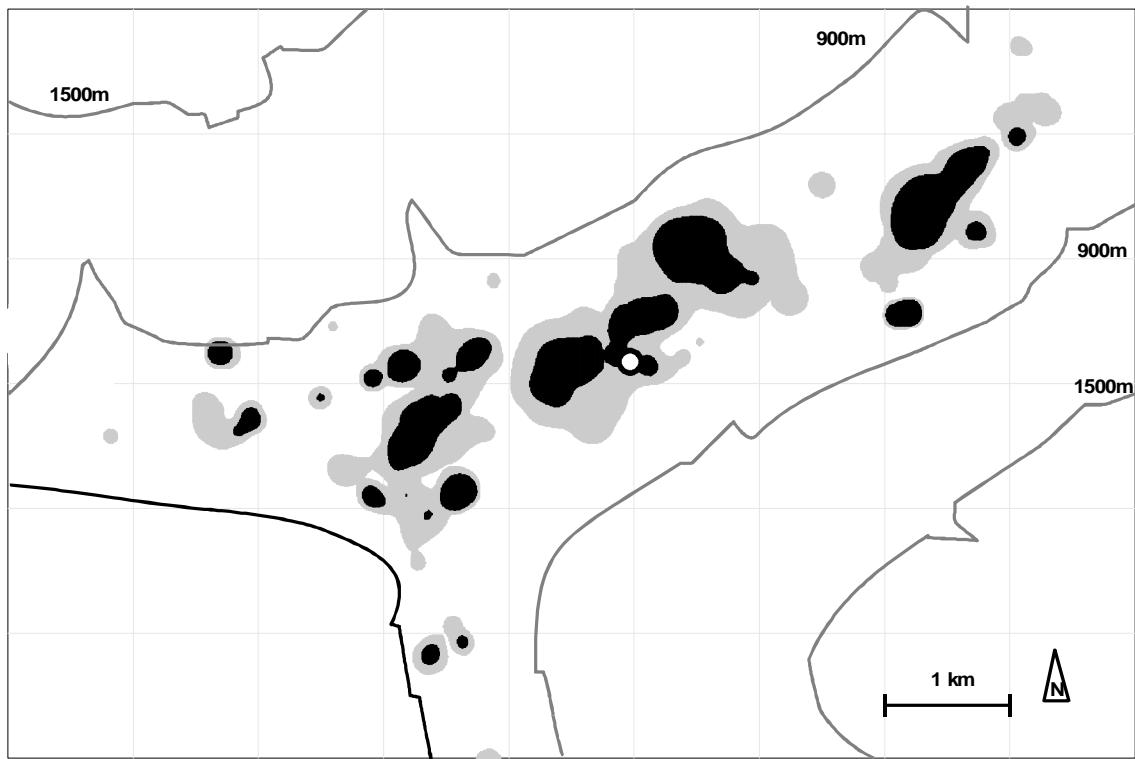


Fig. 2: Mean utilisation density (with 95 % confidence intervals) depending on classes of altitude above sea level.

[Figure 3]

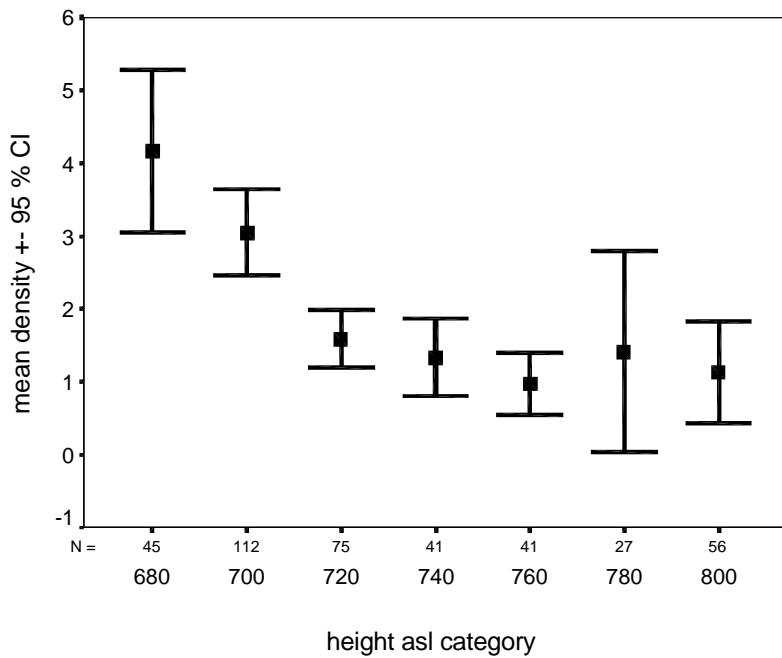


Fig. 3: Mean utilisation density (with 95 % confidence intervals) depending on classes of altitude above sea level.

[Figure 4]

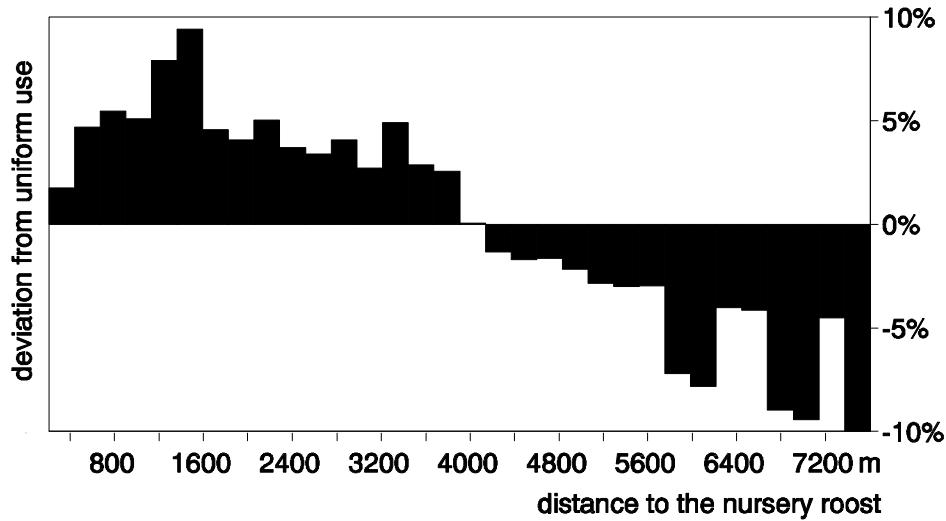
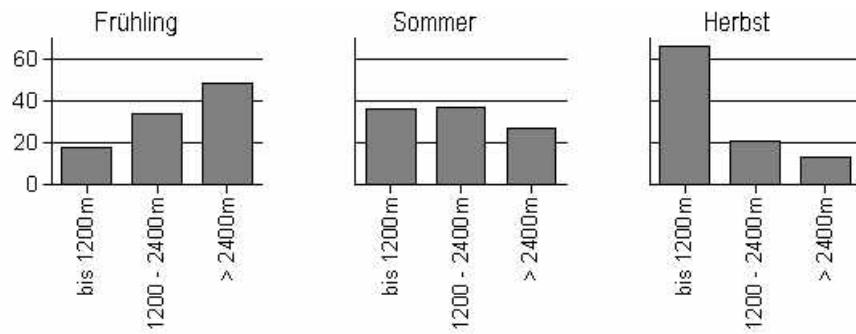


Fig. 4: Deviation of the observed frequency of locations ($n = 1330$) when compared with a model of uniform spatial use. If the bats would have used all areas within 7400 m (maximal range) to the nursery roost equally, no deviation from the baseline would be observed. Distances near to the roost up to about 4 km were used more often for foraging than expected by the uniform model.

[Figure 5]



Jagt die Grosse Hufeisennase *Rhinolophus ferrumequinum* im Wald ? - Grundlagen zum Schutz der letzten grösseren Kolonie in der Schweiz.

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Key words: Habitat use, *Rhinolophus ferrumequinum*, bat, conservation, woodland.

Bontadina, F., Beck, A., Gloor, S., Hotz, Th., Lutz, M. & Mühlethaler, E. (1995):
Jagt die Grosse Hufeisennase *Rhinolophus ferrumequinum* im Wald? - Grundlagen zum Schutz von Jagdgebieten der letzten grösseren Kolonie in der Schweiz.
In: Ingold, P.: Naturschutz und Verhalten - 3. Internationales Symposium der Ethologischen Gesellschaft in Bern, 11. - 15. Oktober 1994. Orn. Beob. 92: 325-327.

Abstract

The Greater Horseshoe Bat is considered an endangered species in all of Central Europe. One of the last larger nursery colonies with 140 animals is situated in an Alpine valley in Switzerland (Vorderrheintal, GR). In 1993 24 bats from the nursery roost were studied by means of radio tracking. Based on echolocation and wing morphology it can be supposed that the Greater Horseshoe Bat is adapted for foraging in dense vegetation. Our analysis of habitat use shows, that in spring the bats mainly hunt in forest areas. In summer and autumn there doesn't seem to be a difference in the use of woodlands and open areas. We therefore propose to see the morphological and bioacoustic adaptations as a response to a strong selective constraint in spring. This allows implications for conservation priorities.

Einführung

Noch Mitte dieses Jahrhunderts war die Grosse Hufeisennase in der ganzen Schweiz verbreitet. Heute ist sie bei uns wie im übrigen Mitteleuropa vom Aussterben bedroht. Als eine der Hauptursachen des Bestandesrückgangs und Arealverlustes werden Lebensraumveränderungen vermutet (Stebbins & Arnold 1989). Eine der letzten grösseren Wochenstubenkolonien in Mitteleuropa mit maximal 144 adulten Tieren befindet sich in einem Kirchenestrich im Vorderrheintal (GR, Schweiz).

Die Grosse Hufeisennase gehört zu den grossen Fledermausarten und wird aufgrund der Flügelmorphologie zur Gruppe der langsam und wendig fliegenden Arten eingeteilt (Norberg & Rayner 1987). Wegen dieser Merkmale und der spezialisierten Ultraschallrufe (Schnitzler & Oswald 1983) kann erwartet werden, dass die Grosse Hufeisennase für die Insektenjagd innerhalb von Vegetation spezialisiert ist.

Da in der näheren Umgebung der Wochenstubenkolonie im Vorderrheintal grössere landschaftliche Veränderungen bevorstehen, wurde die Habitatnutzung von Grossen Hufeisennasen aus der Wochenstubenkolonie untersucht. Um Biotopschutzmassnahmen auf Lebensraumtypen konzentrieren zu können, die für die Nahrungssuche von Bedeutung sind, wurde im vorliegenden Auswertungsteil die Hypothese geprüft, ob die Grosse Hufeisennase hauptsächlich im Wald jagt.

Methoden

Im Frühling (1. 5 - 9. 6.), Sommer (1. 7 - 6. 8.) und Herbst (31. 8. - 8. 9. und 30. 9 - 12. 10. 1993) wurde die Raumnutzung von einer männlichen und 23 weiblichen Grossen Hufeisennasen aus der Wochenstubenkolonie mit Hilfe der Telemetrie überwacht. In Fünf-Minutenintervallen wurden die Aufenthaltsorte der Untersuchungstiere während ihrer Aktivitätszeit mittels Kreuzpeilungen bestimmt. Die Datenmenge umfasste total 743 Ortungen von 66 Nächten. Das Untersuchungsgebiet wurde durch die beobachteten Aufenthaltsorte begrenzt und umfasste ca. 20km². Darin wurde das Habitatangebot anhand des Flächenanteils von 424 zufällig ausgewählten Hektarquadrate bestimmt (Neu et al. 1974). Zusätzlich wurden 23 weitere Habitatvariablen, die Längen von Rand-

strukturen sowie die Biotopdiversität beschreiben, aufgenommen. In einer Habitatanalyse wurden die Flächenanteile von Wald und Offenland in Hektarquadraten, die ein Tier genutzt hatte, dem Anteil Wald und Offenland im Habitatangebot gegenübergestellt. Die Zahl der Tiere mit Überschreitungen des Nutzungswertes gegenüber dem Angebotswert wurde mit dem Vorzeichentest von Dixon & Mood getestet.

Ergebnisse

Das Untersuchungsgebiet setzt sich aus 39.9% Wald und 60.1% Offenland zusammen. Dabei besteht das Offenland zu zwei Dritteln aus Wiesen und Weiden, zu einem kleinen Teil aus Äckern, Obstgärten und Siedlungsgebiet sowie aus Wasser-, Pionier- und Kiesflächen des frei fliessenden Vorderrheins. Der Wald besteht gut zur Hälfte aus Nadelwald, der Rest ist Laubwald, häufig Auenwald.

Die Grossen Hufeisennasen nutzten die Umgebung der Wochenstübnerkolonie im Laufe der Saison unterschiedlich. Im Frühling hielten sich die 8 untersuchten Grossen Hufeisennasen signifikant häufiger als erwartet in Gebieten mit grösserem Waldanteil auf ($p<0.01$, Abb. 1). Zwischen dem Waldanteil und den weiteren Habitatvariablen bestand in keinem Fall eine stark positive Korrelation. Im Sommer nutzten 9 von 11 Tieren eher Offenland als Wald, die Nutzung unterscheidet sich aber wie diejenige von 5 Tieren im Herbst nicht signifikant vom Angebot im Untersuchungsgebiet.

Diskussion

Alle 8 untersuchten Tiere nutzten im Frühling (Mai und Anfang Juni) Gebiete mit grossem Waldanteil. Dies zeigt, dass die Grossen Hufeisennasen zu dieser Zeit im Wald oder am Waldrand nach Insekten jagen. Im Frühling waren im Gegensatz zum Sommer und Herbst nie Sichtbeobachtungen jagender Tiere mit einem Nachtsichtgerät möglich. Dies und der Umstand, dass die Waldrandlänge wie auch die anderen erhobenen Habitatmerkmale nicht mit dem Waldanteil korreliert sind, deuten darauf hin, dass die Grossen Hufeisennasen im Frühling im Waldesinnern jagten.

Später im Jahr ergab sich keine bevorzugte Nutzung von Wald oder Offenland mehr. Stebbings (1982) und Jones & Morton (1992) fanden in England im Frühling ebenfalls eine Bevorzugung von Waldgebieten, obwohl diese in ihren Untersuchungsgebieten nur kleine Flächen ausmachten.

Um Prioritäten für den Biotopschutz aufstellen zu können, braucht es Angaben über kritische Jahreszeiten für die Nahrungssuche der Grossen Hufeisennase. Denn sowohl Waldgebiete wie auch Offenland wurden

von einzelnen Grossen Hufeisennasen zu gewissen Jahreszeiten über Erwarten genutzt und könnten von Bedeutung sein.

Die aufgrund von Flügelmorphologie und Merkmalen der Ultraschallrufe aufgestellte Hypothese, dass die Grossen Hufeisennasen im Wald jagen, bestätigt sich nur im Frühling. Werden die morphologischen und bioakustischen Spezialisierungen der Grossen Hufeisennase als Anpassung an einen starken Selektionsdruck im Frühling interpretiert, könnte daraus auf eine grosse Bedeutung der im Frühling genutzten Waldgebiete geschlossen werden.

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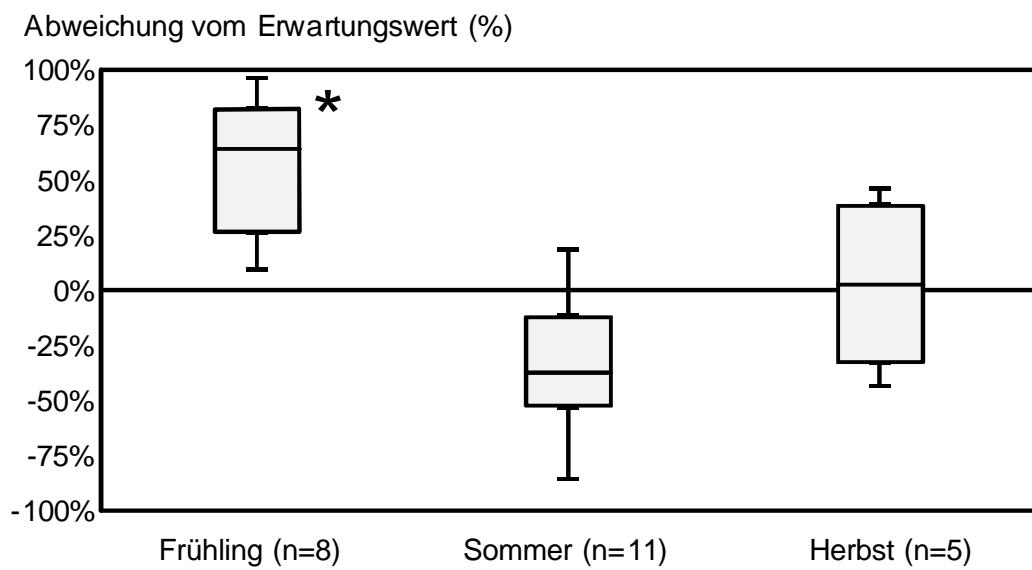


Abb. 1: Nutzung von Wald durch 24 Grosse Hufeisennasen im Laufe der Saison.
 Die Nulllinie bedeutet eine Nutzung von Wald entsprechend dem Angebot. Die Abweichungen sind als Bereich, Interquartile sowie Median in Prozent des Erwartungswertes jeweils für die untersuchten Tiere einer Saison dargestellt (* = $p<0.01$, Vorzeichentest).

Schutz von Jagdgebieten von *Rhinolophus ferrumequinum*. Umsetzung der Ergebnisse einer Telemetrie-Studie in einem Alpental der Schweiz.

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Bontadina, F., Hotz, T., Gloor, S., Beck, A., Lutz, M. & Mühlethaler, E. (1997): Schutz von Jagdgebieten von *Rhinolophus ferrumequinum*. Umsetzung der Ergebnisse einer Telemetrie-Studie in einem Alpental der Schweiz. In: Zur Situation der Hufeisennasen in Europa: 33-39. Ohlendorf, B. (ed.). Berlin: IFA.

Zusammenfassung

Aufgrund der Ergebnisse einer Untersuchung von 24 sendermarkierten Grossen Hufeisennasen einer Population von schätzungsweise 200 Tieren werden konkrete Massnahmen zum Schutz von Jagdgebieten und Prioritäten bei der Umsetzung vorgeschlagen.

Für die Grossen Hufeisennasen müssen für den Schutz von Jagdgebieten Artenschutzmassnahmen durchgeführt werden: 1. Geeignete Lebensräume müssen über 30 % der Fläche im Umkreis von 3.5 km um das Wochenstubenquartier ausmachen. 2. Diese Gebiete müssen kleinräumig eine hohe Diversität an Lebensraumtypen und dadurch einen grossen Anteil an Grenzflächen aufweisen.

Wir definieren drei Umsetzungs-Perimeter. Als Kernjagdgebiete werden die Gebiete mit der grössten Aufenthaltsdichte von jagenden Grossen Hufeisennasen bezeichnet. In der Fallstudie machen sie 1.6 km² aus. Sie sollen umfassend geschützt werden. Das Aktivitätsgebiet um das Wochenstubenquartier beinhaltet die bekannten oder potentiellen Jagdgebiete. Diese sollen erhalten und aufgewertet werden. Im Verbreitungsgebiet sollen bei grösseren Landschaftsveränderungen die Ansprüche der Grossen Hufeisennasen berücksichtigt werden.

Die Erhaltung einer Population ist durch die Quartiertradition eng mit dem benützten Wochenstubenquartier verknüpft. Damit eine Wochenstubenkolonie erhalten bleibt, müssen die mikroklimatischen Anforderungen an das Wochenstubenquartier und die Ansprüche an die direkt umgebende Landschaft erfüllt sein. Die vorgeschlagenen Massnahmen sind Hypothesen, deren Wirkung zu kontrollieren ist.

Protection of feeding areas of *Rhinolophus ferrumequinum*. An action plan based on the results of a radiotracking study in an alpine valley of Switzerland.

Abstract

When investigating a population of about 200 greater horseshoe bats 24 individuals were provided with a transmitter and their habitat use and spatial organisation were studied. The results served as a basis for proposing practical measures to protect the feeding areas as well as for setting priorities in putting them into effect.

Deciduous woodland and permanent meadows are important feeding areas. Pine forests and a great share of ploughed meadows and farmland have a negative effect on the range of food. For the greater horseshoe bats the following measures must be taken so as to protect the species and its feeding areas:

1. Suitable biotopes must cover over 30 percent of the surface within a distance of 3.5 km around the nursery roost.
2. Such areas must feature many different types of vegetation on narrow space and hence a high share of interfaces.

We define three perimeter for conservation measures. Areas with the highest density of feeding greater horseshoe bats are considered as key feeding areas. In the present case they are totalling 1.6 km² and ought to be protected as a whole. The activity area around the nursery roost covers the areas of observed or potential nightly activity, due to be protected and raised in value. In the distribution area the demands of the greater horseshoe bats ought to be taken into account in the event of major projects likely to change the landscape.

Owing to the roost tradition, conservation of the population is closely linked to the existing nursery roost. To protect a nursery colony it is a must that the microclimatic requirements of the nursery roost are fulfilled as well as the demands placed on the immediate environment. The measures proposed can be understood as hypothesis and their effects has to be checked.

Protection des terrains de chasse de *Rhinolophus ferrumequinum*. Mise en pratique des résultats obtenus par une étude télémétrique dans une vallée alpine en Suisse.

Résumé

Lors de l'exploration d'une population de 200 grands rhinolophes, 24 individus équipés d'un émetteur ont été étudiés en ce qui concerne l'utilisation de leur espace et habitat. Ces résultats donnent lieu à proposer des mesures concrètes pour la protection de terrains de chasse et à établir des priorités lors de leur mise en pratique.

Les forêts d'arbres à feuilles et les herbages permanents représentent des terrains de chasse importants, tandis que les forêts de conifères et une grande quote-part de champs et prés labourés exercent une influence négative sur la gamme de nourriture. Pour la protection des terrains de chasse des grands rhinolophes et de l'espèce même, il faut donc prendre les mesures suivantes:

1. Des biotopes appropriés doivent couvrir plus de 30 pour-cent de la surface dans une distance de 3.5 km autour du gîte de reproduction. 2. Ces terrains doivent avoir beaucoup de types de végétation différents et par conséquent une quote-part d'interfaces élevée.

Il y a trois périmètres à définir pour la mise en pratique. Les terrains avec la plus grande densité de grands rhinolophes chassants sont considérés comme terrains de chasse principaux. Dans le cas de l'étude, ils comprennent 1.6 km² et il faudrait les protéger de façon intégrale. Le terrain d'activité autour du gîte de reproduction renferme les terrains d'activité nocturne. Ceux-ci doivent être conservés et révalorisés. Au sein de l'aire de répartition, il faut tenir compte des exigences des grands rhinolophes lors de projets importants qui pourraient changer la physionomie du paysage.

En raison de la tradition de demeure, la conservation d'une population est étroitement liée au gîte de reproduction existant. Pour pouvoir conserver une colonie, il faut que les conditions microclimatiques du gîte de reproduction soient remplies ainsi que celles posées au paysage des environs immédiats. Les mesures proposées en faveur du grand rhinolophe sont des hypothèses et dont les effets sont à contrôler.

Einleitung

Artenschutzmassnahmen für Fledermäuse sollten sich mindestens auf Fortpflanzungskolonien als kleinste Einheiten beziehen. Ein Konzept zur Erhaltung und Förderung einer Population muss dabei alle räumlichen Ansprüche der Wochenstabenkolonie an den Lebensraum in ihren zeitlichen und funktionellen Dimensionen berücksichtigen (Übersicht in Stebbings 1988).

Bei der Grossen Hufeisennase lassen sich die räumlichen Ansprüche einer Wochenstabenkolonie in die Bereiche Quartiere, Flugrouten, Jagdgebiete und Entwicklungsgebiete der Beutetiere aufteilen. Die räumlichen Anforderungen einer Population müssen unter Berücksichtigung dieser vier Bereiche untersucht werden.

Die Bedeutung von Quartieren, Flugrouten, Jagdgebieten und Beuteentwicklungsgebieten kann je nach Jahreszeit und Region sehr unterschiedlich sein. Zur Festlegung von Prioritäten bei den Artenschutzmassnahmen müssen diese vier Bereiche deshalb nach Saison (z.B. Frühlingsjagdgebiete), ihrer funktionellen Bedeutung (z.B. Paarungsquartiere) oder der Intensität der Benutzung (z.B. bei Flugrouten) unterschieden werden.

Bis heute wissen wir nur wenig über die Bedeutung von verschiedenen Bedrohungursachen der Grossen Hufeisennasen in Nord- und Mitteleuropa. Als Hauptursache des dramatischen Bestandesrückgangs wird die Veränderung des Lebensraumes und damit des Beuteangebotes vermutet. Weiter haben wahrscheinlich direkte Vertreibungen, Quartierverluste, Holzbehandlungen in Quartieren sowie Insektizide aus der Landwirtschaft zum Rückgang beigetragen. (Ransome 1990, Stebbings & Arnold 1987, Roer 1983/84).

Dem Schutz von Jagdgebieten von Grossen Hufeisennasen ist bisher im Verhältnis zur wahrscheinlichen Bedeutung wenig Aufmerksamkeit gewidmet worden, was mit methodischen Schwierigkeiten bei der Untersuchung von Jagdgebieten, aber auch mit dem grossen Konfliktpotential bei der Umsetzung von Schutzmassnahmen zur Erhaltung oder Förderung von Jagdgebieten zu tun hat.

Für die Erhaltung und die Schaffung von Jagdgebieten fehlten bis heute Angaben zu geeigneten Habitattypen und anderen qualitativen Anforderungen, die für Jagdgebiete erfüllt sein müssen. Ebenso fehlten konkrete Angaben über den Flächenbedarf an geeigneten Jagdgebieten für die Kolonien.

Die letzte grosse Kolonie der Grossen Hufeisennase in der Schweiz lebt in einer Landschaft, die zur Zeit von grösseren Veränderungen, wie der Schaffung von Kiesabbaugebieten und neuen Industriezonen, bedroht ist. Eine grossflächige Güterzusammenlegung ist geplant. In den letzten Jahren wurde zudem eine schleichende Intensivierung der landwirtschaftlich genutzten Gebiete festgestellt. Um die Anforderungen der Grossen Hufeisennasen an die Jagdgebiete in die Planungsvorhaben einbringen zu können, mussten dringend Grundlagen erarbeitet werden. Unsere Arbeitsgruppe führte dazu im Jahr 1993 eine Untersuchung zur Raum- und Habitatnutzung dieser Kolonie durch.

Aufgrund der Ergebnisse der Untersuchung schlagen wir für die untersuchte Kolonie und abgeleitet auch für andere Kolonien in Mitteleuropa konkrete Massnahmen zur Erhaltung und Schaffung von Jagdgebieten für die Grosse Hufeisennase sowie Prioritäten bei der Umsetzung dieser Massnahmen vor.

Methoden

Die Grundlagen für die Empfehlungen zum Schutz der Jagdgebiete der Grossen Hufeisennase wurden mittels einer Telemetriestudie an der letzten grossen Wochenstubenkolonie in der Schweiz erhoben. Diese isolierte, auf 200 Tiere geschätzte Population benutzt mit bis zu 144 adulten Individuen ein Wochenstudenquartier, das sich in einem Kirchenestrich befindet. Das Quartier liegt auf 700 m ü. M. im Vorderrheintal, einem Alpental im Ostschweizer Kanton Graubünden.

Die Landschaft ist geprägt durch die zwei Flüsse Vorderrhein und Glenner, die von Kiesbänken und Auenvegetation begleitet werden.

Kleingehölze, Hecken und Buschgruppen strukturieren die landwirtschaftlich genutzten Flächen des Talbeckens. Der von den Grossen Hufeisennasen bis zu einer Höhe von 900 m genutzte Talkessel setzt sich aus 60 % Offenland und 40 % Wald, je etwa zur Hälfte Nadel- bzw. Laubwald, zusammen. Die Nadelwälder liegen häufig an den steilen Hängen. Das Talbecken und die weniger steilen Hänge werden für Ackerbau und Viehwirtschaft genutzt. Insgesamt machen Äcker 8 % und Wiesen und Weiden 38 % der Fläche aus. Nähere Angaben zum Untersuchungsgebiet können Zahner (1996) entnommen werden.

Die räumlichen Prioritäten von Schutzmassnahmen wurden aufgrund der Ergebnisse zur Raum- und Habitatnutzung der 24 untersuchten Grossen Hufeisennasen aus der Wochenstubenkolonie (unpubl. Daten) aufgestellt. Die Darstellungen der räumlichen Nutzung erfolgte dabei mit einer kernel estimation, einem Modell, mit dem Aufenthaltsdichten berechnet werden können (Naef-Daenzer 1993). Die Habitatnutzung der einzelnen Tiere wurde aufgrund einer Rastermethode (Neu et al. 1974) analysiert. In die Auswertungen wurden nur die Aufenthalte von aktiven (fliegenden oder wartenjagenden) Tieren einbezogen, so dass angenommen werden kann, dass sich die Untersuchungstiere, ausgenommen bei kurzen Überflügen, auf Nahrungssuche befunden haben. Die Resultate, die den empfohlenen Schutzmassnahmen zugrunde liegen, werden im folgenden nur summarisch dargestellt. Publikationen mit den detaillierten Ergebnissen zur Raum- und Habitatnutzung und zur Nahrungsökologie sind in Vorbereitung (Bontadina et al. 1995, Beck et al. 1996 und andere).

Bei der Ausarbeitung der Empfehlungen wurde von der Annahme ausgegangen, dass Gebiete und Strukturen, die signifikant häufiger genutzt werden, als bei einer zufälligen Verteilung zu erwarten ist, für die Nahrungssuche besonders interessant sind. Die Förderung solcher Gebiete sollte sich positiv auf das Nahrungsangebot der Grossen Hufeisennasen auswirken.

Grundlagen für die Empfehlungen zum Schutz von Jagdgebieten

Raumnutzung: Die untersuchten Grossen Hufeisennasen nutzten zu jeder Jahreszeit die Landschaft in der Umgebung des Wochenstabenquartiers sehr selektiv. Am intensivsten wurde über dem Talboden auf 700 m ü. M. nach Nahrung gesucht. Höhenlagen über 900 m ü. M. wurden nicht genutzt. Dies hatte zur Folge, dass vom Wochenstabenquartier aus praktisch nur Gebiete talauf- oder talabwärts als Jagdgebiete in Frage kamen. Während der ganzen Saison wurden nur 31% der Fläche innerhalb eines Radius von 3.5 km um das Wochenstabenquartier beflogen.

Die Jagdgebiete lagen häufig nahe beim Tagesquartier. Meist jagten die Untersuchungstiere im Umkreis von 3.5 km um das Tagesquartier. Nur vereinzelt wurden auch Jagdgebiete in weiterer Entfernung und bis zu einer Flugdistanz von über 9 km aufgesucht.

Im Mittel befanden sich alle Jagdgebiete der untersuchten Tiere innerhalb einer Distanz von 3250 m zum Tagesquartier. Besteht keine Beschränkung hinsichtlich der Höhenlage in der Umgebung des Quartiers, könnten die Jagdgebiete in kleinerer Distanz zum Tagesquartier erwartet werden. Abbildung 3 zeigt, dass Jagdgebiete um so häufiger genutzt werden, je näher sie beim Tagesquartier liegen. Es kann deshalb angenommen werden, dass auch die Bedeutung von Jagdgebieten für die Grosse Hufeisennase um so grösser ist, je näher diese beim Tagesquartier liegen. Landschaftsveränderungen im zentralen Aufenthaltsgebiet einer Wochenstabenkolonie der Grossen Hufeisennase könnten deshalb fatale Folgen für diese Kolonie haben.

Habitatnutzung im Wald: Die Grossen Hufeisennasen jagten im Frühjahr bevorzugt im Wald beidseits von zwei Flüssen. Auch zu anderen Jahreszeiten wurden Wald- und Waldrandgebiete in Flussnähe genutzt. Dabei spielen Waldränder für die charakteristische Wartenjagd der Grossen Hufeisennasen eine wichtige Rolle. Die Grossen Hufeisennasen bevorzugten Wald- und Waldrandgebiete mit grossem Laubholzanteil. Waldgebiete mit grossem Nadelholzanteil wurden gemieden.

Da die Laubwälder in den meisten bekannten Jagdgebieten der Grossen Hufeisennasen die standortheimischen Waldtypen aufweisen, scheint eine Förderung solcher Waldtypen besonders wichtig.

Habitatnutzung im Offenland: Grosse Hufeisennasen jagen auch über offenen Gebieten, meiden dabei aber Äcker. Gebiete mit grosser Vielfalt an Habitattypen und Lebensraumstrukturen werden bevorzugt. Da die Vielfalt der Lebensräume und die Flussnähe im Untersuchungsgebiet miteinander korreliert sind, kann nicht entschieden werden, ob beide Faktoren oder nur einer kausal bedeutend ist.

Offenlandflächen mit einer grossen Vielfalt an Habitattypen und Lebensraumstrukturen sollten erhalten bleiben und gefördert werden. Zudem sind Wiesen und Weiden, die nicht umgebrochen werden, für die Larvenstadien wichtiger Beutetiere der Grossen Hufeisennasen von existentieller Bedeutung (Beck et al. 1996).

Flugrouten: Grosse Hufeisennasen benutzen teilweise Flugrouten beim Wechsel vom Quartier in die Jagdgebiete. Dabei fliegen die Fledermäuse entlang von Grenzlinien mit vertikalen Lebensraumstrukturen wie beispielsweise Hecken und Waldrändern. Flugrouten werden zum Teil von zahlreichen Grossen Hufeisennasen in kurzer Folge beflogen. Grenzlinien könnten deshalb für die räumliche Orientierung der Grossen Hufeisennasen von Bedeutung sein.

Massnahmen zur Erhaltung und Aufwertung von Jagdgebieten

Für die Umsetzung der Massnahmen zur Erhaltung und Schaffung von Jagdgebieten wurden drei Perimeter unterschieden: I Kernjagdgebiete, II Aktivitätsgebiet um das Wochenstubenquartier und III Verbreitungsgebiet. Die drei Perimeter wurden aufgrund von der beobachteten Aufenthaltsdichten von jagenden Grossen Hufeisennasen und abhängig von der Distanz zu den Quartieren definiert. Die Reihenfolge der Perimeter stellt gleichzeitig die Priorität für deren Umsetzung dar. Die umfassendsten Massnahmen fordern wir für die Kernjagdgebiete, während die

Bedeutung der beiden nachfolgenden Perimeter ab- und ihre Flächen zu- nehmen.

Für andere Kolonien in Mitteleuropa, für die keine genauen Grundlagen zur Verfügung stehen, versuchen wir in einem gesonderten Abschnitt, allgemein gültige Empfehlungen für Massnahmen aus unseren Ergebnissen abzuleiten.

Perimeter I: Kernjagdgebiete (key feeding areas):

Als Kernjagdgebiete werden die Jagdgebiete mit den grössten Aufenthaltsdichten von jagenden Grossen Hufeisennasen bezeichnet.

Wir wählten dazu in unserem Untersuchungsgebiet die 10 % der insgesamt durch die Untersuchungstiere genutzten Fläche mit den höchsten Aufenthaltsdichten (Abb. 4). Sie können als die bedeutendsten Jagdgebiete der untersuchten Grossen Hufeisennasen interpretiert werden. Diese Flächen (Abb. 5), die im untersuchten Fall 1.6 km^2 ausmachen, sollen umfassend geschützt werden.

Der Erhaltung der Qualität dieser Gebiete kommt höchste Dringlichkeit zu. Es sollen nur Veränderungen vorgenommen werden, wenn positive Auswirkungen auf die Grossen Hufeisennasen erwartet werden können.

Für andere Kolonien der Grossen Hufeisennase: Sind die Jagdgebiete einer Kolonie der Grossen Hufeisennase nicht bekannt, schlagen wir vor, Gebiete mit einer der Koloniegrösse angepassten Fläche (2 km^2 für eine Population von 200 Tieren) mit Hilfe der unter Perimeter II aufgeführten Empfehlungen zur Erhaltung und Aufwertung von Jagdgebieten im Wald und im Offenland auszuwählen. Diese Gebiete müssen innerhalb eines Umkreises von 3.5 km (Abb. 5), am besten möglichst nahe beim Wochenstubenquartier, liegen. Zusätzlich sollten in diesem Umkreis potentielle Flugrouten vom Wochenstubenquartier zu den Jagdgebieten erhalten und geschaffen werden (vgl. Perimeter II).

Erhaltung der Kernjagdgebiete:

- Umfassender Schutz als Landschaftsschutzgebiete.
- Erhaltung der Qualität (vgl. Perimeter II) durch Sicherung einer angepassten Bewirtschaftung.
- Sämtlichen Eingriffe mit ungewissen Auswirkungen auf die Grossen Hufeisennasen sollten vermieden werden.
- In angemessenen Pufferzonen um die Kernjagdgebiete sollten keine Landschaftseingriffe vorgenommen werden, die die Kernjagdgebiete beeinträchtigen könnten.
- Der Anteil der umgebrochenen Landwirtschaftsfläche und der Nadelwaldanteil sollten vermindert werden.

Perimeter II: Aktivitätsgebiet um das Wochenstubenquartier

Dieser Perimeter umfasst alle Gebiete, die von den Grossen Hufeisennasen eines Wochenstubenquartieres genutzt werden. Er beinhaltet neben den Kernjagdgebieten auch alle Flächen, die von den Untersuchungstieren gelegentlich bis häufig genutzt wurden (Abb. 6). In unserem Untersuchungsgebiet umfasst er ca. 16 km². Die Gebiete dieses Perimeters sollten in ihrer Qualität nicht verschlechtert, sondern wenn immer möglich, aufgewertet werden. Bei unvermeidbaren Qualitätsverminderungen müssen Ausgleichsmassnahmen getroffen werden. Um eine möglichst grosse Wirkung der Massnahmen zu erreichen, sollten sie mit Priorität in Wochenstubennähe und in Flussnähe durchgeführt werden.

Für andere Kolonien der Grossen Hufeisennase: Liegen keine Angaben zu den Aktivitätsräumen der Grossen Hufeisennasen eines Wochenstubenquartieres vor, kann das Gebiet innerhalb eines Umkreises von 3.5 km um das Wochenstubenquartier als potentielles Aktivitätsgebiet behandelt werden (Abb. 6). Je näher geeignete Jagdgebiete zum Wochenstubenquartier liegen, desto grösser kann ihre Wirkung vermutet werden.

Erhaltung und Aufwertung von Jagdgebieten im Wald

- Standortheimische Laubwaldgesellschaften sowie ein erhöhter Laubholzanteil sollten gefördert werden.
- Bestehende Auenwaldgebiete sollten erhalten und beeinträchtigte Auenwälder revitalisiert werden.
- Die Waldrandlinie sollte durch eine geschwungene Form möglichst lang gehalten oder geschaffen werden.
- Auf Wege, Äcker und Kunstwiesen direkt angrenzend an Waldränder und Hecken sollte verzichtet werden.
- Waldränder und Hecken sollten von einem Dauergrünlandstreifen von mindestens 10 m Breite begleitet sein (Abb. 7).

Erhaltung und Aufwertung von Jagdgebieten im Offenland

- Der Anteil der umgebrochenen Landwirtschaftsfläche sollte reduziert, der Anteil Dauergrünland (nicht umgebrochene Wiesen und Weiden) sollte erhalten und erhöht werden.
- Lebensraumstrukturen wie Hecken, Kleinsthecken, Einzelbäume, Büsche, Obstgärten etc. sollten erhalten bleiben und ergänzt werden. Bei einer unvermeidbaren Beseitigung solcher Elemente muss für gleichwertigen Ersatz gesorgt werden.

Erhaltung und Schaffung von durchgehenden Flugrouten

- Linienförmigen Strukturen, die vom Quartier wegführen, sollten erhalten bleiben. Bei unvermeidbarer Beseitigung muss Ersatz geschaffen werden.
- Grössere Lücken von mehr als 10 m in linearen Strukturen, die als Flugrouten dienen könnten, sollten ergänzt werden. In ausgeräumten Gebieten können durchgehende Hecken als mögliche Flugrouten geschaffen werden.
- Mögliche Flugrouten sollten von Dauergrünlandstreifen von mindestens 10 m Breite begleitet sein.

Verträglichkeitsprüfung:

- Bei grösseren Raumplanungs- und Bauvorhaben ausserhalb der Bauzonen sowie bei grösseren land- und forstwirtschaftlichen Projekten (z.B. Güterzusammenlegungen) sollten die Verträglichkeit dieser Vorhaben mit den Ansprüchen der Grossen Hufeisennasen überprüft und Massnahmen zur Verbesserung der Situation für die Grossen Hufeisennasen einbezogen werden. Für eine Bewertung der Eignung der Landschaft als Jagdgebiete für die Grosse Hufeisennase ist eine Kartierung des Offenlandes mit einer Inventarisierung der Lebensraumstrukturen nötig.

Perimeter III: Verbreitungsgebiet

Dieser Perimeter umfasst das bekannte Verbreitungsgebiet der Grossen Hufeisennase. Er setzt sich aus den Gebieten zusammen, die innerhalb eines Umkreises von 10 km um Quartiere mit Grossen Hufeisennasen liegen sowie aus bekannten Jagdgebieten (Abb. 8). Im Verbreitungsgebiet sollten die Lebensräume für die Grossen Hufeisennasen erhalten bleiben. Eine Berücksichtigung dieser vom Aussterben bedrohten Tierart bei grösseren landschaftsverändernden Projekten ist deshalb angezeigt.

Berücksichtigung bei der Projektbeurteilung:

- Grössere Bauvorhaben und Grossprojekte, die bedeutende Landschaftsveränderungen zur Folge haben können, müssen auf ihre Verträglichkeit mit den Ansprüchen der Grossen Hufeisennase geprüft werden.

Diskussion

Festlegung von Prioritäten

Die Jagdgebiete einer Kolonie der Grossen Hufeisennase müssen in ihrer Ausdehnung und Qualität so beschaffen sein, dass sie während der ganzen Saison ein ausreichendes Nahrungsangebot bereitstellen können.

Solange keine Ergebnisse zu saisonalen Engpässen in der Nahrungsverfügbarkeit vorliegen, muss davon ausgegangen werden, dass alle im Verlaufe der Saison von der Kolonie häufig genutzten Gebiete für sie bedeutend und deshalb zu erhalten sind.

Die selektive Raumnutzung der untersuchten Kolonie zeigt jedoch, dass bei der Umsetzung von Massnahmen räumliche Prioritäten gesetzt werden können. Solche Prioritäten können dazu beitragen, bei Nutzungskonflikten im Lebensraum der Grossen Hufeisennasen das beste Verhältnis zwischen Aufwand und Wirkung von Schutzmassnahmen zu erreichen.

Der Schlüsselfunktion des Wochenstabenquartiers als einzigm Ort der Fortpflanzung einer Kolonie Rechnung tragend und unter Berücksichtigung der abnehmenden Intensität der Raumnutzung mit zunehmender Distanz zum Quartier, schlagen wir folgende Prioritäten vor:

1. In der Umgebung des Wochenstabenquartiers müssen die umfassendsten Massnahmen vollzogen werden. 2. Geeignete Jagdgebiete sollen möglichst nahe bei den Tagesquartieren und in Flussnähe erhalten oder geschaffen werden. Indem wir daraus für drei Perimeter in unterschiedlichem Mass Schutzmassnahmen formulieren, versuchen wir den Anforderungen der Praxis nach konkreten Angaben für die Planungsprozesse entgegenzukommen.

Die Formulierung von konkreten Massnahmen birgt allerdings die Gefahr, dass auch bei kausalen Faktoren mit gradueller Wirkung der Eindruck vom Vorhandensein eines absoluten Grenzwertes vorgetäuscht wird. So muss die Empfehlung eines Dauergrünlandstreifens von 10 m Breite als Vorschlag aufgefasst werden, der auf dem bisherigen Wissen und der Erfahrung aus der Feldarbeit basiert. Je nach räumlichen Voraussetzungen könnte auch ein Streifen von 5 m Breite genügen oder einer von 20 m Breite mehr bewirken.

Weiter muss man sich vor Augen halten, dass die empfohlenen Massnahmen aufgrund einer Fallstudie im Schweizer Vorderrheintal entstanden sind. Erste Ergebnisse von Studien in England (Stebbins 1982, Jones & Morton 1992, Jones et al. 1995, Duvergé, mündl. Mitt.), Deutschland (Geiger et al. 1993) und Norditalien (Scaravelli, mündl.

Mitt.) weisen aber darauf hin, dass die beschriebene Raumnutzung für die Grossen Hufeisennase charakteristisch ist.

Bei der Habitatnutzung zeichnen sich dagegen Unterschiede zwischen diesen Regionen ab, die auch von einem anderen Angebot an Habitat-typen in den betreffenden Untersuchungsgebieten bestimmt werden. Deshalb ist in Regionen mit anderen Lebensräumen eine ausführliche Untersuchung über die Jagdgebiete einer Kolonie die Voraussetzung für eine sichere Festlegung von Kernjagdgebieten.

Aufgrund der hier vorliegenden Vorschläge von Schutzmassnahmen und mit Berücksichtigung von Ergebnissen aus anderen Ländern (Jones & Morton 1992, Jones et al. 1995) können aber bereits ohne Untersuchungen und mit sehr bescheidenem Aufwand Gebiete im näheren Umkreis eines Wochenstubenquartiers ausgeschieden werden, die mit grosser Wahrscheinlichkeit bedeutende Jagdgebiete sind.

Kernjagdgebiete

Für die Abgrenzung der Kernjagdgebiete waren neben biologischen Grundlagen auch Überlegungen der Realisierbarkeit bestimmend. Für die Kernjagdgebiete fordern wir einen absoluten Schutz. Es erschien uns eine vertretbare Forderung mit Chance zur Realisierung, eine Fläche von weniger als 2 km² Fläche in der nächsten Umgebung des Wochenstubenquartiers vollständig zu erhalten. Ob die Erhaltung einer Fläche von diesem Ausmass für den langfristigen Schutz einer Kolonie ausreicht, kann aufgrund der vorliegenden Untersuchung nicht entschieden werden.

Da während der ganzen Saison nur ein Drittel der Fläche im Umkreis von 3.5 km um das Wochenstubenquartier von den Untersuchungstieren beflogen wurde, kann angenommen werden, dass dieser Anteil an geeigneten Lebensräumen in der Umgebung eines Quartiers genügen kann, um eine ausreichende Nahrungsbasis zu bieten. Die Kernjagdgebiete, die nur gut 3 % der Fläche in diesem Umkreis ausmachen, aber einen Grossteil der Jagdaktivität enthalten, sind demnach Gebiete, in denen der beste Schutz mittels einer Beibehaltung der Situation erreicht werden kann. Da wir in den Jagdgebieten keine Zeichen von Territorialität zwischen Grossen Hufeisennasen beobachtet haben, scheint uns ein

solcher Flächenanteil für die Kernjagdgebiete ausreichend. Im übrigen Gebiet können Aufwertungen nach dem Vorbild der Kernjagdgebiete vermutlich Verbesserungen bewirken.

Mitchell-Jones (1995) schlägt im Umkreis eines Wochenstubenquartiers ebenfalls die Errichtung einer speziellen Zone vor, in der mit finanziellen Anreizen geeignete Habitattypen gefördert werden. Diese Zone entspricht etwa unserem Perimeter „Aktivitätsgebiet um das Wochenstabenquartier“. Bei der Eingrenzung der relevanten Fläche stützt er sich auf die Angaben von Stebbings (1982) und Jones & Morton (1992), die einen Aktivitätsradius von etwa 3 km um das Tagesquartier beschreiben. Jones et al. (1995) schätzen den für die Jagd bedeutenden Umkreis auf 3-4 km um ein Wochenstabenquartier. Die von Mitchell-Jones (1995) vorgeschlagenen key feeding areas innerhalb dieses Umkreises entsprechen unseren Kernjagdgebieten. Diese wichtigsten Nahrungsgebiete, die nach seinem Vorschlag ausschliesslich aufgrund der Habitattypen ausgewählt werden, sollen einem umfassenden Schutz unterstellt werden. Für das übrige Gebiet schlägt Mitchell-Jones vor, mit Direktzahlungen eine für die Grossen Hufeisennasen günstige Bewirtschaftung der Landschaft zu erreichen. Dieses Vorgehen stimmt mit unseren Vorschlägen überein.

Noch unklar ist die Bewertung der jeweiligen Umgebung der übrigen Tagesquartiere. Während Mitchell-Jones (1995) und Ransome (1968) vorschlagen, im Idealfall in der Umgebung aller Quartiere Schutzmassnahmen durchzuführen, haben wir uns aufgrund der grossen Zahl an Tagesquartieren für die aktive Umsetzung von Schutz- und Förderungsmassnahmen auf das Wochenstabenquartier beschränkt. Bei den übrigen Tagesquartieren müssen aber im Falle von Grossprojekten mindestens die Auswirkungen auf die Grossen Hufeisennasen möglichst klein gehalten werden. Es wäre wünschenswert, wenn mindestens Tagesquartiere, die von einer grösseren Zahl von Grossen Hufeisennasen aufgesucht werden, ähnlich wie Wochenstabenquartiere behandelt werden könnten.

Zur Problematik der Bereitstellung oder Wiedereröffnung von verschlossenen, ehemaligen Wochenstabenquartieren kann gesagt werden, dass die Eignung eines Quartiers als Wochenstabenquartier von seiner unmittelbaren Nähe zu grossflächigen, günstigen Jagdgebieten abhängt.

Landschaft und Quartiere

Obwohl nur in wenigen Fällen eine direkte Quartierzerstörung als Ursache des Rückgangs oder der Auslöschung einer Kolonie der Grossen Hufeisennase nachgewiesen ist, sind bisher hauptsächlich Quartierschutzmassnahmen für die Grosse Hufeisennase durchgeführt worden.

Die Ansprüche der Grossen Hufeisennasen beschränken sich jedoch nicht auf die Quartiere, sondern beziehen sich auch auf die Landschaft in deren Umgebung.

Neben den mikroklimatischen Ansprüchen, die ein Quartier erfüllen muss (Ransome 1968, 1990), muss die nähere Umgebung genügend grosse Gebiete mit geeigneten Lebensräumen aufweisen. Eine Population ist durch die Quartiertradition eng mit dem benützten Wochenstubenquartier verknüpft. Eine Wochenstubenkolonie kann deshalb nur erhalten werden, wenn gleichzeitig die mikroklimatischen Anforderungen an das Wochenstubenquartier und die Ansprüche an die direkt umgebende Landschaft erfüllt sind.

Aufgrund unserer Untersuchung konkretisieren wir die Ansprüche der Grossen Hufeisennase an ihre Jagdgebiete, indem wir geeignete Habitat-typen, Lebensraumstrukturen und den Flächenbedarf angeben.

Mit diesen Angaben und den daraus abgeleiteten Vorschlägen von Massnahmen zur Erhaltung und Schaffung von Jagdgebieten für die Grosse Hufeisennase bestehen nun Grundlagen, mit deren Hilfe die Landschaft in der Umgebung einer Kolonie analysiert und Massnahmen zur Erhaltung und Aufwertung der Jagdgebiete ergriffen werden können.

Biotop- und Artenschutz

Eine zentrale Diskussion bei der Umsetzung von Schutzmassnahmen in der Landschaft betrifft die Frage, ob spezifische Massnahmen für die Erhaltung und Förderung einer Art, sogenannte Artenschutzmassnahmen, für die einzelnen Fledermausarten nötig sind, oder ob dieses Ziel mit reinen Biotopschutzmassnahmen erreicht werden kann.

Für die Grossen Hufeisennasen sind Laubwälder, Dauerwiesen und Weiden Lebensräume von grosser Bedeutung. Sie brauchen zudem in

der unmittelbaren Umgebung des Wochenstubenquartiers eine vielfältige Landschaft, in welcher sich Auen- und andere Laubwälder, blumenreiche Wiesen, Weiden und natürliche Kiesflächen mosaikähnlich verzahnen und Hecken, Gebüsche, Baumgruppen sowie Einzelbäume die offene Fläche bereichern. Die Erhaltung einiger dieser Lebensräume ist heute bereits der Inhalt von Biotopschutzbemühungen. Darüber hinaus müssen jedoch spezifisch für die Grosse Hufeisennase die folgenden Anforderungen mitberücksichtigt werden: 1. Geeignete Lebensräume müssen über 30 % der Fläche im Umkreis von 3.5 km um das Wochenstubenquartier ausmachen. 2. Diese Gebiete müssen kleinräumig eine hohe Diversität an Habitattypen und dadurch einen grossen Anteil an Grenzflächen aufweisen.

Für die Grosse Hufeisennase wie vermutlich auch für andere Fledermausarten muss also neben den Artenschutzmassnahmen für die Quartiere auch die Berücksichtigung der artspezifischen Ansprüche an den Lebensraum gefordert werden: In der näheren Umgebung der Quartiere muss mit einer Häufung von Biotopschutzmassnahmen ein Flächenanteil an geeigneten Habitattypen erreicht werden, der den hohen Ansprüchen der Art entspricht.

Für das längerfristige Bestehen einer ganzen Population, die ein gemeinsames Wochenstubenquartier benutzt, müssen vermutlich Gebiete von 1'000 km² oder mehr mit einem hohen Anteil an naturnaher Fläche vorhanden sein (Stebbins & Arnold 1987). Wenn im noch verbliebenen Verbreitungsgebiet der Grossen Hufeisennase wichtige Lebensräume zerstört werden, muss mindestens im gleichen Raum Ersatz geschaffen werden.

Wirkungskontrolle

Dass die vorgeschlagenen Massnahmen zur Erhaltung und Aufwertung von Jagdgebieten die gewünschte Wirkung auf die Grossen Hufeisennasen haben, ist vorläufig als Hypothese aufzufassen. Sobald feststeht, dass Massnahmen in Gebieten realisiert werden, ist eine Kontrolle der Wirkung dieser Massnahmen anzustreben. Da eine Wirkung voraussichtlich erst nach längerer Zeit erwartet werden kann, muss sich eine Kontrolle über einen entsprechenden Zeitraum erstrecken.

Die vorgeschlagenen konkreten Massnahmen sollen nicht zuletzt auch Grundlage für kritische Diskussionen sein, um in Zukunft Verbesserungen des Lebensraumes für bedrohte Fledermausarten zu erreichen.

Danksagung

Für die finanzielle Unterstützung danken wir der Schweizerischen Koordinationsstelle für Fledermausschutz, dem Bundesamt für Umwelt, Wald und Landschaft BUWAL, der Dr. Bertold Suhner Stiftung für Natur-, Tier- und Landschaftsschutz, dem Zürcher Tierschutz, dem Amt für Landschaftspflege und Naturschutz Graubünden, dem Bündner Naturschutzbund, der E. Rentschler-Stiftung für Tierschutz sowie der G. und A. Claraz-Schenkung.



Abb. 1: Im Dachstock dieser Kirche befindet sich das letzte grosse Wochenstubenquartier der Grossen Hufeisennase in der Schweiz. - The last large nursery roost of the greater horseshoe bat in Switzerland is situated in the attic of this church. - Le dernier grand gîte de reproduction des grands rhinolophs en Suisse se trouve dans le grenier de cet'église.



Abb. 2: Jagdgebiet in der Umgebung des Wochenstubenquartier im Vorderrheintal. - Feeding areas near of the nursery roost in the Rhine

river valley (Vorder Rhein). - Terrain de chasse près du gîte de reproduction en Vallée du Rhin antérieur.

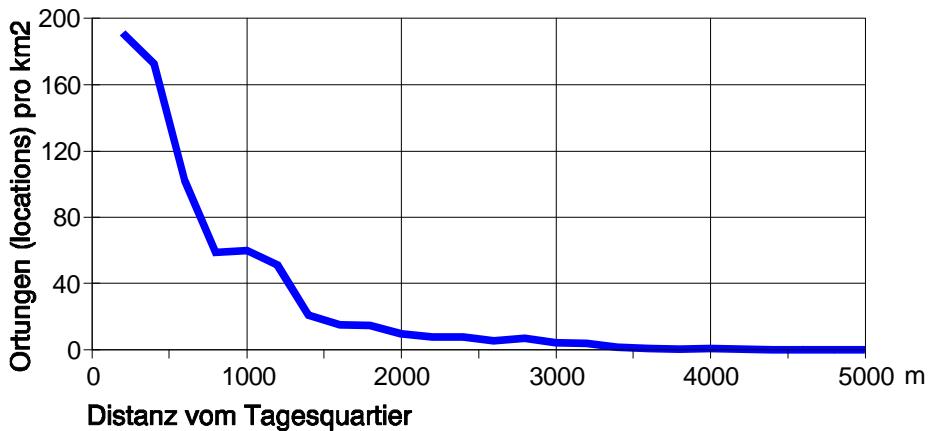


Abb. 3: Aufenthaltsdichte von jagenden Grossen Hufeisennasen in Abhängigkeit von der Distanz zum Tagesquartier ($n=1322$ Ortungspunkte von 24 Grossen Hufeisennasen). Bereits nach 1720 m ist die Aufenthaltsdichte kleiner als 10% des Maximalwertes. - Density of hunting greater horseshoe bats as a function of the distance to the roost ($n = 1322$ locations of 24 greater horseshoe bats). Already after 1720 m the density is less than 10 percent of the maximum value. - Densité de grands rhinolophes chassants en fonction de la distance du gîte ($n = 1322$ points de localisation de 24 grands rhinolophes). Après 1720 m déjà, la densité est inférieure à 10 pour-cent de la valeur maximale.

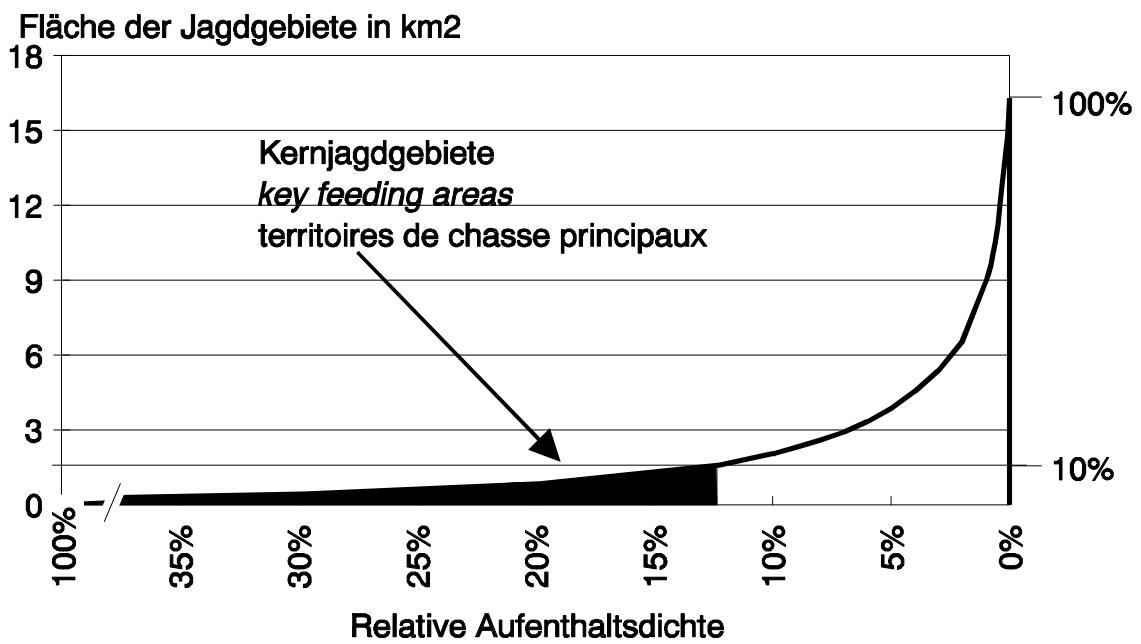


Abb. 4: Als Kernjagdgebiete werden die 10 % der Fläche mit der grössten Aufenthaltsdichte von jagenden Grossen Hufeisennasen definiert. Der Bereich der Kernjagdgebiete ist in der Abbildung schwarz eingefärbt. Er umfasst im untersuchten Fall alle Gebiete mit einer relativen Dichte >12% der maximal beobachteten Aufenthaltsdichte und entspricht einer Fläche von 1.6 km². - As key feeding areas are regarded those 10 percent of area with the highest density of hunting greater horseshoe bats. The key feeding areas are inked black in the figure. In the present case they cover all areas with a relative density of more than 12 percent of the maximum density observed and correspond to a surface of 1.6 km². - Comme terrains de chasse principaux sont considérés les 10 pour-cent de la surface avec la plus grande densité de grands rhinolophes chassants. La zone des terrains de chasse principaux est marquée en couleur noire dans l'illustration. Dans le présent cas, elle embrasse tous les terrains avec une densité relative supérieure à 12 pour-cent de la densité maximale observée et correspond à une surface de 1,6 km².

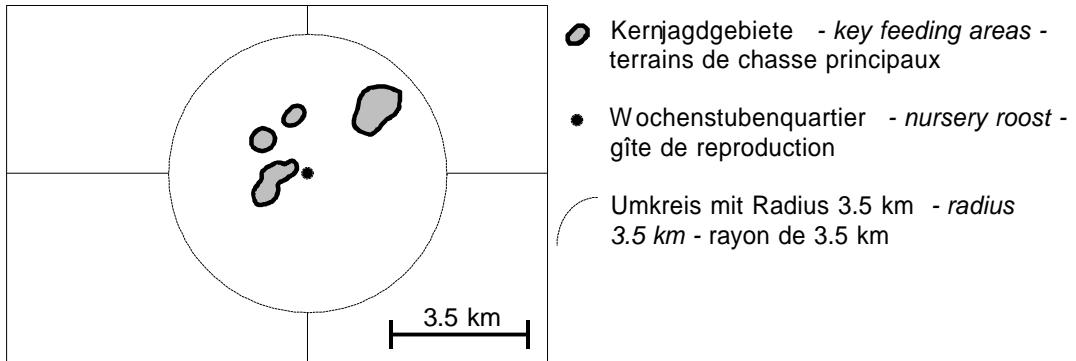


Abb. 5: Perimeter I: Kernjagdgebiete. - Perimeter I: key feeding areas. - Périmètre I: terrains de chasse principaux.

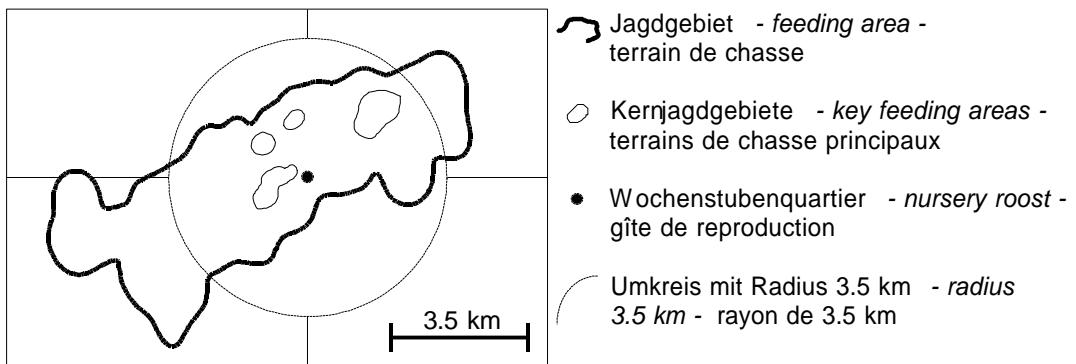


Abb. 6: Perimeter II: Aktivitätsgebiet um das Wochenstubenquartier. Die Kreisfläche kann als vereinfachtes Aktivitätsgebiet von Tieren aus dem Wochenstubenquartier verwendet werden. Die kleinen Flächen sind die Kernjagdgebiete, die bereits im Perimeter I erfasst sind. - Perimeter II: Activity area around the nursery roost. The circular area may be used as simplified activity area of the nursery colony. The small surfaces are the key feeding areas already outlined in the perimeter I. - Périmètre II: terrain d'activité autour du gîte de reproduction. La surface circulaire se laisse utiliser comme terrain d'activité simplifié de la colonie de reproduction. Les petites surfaces représentent les terrains de chasse principaux déjà enregistrés en périmètre I.

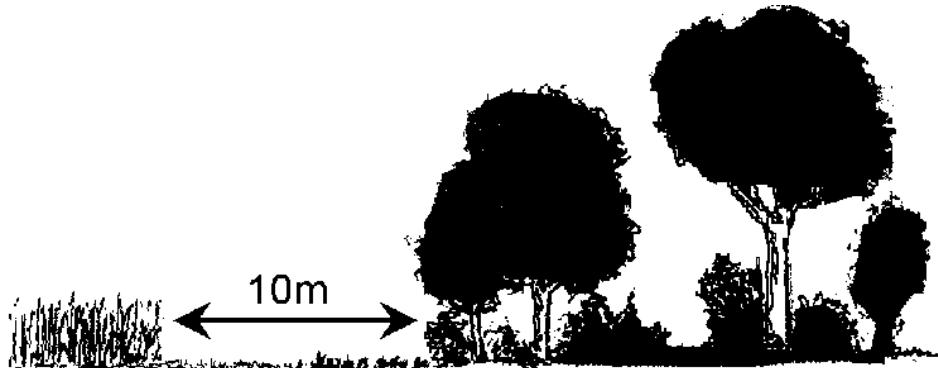


Abb. 7: Ein Streifen von mindestens 10 m Dauergrünland (nicht umgebrochene Wiesen und Weiden) entlang von Waldrändern und Hecken soll das Nahrungsangebot vergrössern und Wartenjagd ermöglichen. - A strip of at least 10 m permanent grassland (pastures and unploughed meadows) along hedges and the outskirts of woods ought to increase the range of food while also making perch hunting possible. - Une bande d'herbage permanent d'au moins 10 m (pâturages et prés non labourés) le long de haies et de lisières de forêt doit augmenter la gamme de nourriture et permettre la chasse à partir d'une perchoir.

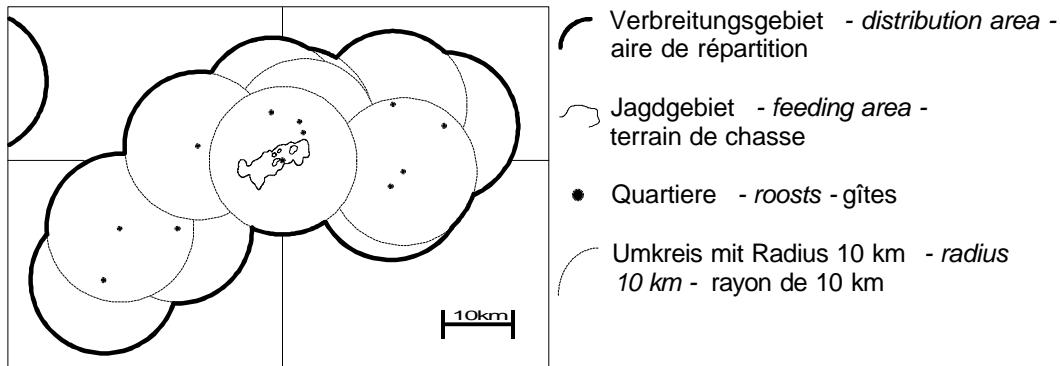


Abb. 8: Perimeter III: Verbreitungsgebiet. Er setzt sich aus den Gebieten zusammen, die innerhalb eines Radius von 10 km um Quartiere mit Grossen Hufeisennasen liegen sowie aus eventuellen Nachweisen aus Jagdgebieten. - Perimeter III: distribution area. It covers all those areas within a radius of 10 km around the roosts of greater horseshoe bats, supported by evidence from feeding areas. - Périmètre III: L'aire de répartition. Ce périmètre renferme les terrains qui se trouvent dans un rayon de 10 km autour des gîtes de grands rhinolophes ainsi que l'évidence provenant des terrains de chasse.

Radio-tracking bats: a short review with examples of a study in Italy

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Abstract

Chances and limits of radio-telemetry of European bat species are presented based on a telemetry study about *Rhinolophus ferrumequinum* in Italy. As prerequisites for the use of radio-tracking, study objectives and research design, weight and attachment of transmitter and radio-tracking equipment are discussed. Literature and examples from the field study are given concerning activity, selection of roosts, foraging areas, habitat use and behavioural observations. A list of references and some web resources should help to find further information.

Introduction

Bats forage in the dark and often move very fast. Therefore we need a special technique to study their nightly activity. Radio-tagging, the marking of bats with a small radio transmitter, is one of the unique tools to study moving and activity patterns of individual bats (Wilkinson & Bradbury 1988). This method provides information of the bats' behavioural ecology and it contributes to the knowledge needed for the conservation of endangered bat species.

The aim of this paper is to present chances and limits of radio-telemetry of European bat species based on studies recently carried out and by this means to provide some of the most important references on the topic. In addition we try to give some useful recommendations for beginners.

To illustrate the application of telemetry, we present some results of a study about *Rhinolophus ferrumequinum* in the Romagna region (paragraphs in *italics*), which is one of the first radio-tracking studies on a bat species in Italy.

The greater horseshoe bat

Originally the greater horseshoe bat *Rhinolophus ferrumequinum* (Schreber, 1774) was a Mediterranean species, but it was able to expand its distribution area to the north because it had the ability of using human buildings for reproduction. Only 50 years ago this species was widely spread and known to be common in Central Europe. Since then the populations of the greater horseshoe bat have experienced a dramatic decline. Today it is thought to be one of the most endangered bat species in Central Europe (Stebbins 1988). Pesticides, the changes of the landscape, and the loss of roosts are supposed to be the most important reasons for their decline (Ransome 1990, Stebbings & Arnold 1989, Roer 1983-84). Habitat use of *Rhinolophus ferrumequinum* has been studied in different landscapes of Europe (Stebbins 1982, Jones & Morton 1992, Duverg   & Jones 1995, Geiger 1996, Pir 1994, Bontadina et al. 1995, 1997).

We chose a colony in the Mediterranean region of Romagna in northern Italy to study habitat use of this species in its original distribution area. In this area the greater horseshoe bat is the most often observed bat species in caves apart from *Myotis myotis/blythii* and *Miniopterus schreibersi* (Gellini et al. 1992, Scaravelli unpubl.).

Study area and methods

The Romagna region is located in northern Italy and it has its biogeographical boundaries along the northern Apennine ridge, the Adriatic sea and the beds of the rivers Santerno and Reno, covering an area of about 1000 km². Half of it is a plain with mainly intensively cultivated orchards, the other part belongs to the Apennin mountains. More than 40 sites of the greater horseshoe bat are known in this area, most of them are winter roosts in caves. Usually only a few and never more than some dozens of individuals are found in the roosts (Bassi & Fabbri 1984, Gellini et al. 1992, Scaravelli & Bassi 1993, Scaravelli unpubl.).

The starting point of our investigation was a nursery roost, situated on the first floor of an old unoccupied villa and a roost in a nearby artificial cave system of an old fortification. These roosts are situated in the village of Terra del Sole (UTM-GRID reference T32 QP39), a typical Renaissance place, situated in a hilly area (50 to 300m a.s.l) near the Apennin Mountains. The colony has 40 adult individuals and has been known for several years.

We mist-netted greater horseshoe bats on flightpaths outside of the roost of Terra del Sole and radio-tracked 9 females and one male in May 1994 during their first foraging bout.

Prerequisites for the use of radio-tracking

Radio-tracking opens a lot of possibilities, but also has its limitations. We would like to address some points which have to be considered when radio-tracking is being used. These points are not only important for the animal safety but also for the quality of your data.

1. Transmitter weight

The weight of the transmitter is one important limitation when working with small flying animals such as bats. A rough rule says that a transmitter should not be heavier than 5% of the bat's body weight (Aldridge & Brigham 1988, Caccamise & Hedin 1985). In exceptional circumstances and for short time studies transmitters of up to 10% of body mass were used before, but a surplus weight of this range influences the flight performance of the bat, and reduces its manoeuvrability (Aldridge 1985-86). Hickey & Brian (1992) showed that the studied bat species reduced catching success as a consequence of the transmitter load.

Before starting to put the transmitters on the bats, you have to be sure that the size, the shape and the weight of the transmitter influences the behaviour of the animal as little as possible. And of course the cumulative mass of transmitter, glue and wing bands has to be considered.

In Romagna we caught 23 greater horseshoe bats. Their weight differed between 16 and 25 g (mean 18.8 +- 2.6 g). The heaviest individuals were clearly pregnant females, so we didn't load another extra weight on these bats. We chose 10 of the other bats with an average weight of 20.0 g. The used transmitters (Holohil model BD-2B) with position sensing, which were specially designed for this species (long and narrow) have a total weight of 1,1 g inclusive glue for attachment. Therefore the extra weight of the transmitters ranged between 4.4 and 6.1% of the studied animals' body weight.

2. Transmitter attachment

You have to decide how the transmitter should be fixed to the animal. It can be glued to the back or fixed with a collar. On different species it has to be fixed differently.

If you decide to glue the transmitter to the back of the bat, the use of a medical glue or an eyelash glue is recommended. Unlike cyanoacrylate instant-glue they stay elastic and are not poisonous. Usually the transmitter is scraped off by the bat after some days.

Collars can be made of different materials (plastic or silicon) and may be delivered by the provider if ordered. When using collars, they need to have a point of fracture where they wear out and fall off after a certain time. This problem may be solved by a small piece of strong paper placed in-between the collar (see figure in Fuhrman & Seitz 1992).

In our study we fixed the transmitters with SkinBond to the back (for an instruction see the web-page from Holohil, appendix I). Former tests with a caged animal have shown that the use of collars on greater horseshoe bats is not possible because of their special hunting technique (perch hunting, see chapter “5. behavioural studies”).

The transmitters dropped off after 2 to 11 days (median 4.5 days, n=10). In comparison to our experiences of studies in Central Europe this is short, probably induced by the higher roost temperature.

3. Radio-tracking equipment

There are a lot of different providers who sell radio tracking material and who are specialised on different types of material. To find out which provider sells the best material for the species you plan to work with, it is worth talking with people who already work with the same or similar species. Profit of other people's experience! In appendix I we list some www addresses, where you can get helpful information.

4. Objectives and study design

Radio-tracking opens a wide field of topics and questions you can work on (Amlaner & Macdonald 1980, Wilkinson & Bradbury 1988, Priede & Swift 1992)). However, for every question you want to answer, you have to collect different data. So it is necessary to plan your study as well as possible, to ask yourself what exactly you want to know and which data you need to answer your question, or to test your hypothesis. How to collect data is defined by the bat species. So it is possible for more sedentary species to locate them by one person with the “homing-in” method (used e.g. by Arlettaz 1996). Other species, which are foraging

by aerial hawking in big areas have to be located by crosstriangulation (e.g. Bontadina et al. 1995), for general information about the data sampling methods see White & Garrott (1990). It is important to plan all this before you start working in the field.

You always study individuals when radio-tracking and you need to have in mind that you can get data only from a few animals. On the other hand, very often you can collect a large amount of information from the few individuals tracked. This has statistical implications: if you like to draw conclusions about a population of bats and not only to describe the behaviour of the studied individuals, you need to study at least 6 to 8 animals of the same age, class or sex, and it would be even better to track ten or more animals just to be on the safe side (basic conditions for application of statistical tests, see e.g. Sokal 1981). This means a lot of work has to be done to get enough data. In fact, radio-tracking is a very time consuming method. Moreover it is a high-tech method, and you need quite expensive equipment such as transmitters, receivers and antennas.

After you have collected the data, the big job to analyse them will start. Today there is a great amount of techniques, software and statistical methods available for the sampling and the analysis of radio-tracking data. It would exceed the possibilities of this short review to present all of it. So we only refer to some extending literature (Wilkinson & Bradbury 1988, Harris et al. 1990, White & Garrott 1990, Worton 1989, Aebischer et al. 1993, for software see the references about web pages in appendix I).

Radio-tracking in behavioural ecology studies of bats

1. activity

In difference to e.g. emergency counts at a roost, where you get an impression of the activity pattern of the whole colony, with radio-tracking you get the activity pattern of an individual bat. You can find out when the tracked bat leaves its roost, when it hunts or moves to another place, when and how long it rests or sleeps and when it returns

to its roost. Most of the time it is possible to tell whether a tracked bat is moving or not because the transmitter signal changes its loudness as soon as the bat moves.

Determination of the activity by radio-tracking was used in *Nyctalus noctula* by Kronwitter (1988), in *Rhinolophus ferrumequinum* by Jones & Morton (1992), in *Plecotus auritus* by Fuhrmann & Seitz (1992), in *Eptesicus nilsonii* by De Jong (1994). A study on activity with implications for conservation are described in Jones et al. (1995).

We observed the male greater horseshoe bat M1 during the whole night of the 13th May 1994. It showed two phases of activity. The first foraging bout was from 20:45 until 21:50 (duration 55min), then the male returned for night roosting and started again at 3:57 until 5:15 for 78 minutes.

Out of 7 animals we could observe the duration of the first foraging bout 9 times. The time of leaving the roost is very similar, but the length of the first bout has a great variance (median duration 98 minutes, range between 42 and 305 minutes, n=9, Fig. 1). The data seems to show an increase of the foraging duration in May, maybe because the time of parturition approaches.

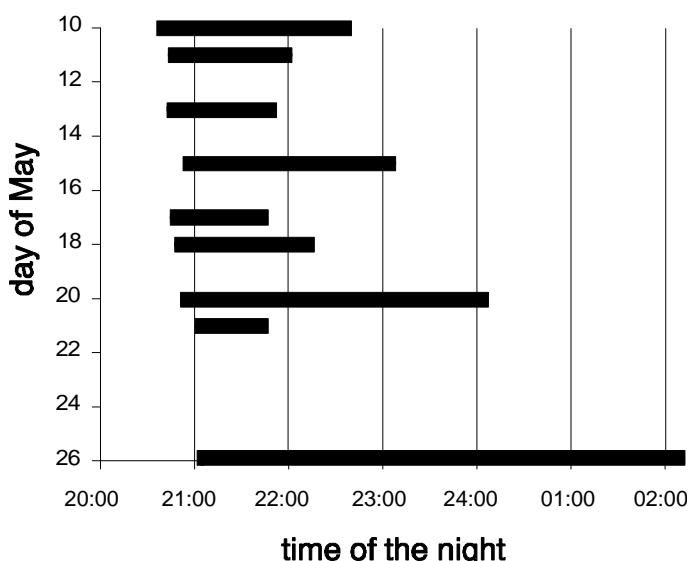


Fig. 1: Foraging activity of 9 Greater horseshoe bats in Romagna during their first foraging bout.

2. Selection of roosts

Usually roosts of bats are found by checking a certain type of building or cave. This method gives a biased picture of bat roosts, because you only look in certain places, where you think it could be possible to find bats and you can only find the most obvious roosts.

The only unbiased way to find roosts is to radio-track bats and to find every roost during a longer period. To be sure to have an unbiased data set of roosts, you really need to have every roost for a certain time and not only the ones that can be found easily; this sometimes is a very time consuming challenge. Knowledge about the roost of a colony, especially of nursery colonies, can be crucial to implementing conservation measures.

Until now roost selection in European bat species has been investigated systematically by radio-tracking only in a few studies. Kronwitter (1988) and Bontadina & Gloor (1994) studied tree roost use in *Nyctalus noctula*, Fuhrmann & Seitz (1992) in *Plecotus auritus*. Geiger (1996) and Beck & Schelbert (in press) used radio-tracking to locate the nursery colonies of relict populations of *Rhinolophus ferrumequinum*.

In Romagna we controlled the use of roosts of the 10 studied animals during 47 animal-days. They only used a few different roosts.

During the 47 animal-days 5 dayroosts (3 in houses, one in an underground place and one in an unknown place) and 3 exclusive nightroosts (two in churches, one in an unoccupied house) were used. Two of the dayroosts were found to be used as nightroosts as well. Two animals disappeared and we could not find them any more, neither at day nor at night, although we searched an area of more than 500 km². Two animals changed to other dayroosts, 1 km and 11 km away. One of them proved to be a new nursery roost. Three months later the marked bat was re-found in that place in a group of 65 adult and juvenile greater horseshoe bats.

bat code	observed days	# of day-roosts	# of night-roosts	cause for end of observation
M1	11	2	2	transmitter loss
F7	10	2	1	transmitter loss
F3	4	1	?	transmitter loss
F5	6	2	2	transmitter loss
F17	3	2	?	transmitter loss
F11	1	1	1	bat disappeared
F13	4	2	?	transmitter loss
F23	3	1	?	transmitter loss
F27	3	1	?	transmitter loss
F15	2	1	?	bat disappeared
total 10 animals	total 47 day-roosts	total 5 different day-roosts	total 3 exklusiv night-roosts	

Tab. 1: Use of day roost by 10 greater horseshoe bats in Romagna. The bats only used one to three different roosts in the study period of May.

3. Flight paths and foraging areas

The technique how to take fixes of flying bats depends on the species specific behaviour. If the animal forages at patches for a longer time, it is possible to reveal the animal's place by taking two or more successive bearings from different vantage points ("homing in"). If an animal moves fast and for longer distances, two mobile people or some fixed aerial-towers are needed to track synchronically. Cross-triangulation means that the location of the animal is where the two ore more bearings cross (for the methods see White & Garrott (1990), Wilkinson & Bradbury (1988)).

Commuting time of bats is usually short and they then fly very fast, therefore it is nearly impossible to estimate accurately flight paths with radio-tracking. Often it is necessary to wait near an expected flightpath and to check with the receiver whether the bat is passing (e.g. Rieger et al. 1990). Some bat species commute every night up to 26 km to their

foraging areas (*Myotis myotis*, Audet (1990), Arlettaz (1996), Güttinger 1997).

On the other hand there are bat species, that stay in small foraging areas nearby after leaving their roost (e.g. De Jong (1994), Flückiger & Beck (1995), Fuhrmann & Seitz (1992)), whereas others forage on the wing in much greater areas (Kronwitter (1988), Sierro & Arlettaz (1997)).

Examples of the spatial use of bats revealed by radio-tracking you can find in every field-study quoted in the references. Duvergé & Jones (1995) and Bontadina et al. (1997), as for example, derive from these field studies implication in the conservation of foraging areas.

We worked with the method of cross-triangulation because of the rapid movement of our studied greater horseshoe bats in Romagna. The area was quite selectively used by the bats. After leaving the roost they used flightpaths in different directions. Often the river was used as a flight path. All the animals we observed foraging on the plain passed along the river. They did not use small areas for foraging, but often changed continuously to a larger area. Only while perch-hunting from twigs (see „5. Behavioural studies“), they stayed at the same place for a longer time.

Although they sometimes crossed the nearby hills, they usually stayed in the valley of the day-roost for most of the observed nights. The maximum distance from the day-roost for foraging was 5.5 km, while most of the time they stayed at a distance of 1500 m to 4000 m apart from the day roost. This gives an implication in the protection of foraging areas. The most important area for protection lies within about 4 km around a colony.

There was no correlation between the observed utilisation density and the distance to the roost. This means that the bat foraged with the same frequency at any possible distance apart from the roost.

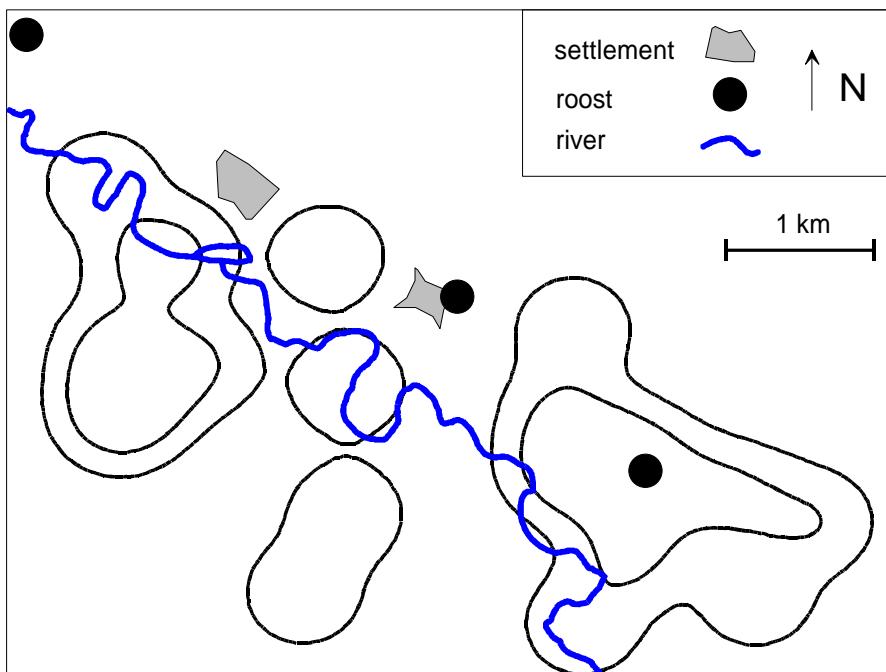


Fig. 2: Foraging area of male M1. The lines show the 90% and 50% kernel density estimation contour lines (computed from n=26 locations). They contain 90% and 50% of the estimated foraging areas, respectively.

4. Habitat use

The determination of habitat types is a key feature to describe association with vegetation or structures and to test hypotheses about niche separation between species. Data collection of habitat use with radio-tracking is normally based on the assumption that the duration of association is correlated with the relative importance of that habitat type (White & Garrott 1990). Habitat analyses give argument and priorities for conservation and land use management recommendations. All of the cited references to field studies about European bat species give information about habitat use.

The studied greater horseshoe bats foraged in different landscapes surrounding the day roosts. Their foraging areas were not restricted to the valley-ground, but they hardly crossed the hills and sometimes foraged in

bushes at higher altitude. All areas, where the bats could be observed for a longer time, were near the rivers at the ground of the valley. The most important foraging areas lied within 50m to the water, although we did not observe them foraging over the open water.

The vegetation in the plain along the rivers, bushes and small trees, seemed to be suitable foraging areas. In the plain one animal also used intensively cultivated orchards for perch hunting. We could never observe greater horseshoe bats foraging in open areas.

5. Behavioural studies

Different methods like nightvision devices, light tags, infrared video equipment are used to study bat behaviour in the roost or in their foraging habitat. An overview is given in Barclay & Bell (1988). Marking the transmitter with a reflecting tape, makes it is easy to find the radio-tagged animal in a group or while it forages by using a torch or an infrared lamp.

Audet (1990), Arlettaz (1996) and Güttinger (1997) describe foraging behaviour in *Myotis myotis* and *M. blythii*, Bontadina et al. (1997), Geiger (1996) in *Rhinolophus ferrumequinum*. Catto et al. (1996) and Robinson & Stebbings (1997) give information for *Eptesicus serotinus*, Kronwitter (1988) in *Nyctalus noctula*, Rieger et al. (1990, 1992) in *Myotis daubentonii*, Sierro & Arlettaz (1997) in *Barbastella barbastellus*.

We could observe two foraging strategies of the radio-tracked greater horseshoe bats. They foraged in flight (aerial hawking) and by perch hunting. When perch hunting, the greater horseshoe bat hangs on a twig of a tree or a shrub, between 0.5 and 6m above ground (n=5 perches found) and waits for insects that fly by. The bat constantly turns around its body to both sides. If an insect passes by, the bat leaves its perch for a few seconds, tries to catch the insect and returns to the perch to eat the prey or to continue to turn around and to look for prey. Most of the perch hunting time, the bat is hanging on the twig. The maximum perch hunting period we observed lasted 3 h 10 min, the maximum time we observed it hunting at the same perch was 52 min.

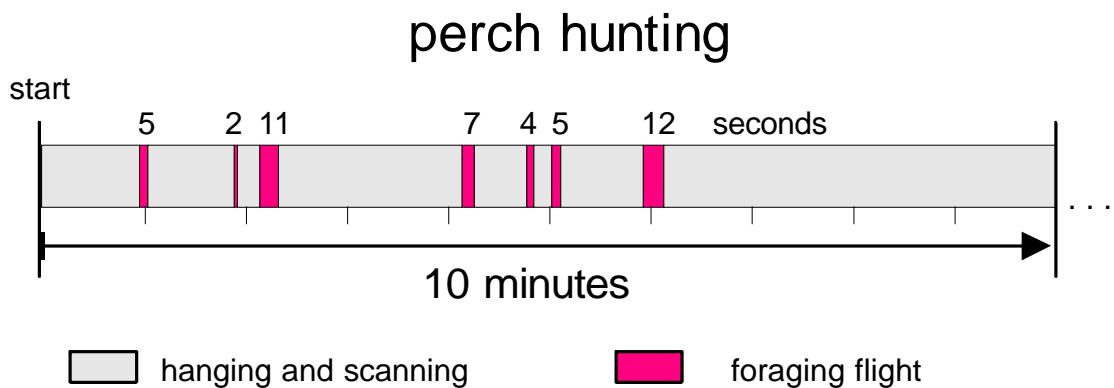


Fig. 3: A part of one perch hunting sequence of female F27 on 26th May 1994. Starting at 23:38, the whole sequence ended at 0:01, because of an interference with another greater horseshoe bat.

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Appendix I

Some useful www addresses:

(an online version of these links you find on www.swild.ch/telemetry)

Wildlife telemetry and software

- Wildlife Ecology Software Server from Illinois Natural History Survey: <http://detritus.inhs.uiuc.edu/www>
- References for data processing and analysis software:
<http://www.uni-sb.de/phifak/fb6/fr66/tpw/telem/dataproc.htm>

Radio-tracking equipment

- Directory of biotelemetry equipment manufacturers:
<http://www.biotelem.org/manufact.htm>
- BioTrack: <http://www.biotrack.co.uk>
- Holohil transmitters: <http://www.holohil.com>
instruction for transmitter attachment:
<http://www.holohil.com/bd2att.htm>
- Titley Electronics
<http://www.nor.com.au/business/titley/index.html>

Mailing lists

- Biotelemetry mailing list:
<http://www.bgu.ac.il/life/bouskila/telemetry.html>
- Batline. Discussion group on bat research and education. Send an email to: esquire@basicallybats.org with body of the message:
subscribe batline yourfirstname yourlastname

Radio-tracking reveals that lesser horseshoe bats forage in woodland

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Abstract

Over the past fifty years European populations of the lesser horseshoe bat, *Rhinolophus hipposideros*, have severely declined, probably due to the loss of foraging habitat.

To date studies of the foraging behaviour of this species have been limited as its low mass (4.8 g) precluded the use of radio-telemetry because commercially available radio-transmitters exceeded 10 % of its body mass. In this study we built radio-transmitters weighing less than 0.35 g. These increased the body mass of the animals from 4.5 to 8.1 %, with no demonstrable adverse effect on their flight behaviour. The habitat selection of eight female lesser horseshoe bats was studied in Monmouthshire, UK.

The bats had foraging ranges between 12 – 53 ha (100 % kernel). Although one bat foraged 4.2 km from the roost, for 50 % of the time tracked bats were recorded within 600 m of the nursery roost. The estimated density within 200 m of the roost was 5.8 foraging bats / ha. This decreased to 0.01 at 1200 m. Compositional analysis revealed that this species used woodlands, predominately broadleaf, more than any other habitat. In addition, the bats foraged in areas of high habitat diversity. Conservation management of this species should concentrate on such areas within 2.5 km of the nursery roost.

Introduction

The lesser horseshoe bat, *Rhinolophus hipposideros*, is one of the most endangered European bat species (Stebbins, 1988). Once it was widespread and common in most countries of Western and Central Europe, e.g. the Netherlands (Voûte, Sluiter & van Heerdt, 1980), South Poland (Kokurewicz, 1990), Germany (Rudolph, 1990) and Switzerland (Stutz & Haffner, 1984). A dramatic population decline occurred in the 1950s and 1960s, which led to the loss of large areas of its former distribution.

A number of causes for this decline have been suggested; roost destruction, pesticide contamination of prey and roosts, habitat alterations and competition with other bat species (overview in Stebbings, 1988; Kulzer, 1995; Arlettaz, Godat & Meyer 2000). However, it is believed that habitat destruction and the effects of pesticides are the main causes of the population decline (Bontadina et al., 2000).

In order to plan and implement adequate protection measures for this species, a basic knowledge of its habitat selection is required. To date several attempts have been made to study habitat use in lesser horseshoe bats either using ultrasound detectors or by light tagging animals (McAney & Fairley, 1988; Schofield, 1996). However, the very weak and highly directional echolocation calls of this bat make it difficult to detect in the field. In addition, light tagged animals quickly disappear into dense vegetation making them hard to follow. Consequently, data collected by these methods has been limited.

Since the 1980s radio-tracking has developed as one of the main techniques for studying many aspects of bat ecology (Kenward, 1992; see overview in Bontadina et al., 1999). However, the small body mass of many species, including the lesser horseshoe bat, has precluded the use of radio telemetry as the smallest transmitters exceeded the justifiable surplus weight they added to these animals (Aldridge & Brigham, 1988). Recent advances in transmitter technology have reduced the mass of

radio-tags to the point at which it is feasible to radio-track species such as lesser horseshoe bats. In this study we used new lightweight transmitters to investigate the habitat use of this species in Wales.

The aims of our study were 1) to investigate the performance of the new lightweight radio-tags, 2) to collect data on range and habitat use for the species for the first time by radio-tracking and to compare these results with those obtained by other methods and 3) to make proposals for the conservation of lesser horseshoe bats based on the results of the study.

Methods

Study site, capture methods and selection of study animals

The study was conducted during July and August 1997, and May and June 1998 at a nursery colony of some 300 animals roosting in the roof void of an old church in the Lower Wye Valley, South Wales, UK ($51^{\circ}48' N$, $2^{\circ}42' W$) (Warren, 1998). The roost is situated 600 m from the river Wye at an altitude of 160 m on a wooded side of the valley. Although some large intensively managed agricultural fields do exist, traditional pastoral farming methods predominate in this area. Copses at the edges of fields have been retained as well as many hedgerows and tree-lines enclosing fields of grazing pasture.

To minimise the disturbance to the colony we caught the bats in mist nets along flight lines at points between 10-30 m from the church when they left the roost at dusk. The bats caught were held in catch bags before having biometric data taken from them. Mass was recorded to an accuracy of 0.1 g and forearm length to 0.1 mm. Animals were sexed and the reproductive condition of the females was assessed. Parous females were identified by the presence of large pelvic nipples (Gaisler, 1963) and palpably pregnant animals were recorded. We assigned bats to one of three age classes. Class 1 were yearlings identified by their grey pelage (Gaisler, 1963), Class 2 were animals over one year but which showed no sign of extensive tooth wear, Class 3 were estimated as being older animals due to extensive tooth wear. We only used females for the

tracking study as sex differences in habitat selection would have been difficult to determine with a small sample size. The females were selected for tagging depending on their reproductive condition and size. Heavily pregnant females were avoided. We selected larger animals (in terms of their forearm length) to reduce possible adverse effects of carrying the transmitter mass.

Radio-transmitters and tracking methods

The bats were tagged with transmitters we built based on the design in Naef-Daenzer (1993), these ranged in mass from 0.332 - 0.440 g, including zinc-air batteries. In the second year 4 bats were tagged with 0.4 g Titley LTM transmitters (Titley Electronics, PO Box 19, Ballina NSW 2478, Australia, www.titley.com.au). The transmitters were attached to the back of the bats between the scapulae, the fur was trimmed and the tag was glued close to the skin using surgical cement (SkinBond, Smith & Nephew United Inc., Largo, Florida, USA). The transmitter batteries had a minimum life of 8 and 11 days, respectively. We tracked the bats using TRX-1000 (Wildlife Materials, Inc., 1031 Autumn Ridge Road, Carbondale 62901, Illinois, USA, www.wildlifematerials.com) and modified YEASU FT-290 receivers (adapted by Karl Wagener, Telemetrie-Material, Herwarthstrasse 22, D-5000 Köln 1, Germany) with hand-held H-aerials.

The location of the tagged bats were recorded in 5 minute intervals throughout the night by triangulating the signal direction. Two field workers co-ordinated their simultaneous bearings using trigger signals from Casio DB-31 watches and hand-held FM-radios were used to remain in contact with one another. If one person lost contact with the bat, the other either tried "homing-in on the animal" (White & Garrott, 1990), or simulated cross-triangulation by taking a bearing in one position and then moving 50 m in less than half a minute before taking the second bearing. This was only possible with any reasonable accuracy when the animal was foraging in a small area. We assigned locations to one of three accuracy classes (50, 100 and 250 m) depending on our con-

fidence in the estimated location. The highest accuracy class (50 m) could only be assigned when we were in close proximity to the bat. The accuracy of these classes was determined during a field test at night with a transmitter being moved around in a foraging area by a colleague. A test of the deviation of the estimated locations from exactly known locations (location error method - Zimmermann & Powell, 1995) gave a location error of \pm 9.3 degrees (STD) with the estimated locations bivariate normally distributed around the “true” transmitter positions. The locations of the estimated accuracy classes of 50, 100 and 250 metres had their centre not significantly different (t-test, $p < 0.01$) from the “true” centre, the standard deviations of the normally distributed location errors were 44, 85 and 162 metres, respectively (Bontadina et al., unpublished data).

Time, location of observers, bearings on the bats, accuracy data and general observations were recorded in the field on a Dictaphone and later transcribed onto data sheets. The positions of the bats in the field were calculated from the bearings and their estimated location written into a Geographical Information System (GIS) MapInfo (MapInfo, Troy, New York 12180, USA, www.mapinfo.com).

Analysis of ranging behaviour and habitat use

The habitat in the area was divided into eleven categories: broadleaf woodland, mixed woodland, conifer woodland, tree-lines, hedgerows, bare areas (including roads), water, riparian vegetation, settlements, arable, pasture. These habitats were mapped into the GIS using 1:25,000 Ordnance Survey Maps and aerial photographs.

The foraging ranges of the tagged bats in Table 3 were determined by two methods: a) using a minimum convex polygon (MCP) of all locations and b) by the 100 % contour line of a kernel estimation. For better comparability we set the smoothing factor h to 100 m (Naef-Daenzer, 1994). To determine the polygon the tracking locations were buffered by circles with radii of 44, 85 or 162 m depending on the STD of

their assigned accuracy class, and the MCP was calculated around these buffered locations for each tracked animal. The areas covered by these ranges and the distances at which individuals foraged from the roost were determined in the GIS. The relationship between the number of locations and foraging range was computed using the animal movement extension in ArcView (Hooge & Eichenlaub, 1997). The estimation of foraging density was calculated based on the utilisation density of the radio-tracking locations and a colony size of 300 bats was assumed.

We investigated habitat selection on two levels. 1) On a broad scale we looked at the selection of foraging ranges compared to the available habitat. The available foraging area was taken as that falling inside the MCP around all tracking locations of all animals. The habitat within this available area was compared with the habitat within the MCPs of individual bats. 2) At a fine scale we looked at habitat selected by individual bats within their foraging range. This was done by comparing the core foraging areas used within the MCP of every animal with the habitat available within that individual MCP. Core foraging areas were defined by the 50 % contour lines of the fixed kernel estimation (Worton, 1989) in the programme GRID (Naef-Daenzer, 1994) and on the GIS ArcView (Environmental Systems Research Institute Inc., Redlands, California, USA, www.esri.com, Hooge & Eichenlaub, 1997). We did not use least square cross validation LSCV as recommended by Seaman et al. (1999), because different smoothing factors for different animals make comparisons unfeasible. To take account of the different accuracies of the locations, we used the standard deviation of the accuracy class (44, 85, 162 m respectively) as the estimator h and adjusted the resulting densities according to n to achieve correct information from all accuracy classes (Bontadina & Naef-Daenzer, in press).

One problem in habitat selection analysis is that the area of a specific habitat class is inversely correlated with the area of the other classes (Otis & White, 1999). To avoid this constraint we used compositional analysis to investigate habitat selection (Aebischer & Robertson, 1992, Aebischer et al., 1993). This nonparametric technique uses the single animal instead of the locations as sample unit. We computed the statistics with

an Excel macro (P. Smith, 1, Bettws Cottage, Bettws, Abergavenny, Monmouthshire, NP7 7LG, Wales, UK, pgsmith@aber1.fsnet.co.uk, beta version of an unpublished program), which also carried out the randomisation procedure recommended by Aebischer et al. (1993).

For the calculations of habitat diversity we used the Levins Index (Krebs, 1989), where $B = 1/(\sum p_i^2)$.

This index ranges from 1 to n, where n is the number of habitat classes. In our study 11 was the theoretical maximum. We compared the indices of the animals with the habitat diversity of 428 generated random locations and tested these with the Dixon Sign Mood Test (Sachs, 1992) according to Kenward (1992).

General Observations

Throughout the study we recorded general observations of the bats behaviour both visually and with Pettersson D240 mini bat detector (Pettersson Elektronik AB, Tallbacksvagen 51, S-756 45 Uppsala, Sweden, <http://www.bahnhof.se/~pettersson>). Notes were also taken of any other buildings or structures used by the tagged bats.

Results

Ninety lesser horseshoe bats were caught during the study, of which 24.4 % were males. Twelve of the largest non-pregnant or post partum females were selected and fitted with radio-transmitters. The non-pregnant animals were all young from the previous year (age class 1), the remaining tagged animals were age class 2, only one animal had excessive tooth wear and was classified as age class 3 (Table 1).

[Table 1]

The Use of Small Transmitters for Tracking Lesser horseshoe Bats

The transmitters increased the body mass of the animals by 4.5 to 8.1 %. With one exception, this increase in mass was within one STD of mass of all animals caught in the respective category of forearm length. (Fig. 1). The weight of one post-lactating female, which was caught returning to the roost after an hour foraging was 35 % higher than the mean mass in the relevant category of size. She was fitted with one of the smallest available transmitters (0.332g).

[Fig. 1]

After the attachment of the transmitters most animals either immediately returned to the roost or hung up in trees close to the release site and spent time trying to groom off the tags. This period lasted between 20 – 150 minutes, after which they left to forage. One tagged animal flew back to the roost and did not emerge again to forage that night.

We collected 309 locations from eight bats during tracking sessions that lasted between one to four nights in duration. Another four tagged bats either left the area or the transmitters failed before sufficient data could be collected. During the sessions, our mean contact time with the animals while they were foraging was 47 % +- 22 %. The transmitters remained attached to the bats between 2 to 16 days and had a maximum range of 1150 m. This range dropped to less than 100 m in wet woodlands, when the animals flew in dense vegetation or when they flew close to the ground.

The bats showed multimodal phases of activity with two to four foraging bouts (mean 2.4 of 13 nights with complete data). Analysis of the time at which location data were taken during three periods of the night (22-24, 24-02 & 02-04 h) showed no difference in our sampling efficiency over the night (Friedman-test, $n = 8$, $df = 2$, $p = 0.88$, ns), therefore we treated the location data as representative samples of foraging activity during the night.

Ranging behaviour and habitat selection

The colony range was predominantly grazing pasture (59.0 %) with woodlands (14.8 %) and arable fields making up 13.4 % of the available habitat. (Table 2). Although there were long lines of hedgerows and treelines in the study area, they both accounted for less than two percent. The following pair of habitats were significantly correlated ($p < 0.05$): pasture and hedgerows, arable land and treelines, settlement and bare areas, riparian vegetation and water. This means that the resolution of the radio-tracking locations not allows the discrimination between e.g. hedgerows and pastures, which always were adjacent to each other. In order to reduce the number of variables for compositional analysis we combined the correlated habitats.

[Table 2]

Range sizes determined by radio-tracking increase depending on the number of locations. At the beginning of a session this relationship is very steep and than approaches an asymptote when the maximal area is reached. Asymptotes for foraging range were achieved in four of the eight animals (three at 30 locations and one at 90). Therefore we calculated the absolute foraging range area for these four bats, for the others the calculated area is a minimum foraging range. The bats had foraging ranges between 1 to 368 ha using the MCP method, but the more precise 100 % kernel method gave areas of 12 – 53 ha. (Table 3). The three non-pregnant sexually immature animals tracked in May and June all had larger foraging areas than the post-partum females in July and August. The foraging ranges extended in all directions around the nursery roost. (Fig. 2). Fifty percent of the tracking locations were made within 600 m

[Table 3]

[Fig. 2]

of the maternity roost. If we assume a random sample of the studied bats, this indicates that bats from the colony foraged half of their time within this distance of the roost. The maximum distance we recorded a bat from the roost was 4.2 km. Within 200 m of the maternity roost the estimated density of foraging lesser horseshoe bats was 5.8 / ha, decreasing to 1.0 bat / ha at 390 m and 0.01 bat / ha at 1200 m. (Fig. 3a). If the utilisation pattern is compared to a uniform distribution, foraging areas up to 2.3 km from the roost are used more than expected (Fig. 3b).

Habitat selection was investigated in two steps. The first step shows which habitats the bats selected for foraging (see the individual foraging ranges in Fig. 2). Compositional analysis of the foraging ranges of the bats compared with the overall colony range revealed woodlands as significantly selected over all other habitat types ($\text{Chi}^2=10.86$, $\text{df}=3$, randomised $p<0.05$. Fig. 4a). Pasture and arable areas were the least used habitats by foraging bats.

In the second step we looked at how the bats selected their core foraging areas. The comparison of core foraging areas with individual foraging ranges showed again woodlands ranking in first place, being significantly selected over pasture and arable ($\text{Chi}^2=13.98$, $\text{df}=3$, randomised $p<0.05$. Fig. 4b). The class rest, composed of settlement, bare areas, riparian vegetation and water, was selected over pasture.

Woodland in the core foraging areas accounted for $58.7 \pm 5.2\%$ (Mean \pm SE) of the habitat. In contrast, the amount of woodland in the foraging ranges was $40.8 \pm 4.2\%$ and in the colony range it was only 14.8 %. In the core foraging areas of all eight bats were broadleaf woodland predominated over other woodland types. One bat foraged in riparian vegetation 4.5 times more frequently than expected from the proportion of available habitat.

[Fig. 4]

The habitat diversity was larger in the foraging areas (used) than in the colony range (available) of all eight bats ($B = 2.39$ (Median, Interquartile range: 1.87 – 2.98) and $B = 1.48$ (1.14 – 2.03) respectively, sign test, $n = 8$, $p < 0.01$).

General Observations

The tracked bats used three night roosts. One in a derelict ice-house, another in an outbuilding of a farm and the third in an old deserted building with a large attic space. This building was also used as an alternative day roost by one animal during the study.

Direct observations of the tracked bats were difficult. However, on two occasions we were able to observe the foraging behaviour of tagged animals. One was observed foraging high in the canopy of a tree. Its behaviour suggested it was catching insects flying within foliage or gleaning them off the outer edge of the canopy leaves. It was not possible to detect the echolocation calls of this bat on a heterodyne detector. The other bat was observed repeatedly flying a beat along the side of woodland track just below the canopy.

Discussion

Relevance of the new lightweight transmitters

To date the smallest bat species studied by radio-tracking have had a mass between 8 – 15 grams, e.g. *Myotis bechsteinii* (Schofield & Morris, 1999), *Myotis emarginatus* (Krull et al., 1991), *Myotis nattereri* (Smith, 1999), *Eptesicus nilsonii* (e.g. De Jong, 1994), *Plecotus auritus*. (e.g. Fuhrmann & Seitz, 1992) and *Plecotus townsendii* (Adam, Lacki & Barnes, 1994). Eight of the 31 European bat species weigh between 4 and 8 g (Schober & Grimmberger, 1987). This study has shown that their foraging and ranging ecology can now be investigated by radio-tracking.

The main drawback in using transmitters trimmed for minimum weight was their very short transmitting ranges, making detection of the animals in dense vegetation or when they were close to the ground very difficult. This may place limitations on their use in some species.

The additional weight of carrying radio-tags on flying animals has consequences for both their energetic costs and their manoeuvrability (Hughes & Rayner, 1991; Caccamise & Hedin, 1985). As a rule of thumb it is recommended that tags should add less than 5 % of the mass of flying animals (Aldridge & Brigham, 1988). However, small bats can carry larger loads relative to their body mass than larger species (Norberg & Rayner, 1987). This is similar to the situation in birds where Caccamise & Hedin (1985) showed that for a 5% reduction in surplus power a 10 g bird could carry a transmitter weighting over 25 % of its body mass, while a 100 g bird can carry only about 8 %. In addition, the mass-carrying capability may also be greater in species with a low wing loading, such as the lesser horseshoe bat (Norberg & Rayner, 1987).

The body weight of small flying animals changes following feeding and during pregnancy by much more than 5 percent: Hughes & Rayner (1993) found short-term differences of 17 % in mean body mass of pipistrelles, and Kurta & Kunz (1987) report the foetal mass of heavily pregnant bats represents 30 to 40 % of their body mass. Female lesser

horseshoe bats have been observed carrying young weighing up to 50% of their body mass (Kokurewicz 1997).

Consequently, as the bats were not tagged when heavily pregnant, the tracking sessions should not have artificially altered their foraging behaviour. Moreover, if the surplus weight had reduced manoeuvrability then we would expect the bats to forage less in cluttered vegetation (Aldridge, 1985-86). As our results indicate the habitat class with most cluttered vegetation was selected over all the others, any reduction in manoeuvrability did not mask this selection.

Carrying the weight of the tag could limit the bats foraging stamina and hence their food intake with consequences for their fitness. However, as the transmitters are only attached for a few days this would appear to be fairly limited.

Habitat selection in accordance with morphological predictions

Bats of the rhinolophid family are specialised in that they have broad wings and narrow tips resulting in generally slow but highly manoeuvrable flight (Neuweiler, 1989) and they have high and constant frequency echolocation calls with a high duty cycle. This enables them to detect fluttering insects amongst cluttered vegetation (Von der Emde & Menne, 1989) and is probably a prerequisite for selective foraging (Jones, 1990). Both of these specialisations can be seen as an adaptation to foraging in highly cluttered environments (Schnitzler & Oswald, 1983). This is supported by our results on habitat use that revealed that lesser horseshoe bats foraged mainly in woodland. The lesser horseshoe bat is the smallest member of the 69 rhinolophid species (Nowak, 1994). Its wings have the smallest aspect ratio within the family (Norberg & Rayner, 1987) and other morphological traits that enhance its wing camber (Stockwell, 2001). From a morphological point of view it should be the most capable of all the rhinolophids at foraging in the cluttered vegetation. Schofield (1996) reported seeing lesser horseshoes flying in the canopy of trees. However, in this study only one animal was

observed foraging within the foliage of the crown of a free-standing tree. But the fact that only two direct observations were made, even though we were often very close to the tracked animals, reinforces the assumption that they often forage within vegetation and are therefore hidden from view.

The habitat choice of female bats is to a large extent determined by the selection of the nursery roost (second order selection in Johnson, 1980). Schofield (1996) analysed roost sites with respect to their surrounding landscape and found deciduous woodlands to be the main habitat class associate with lesser horseshoe roosts. Our results support these findings.

Earlier landscape studies indicated that broadleaf woodland maybe the key foraging habitat of this species. This study of individual bats from one colony has quantitatively confirmed these indications. Moreover we found correlative evidence that areas with high habitat diversity were the most favoured foraging grounds. Although, it remains open whether areas of high habitat diversity are selected because of enriched food resources or an enlarged foraging space.

The habitat selection determined in this study only partly supports the predictions made from dietary analysis of this species. Beck, Stutz & Ziswiler (1989) found Diptera, Lepidoptera and Neuroptera in faecal pellets from Swiss populations of lesser horseshoe bats. They suggested this might indicate foraging in riparian vegetation or along well-structured hedgerows. In this study we found no overall selection for riparian vegetation. This discrepancy could well be derived from different habitat selection in different geographical areas, as documented in the greater horseshoe bat *Rhinolophus ferrumequinum*. In Wales and England this bat species foraged mainly in ancient woodlands and along vegetative structures in pastures (Jones & Morton, 1992, Duverg , 1996), whereas in Luxembourg, Switzerland and Italy it foraged along the riparian vegetation of rivers and streams (Pir, 1994; Bontadina et al., 1997, 1999).

Flight performance in bats is influenced by wing morphology (Norberg & Rayner, 1987). Jones, Duverg   & Ransome (1995) used this to predict the foraging range of several species. In their model the lesser horseshoe bat (aspect ratio 5.7, Norberg & Rayner, 1987) was predicted to have a foraging range of 1.3 km, which agrees closely with our results. However the distances flown by the non lactating females showed that these individuals could forage at a much greater distance.

If we compare the results revealed by radio-tracking with those of former studies it becomes apparent that some types of data cannot be recorded using other methods. This is particularly true in determining their range use where their low foraging density away from the nursery roost and the difficulty in detecting their echolocation calls in the field would make any ultra-sound detection study unfeasible.

This study was based on one of the largest colonies of lesser horseshoe bats known in Western Europe (Ohlendorf 1997). Our results revealed that the colony was foraging half of the time within a radius of 600 m around the nursery roost. If large colony size increases the foraging range of individuals (Jones et al., 1995), the average foraging distances in smaller colonies may be even smaller. We estimated densities of up to 5.8 bats / ha foraging near to the nursery roost. In comparison, Rydell (1992) found about 1.8 bats / ha along illuminated streets where street lamps artificially attract moths and lead to insect densities hardly ever found in nature. The high densities of foraging bats around large nursery roosts must result in a high predation pressure on insects and strong competition between individual bats. Therefore the amount of woodland around maternity sites could determine colony size.

An understanding of the causes of the large-scale decline in this species is needed if the success of long-term conservation measures are to be realised. This study may help to explain this decline. If woodland is the key habitat of this species and if habitat destruction has caused its large-scale decline, we would expect a reduction in woodland cover in the same geographical areas and at the same time as the populations declined.

However, the greatest loss of woodlands in Britain occurred in the eighteenth and nineteenth century (Rackham, 1980), long before the populations of this bat species collapsed after the 1960s (Stebbins, 1988). In the second half of the last century the amount of woodland has even increased in some areas (Smout, 1997). As the bats seem to exploit the habitat immediately surrounding their roost, there could be individual colonies of lesser horseshoe bats affected by small scale reductions of woodland in their vicinity. However, it seems implausible that the large scale reduction in population was caused by the destruction of woodland. An alternative hypothesis maybe that woodlands have reduced in habitat quality, and the consequent reduction in the availability of suitable prey may have caused the decline. To determine this would require further study of micro-habitat selection and prey availability within woodlands.

Recommendations for conservation

From this study the following recommendations can be made: 1) Conservation measures for lesser horseshoe bats should be undertaken within 2.5 km of nursery roosts, with special consideration to the area within 600 metres of the roost. 2) The quantity of woodland and the diversity of habitats within these areas should be maintained and where possible enhanced, especially close to the roost. 3) Further studies should be undertaken to determine whether the finding of the habitat selection presented here are consistent with those of other regions in Europe. Further study is also needed to both derive more detailed information on the woodland microhabitats used by this species, and to investigate seasonal variation in habitat selection.

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Table 1: Morphological and reproductive measurements of the 12 radio-tagged bats.
Age class 1 animals are yearlings (for detailed definition see methods).

Table 2: Availability of habitats around the roost. COR = habitat types marked
with the same letter are significantly positive correlated with each other ($p<0.05$,
two-tailed).

Table 3: Radio-tracking data of eight successfully tracked bats. The size of
foraging areas is given by minimum convex polygons (MCP) and by 100 %
contour lines of kernel estimation (kernel).

Fig. 1: Mass of the bats in relation to forearm length. The body mass of N = 78 untagged lesser horseshoe bats caught when emerging from the roost is given as error bars (mean +-STD) for weight categories. The weight of the 12 radio-tagged bats (including transmitter and attachment cement) are marked with circles.

Fig. 2: Foraging ranges (MCP) of eight radio-tracked female bats caught near the nursery roost (marked as a white dot). The colony range is given as the MCP around all foraging ranges. Woodlands are marked in grey.

Fig. 3. a) Variation in estimated logarithmic density of lesser horseshoe bats with distance from the roost. The regression power function is shown as a dotted line.
3b) Deviation of the observed frequency of locations (n = 309) when compared with a model of uniform spatial use.

Fig. 4. Habitat selection: comparisons of habitat available versus used (mean percentage area plus SE). Classes to the left of the symbol > are selected over those to the right. The symbol * indicates significant differences ($p<0.01$, compositional analysis) between those habitat classes connected by a line.

- a) Selection of foraging ranges: comparison of the habitat available in the colony range (defined as the minimum convex polygon MCP of all animals, see Fig. 2) with the mean foraging ranges (MCP).
- b) Selection of core foraging areas: comparison of the individual foraging ranges (available area, defined as MCP) with individual core foraging areas (defined as 50 % kernel density contours).

[Table 1]

date of capture	animal code	forearm [mm]	mass [g]	breeding status	pelvic nipples	age class
15 Jul 97	F5	39.2	6.2	post lactating	yes	2
16 Jul 97	F4	39.2	6	post lactating	yes	2
24 Jul 97	F7	38.8	6	post lactating	yes	2
24 Jul 97	F9	38.6	6	post lactating	yes	2
28 Jul 97	F8	37.3	7.4	post lactating	yes	2
12 Aug 97	F6	38.1	6	post lactating	yes	3
13 Aug 97	F16	38.1	6.1	post lactating	yes	2
31 May 98	F3	36.4	4.7	not pregnant	no	1
31 May 98	F15	39	5	not pregnant	no	1
7 Jun 98	F17	37	5.1	not pregnant	no	1
7 Jun 98	F2	37.7	4.8	not pregnant	no	1
15 Jun 98	F14	37.4	4.9	not pregnant	no	1

[Table 2]

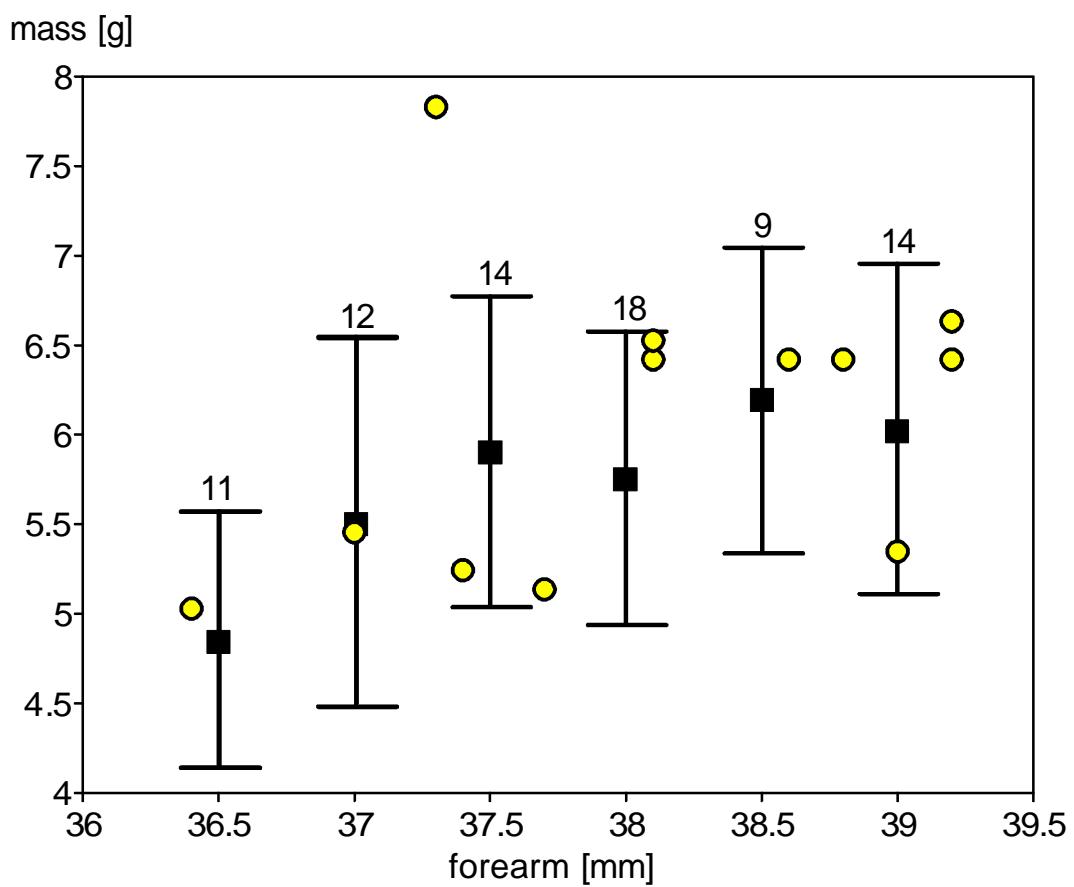
Habitat	Availability in %	COR	classes regrouped to
Pasture	59.0	A	Pasture
Arable land	13.4	B	Arable
Broadleaf woodland	8.5		Woodland
Settlement	4.9	C	Rest
Coniferous woodland	4.8		Woodland
Bare areas	2.9	C	Rest
Treelines	1.7	B	Arable
Hedgerows	1.6	A	Pasture
Mixed woodlands	1.5		Woodland
Riparian vegetation	1.0	D	Rest
Water	0.7	D	Rest

[Table 3]

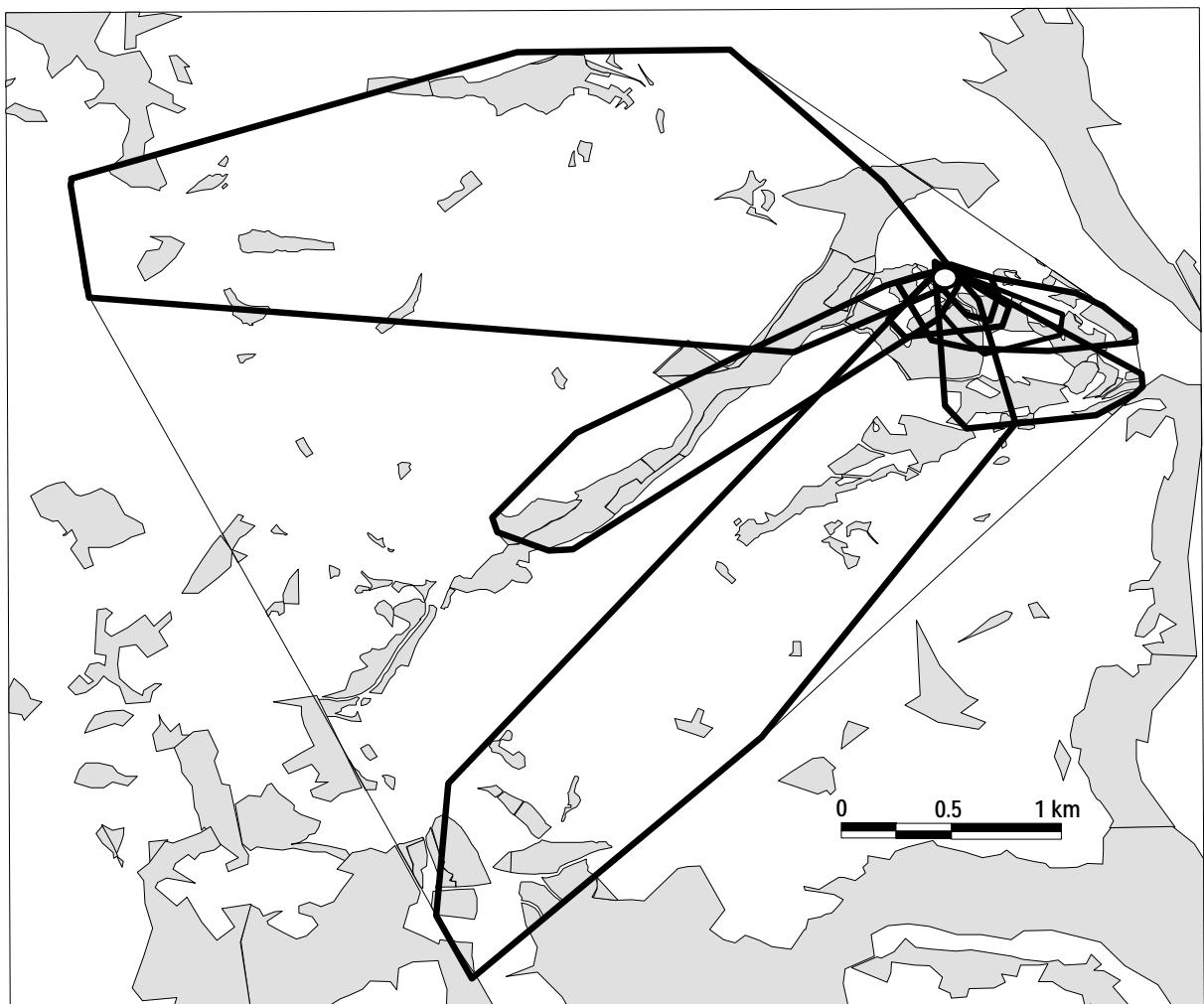
animal code	breeding status	number of locations	foraging area [MCP, ha]	foraging area [kernel, ha]	maximum distance to main roost [m]
F3	not pregnant	8	25.7*	32.5*	994
F17	not pregnant	63	368.4	52.5	2488
F14	not pregnant	36	229.5	52.3	4177
F5	post lactating	11	1*	12.8*	249
F4	post lactating	9	2.6*	11.9*	282
F7	post lactating	96	20.4	28.4	882
F8	post lactating	30	8*	15.2*	560
F16	post lactating	56	57.9	32.2	273

* minimum used area, curve of area in relation to sample size reaches not an asymptote.

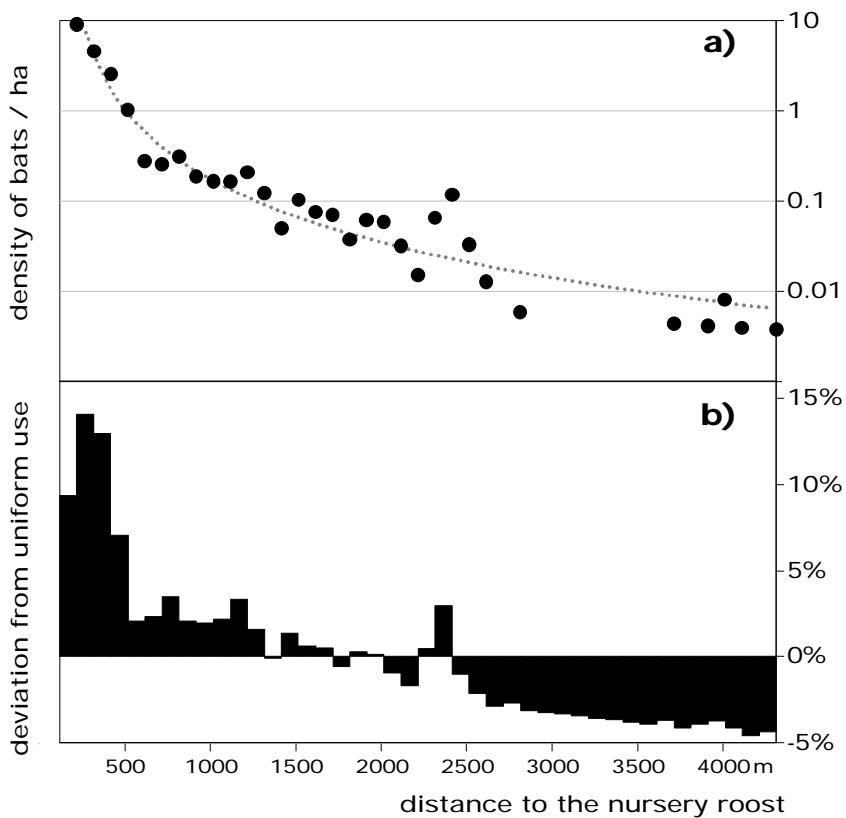
[Fig. 1]



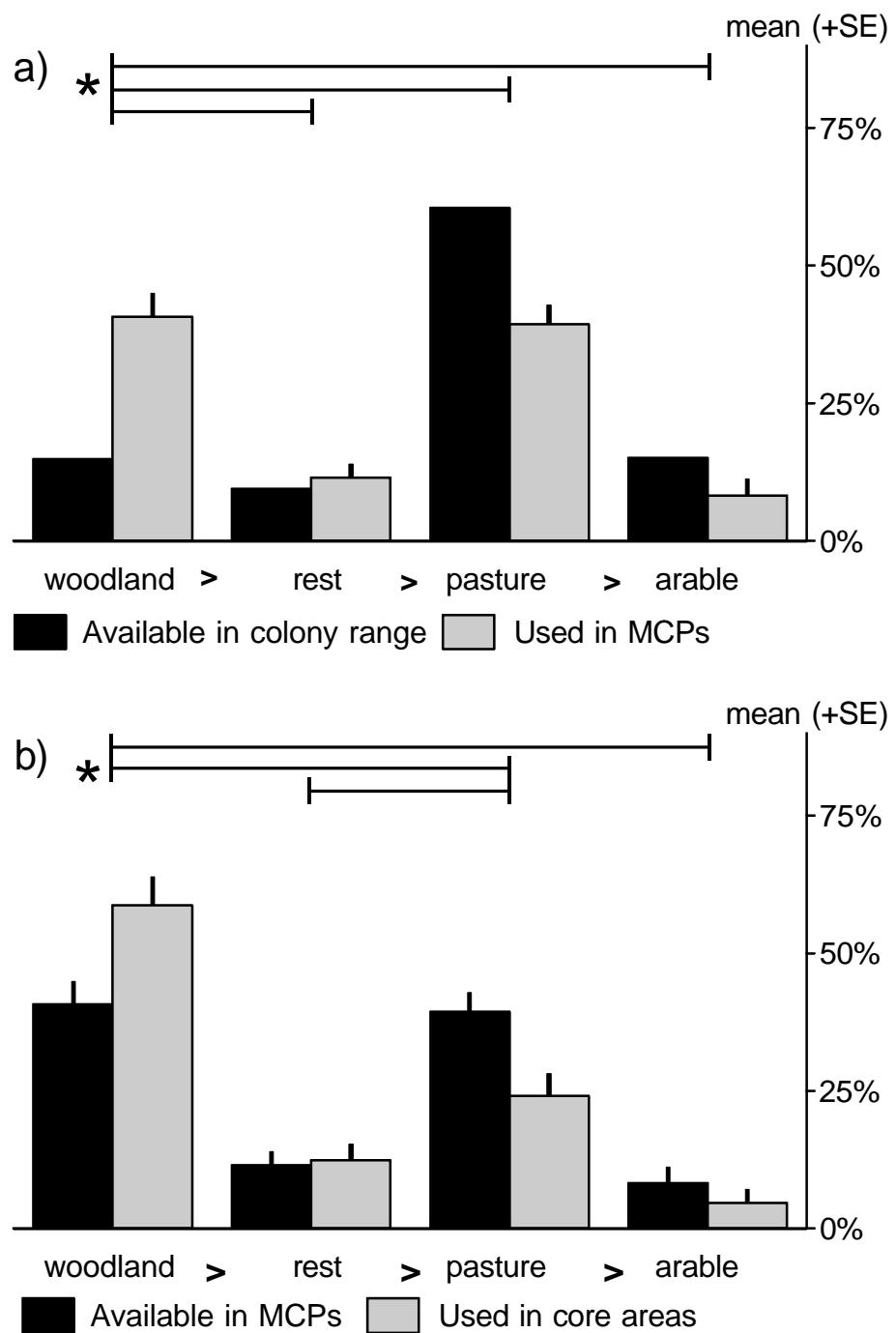
[Fig. 2]



[Fig. 3]



[Fig. 4]



The lesser horseshoe bat *Rhinolophus hipposideros* in Switzerland: present status and research recommendations

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roost, management

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Theiler, A. & Zingg, P. (2001): The lesser horseshoe bat *Rhinolophus hipposideros* in Switzerland: present status and research recommendations. Le Rhinolophe 14: 69-83.

Abstract

Once the lesser horseshoe bat *Rhinolophus hipposideros* (Bechstein, 1800) was known to be widespread and common in Switzerland. In the past 50 years their overall population has undergone a severe decline, as in most countries of Central Europe. With the aim to build a conservation research concept, we collected information about the current status of the remaining regional populations in Switzerland and made an evaluation of the causes of their decline. Then we developed a research program based on the most important research recommendations.

The evaluation of the present status of the populations in Switzerland in 2000 reveals 39 nursery colonies with about 1700 adult individuals, distributed over eight Cantons, mainly in the alpine area. 95% of the animals are found in four clusters of colonies, which could represent separate populations. 55% of the colonies have shown an increase in numbers, 27% have remained stable and 18% have decreased over the last 10 years.

Following an evaluation of possible factors and an enquiry with bat experts, the most threatening factors are thought to be pesticides, changes in the structure of habitats and food shortage. Therefore we propose the following research topics with high priority: resource exploitation, pesticide contamination and the development and implementation of refined methods for monitoring populations. Moreover, depending on the results of the first research phase, studies about population dynamics, roost conditions, climate, population genetics and the colonisation potential of these animals could be included in a second phase. Further we propose to carry out regional public enquiries to find more roosts in private houses and to build action plans to implement protection schemes.

Introduction

Since the 1950s or 1960s lesser horseshoe bats *Rhinolophus hipposideros* (Bechstein, 1800) have undergone a severe decline in most of western and Central Europe (review in STEBBINGS, 1988, OHLENDORF, 1997a). The same dramatic development was recorded in Switzerland, where lesser horseshoe bats were once widespread and common. Today only some isolated populations remain in the alps (STUTZ & HAFFNER, 1984). The exact reason(s) for this decline is/(are) not known. Moreover, it is not clear whether the remnant colonies are still confronted with the problems that led to their decline or whether the situation has changed in the meantime. Therefore, no focused conservation scheme could be developed up to now; and it is not surprising that roost protection has always been given the priority. There is definitely a need for a broader knowledge of the problems faced by the species so as to propose effective conservation measures that may be implemented, first, to foster the recovery of small populations and, second, to promote the progressive recolonisation of once inhabited but today abandoned areas.

We present here an evaluation of the causes of the decline of these bats in Switzerland, give an overview of the recent distribution of colonies of the lesser horseshoe bat and, as conclusion, we suggest a conservation research program which includes the major research recommendations.

This concept for an applied research program was requested by the Scientific Board of the Swiss Bat Coordination Centre with the intention to define a conservation plan for this threatened species based on scientific results.

We hope that the implementation of the conservation measures which will be drawn from the proposed investigations will enable the responsible authorities to act efficiently for the conservation of this highly endangered bat species.

Methods

Status in Europe

We summarise the information gathered at the International Workshop on Rhinolophids, held at 1995 in Nebra, Germany (OHLENDORF, 1997a). The status for Austria, Germany, Italy and Great Britain was updated by contacting experts working with the species in the respective countries.

Status in Switzerland

Regarding the current situation and most recent trends in Switzerland, we obtained good data from an enquiry addressed to all Swiss regional bat coordinators (RFE/CR) and to experts. On the enquiry form, we requested information on all known colonies (with the maximum number of adult animals counted between 1990 and 2000) and also asked whether the colony had decreased, was stable or had increased during the 1990s. We also requested additional data on monitoring to see whether precise population trends could be documented.

Potential causes of the decline

We performed an analysis of the potential causes of decline of *R. hippo-sideros*. For this purpose, we used three sources. Firstly, referring to the literature, we listed all the potential causes suggested by various authors. Secondly, the two first authors made an own list of potential factors, those which seemed the most relevant ones to us and, thirdly, we asked all Swiss regional coordinators, during the enquiry described above, to make their own appraisal of possible factors. The estimation was made on an interval scale, ranging from 0 (irrelevant factor) to 5 (very relevant factor). The scores from the experts were averaged and the factors listed in decreasing order of rank.

Research recommendations

To establish priorities for research, we took into account the following constraints, either set by the framework of the mandate or by ourselves:

- The research program should be realistic and provide a description of research topics, priorities, possible study areas and time schedule.
- Poor knowledge in some fields ranked as relevant for conservation (see above) must dictate research priorities.
- A posteriori, comparative research has to be envisaged, particularly as experimental work is hardly feasible with this highly endangered species.
- Comparative analyses should take advantage of the various geographical situations available in Switzerland, and of the various demographic situations: extinct vs. extant populations of lesser horseshoes, increasing vs. decreasing colonies, etc.
- Research (retrospective) will be carried out in priority in areas where population trends have been sufficiently documented in the long-term or at colonies with the best chance of population increase (prospective).
- The proposed research program includes control procedures.

Database of literature

To generate a comprehensive list of literature we collated information from the following sources:

Database from Réseau Chauves-souris Valais, December 1999

“Centre de coordination ouest pour l’étude et la protection des chauves-souris” (CCO) database, December 1999

“Koordinationsstelle Ost für Fledermausschutz” (KOF) database, June 1997

NISC – Wildlife Worldwide, Mars 1997

Database from Guido Reiter, Austria, August 1998

Database from Fabio Bontadina, December 1999

Estimation of the status of the species and its demographic trends

Europe

We present here a brief review of some data about the present status and recent demographic tendencies of *R. hipposideros* in Central Europe. For a more detailed overview, consult STEBBINGS (1988), KULZER (1995) and OHLENDORF (1997a). *Rhinolophus hipposideros* has become a rare species in Central Europe. This is particularly true for the Netherlands and Benelux countries where the species is almost extinct at present (Fig. 1, FAIRON, 1997). A strong decrease in, and a fragmentation of populations is reported from northern and north-east France. The remaining populations are estimated to number 1700 animals (DUBIE & SCHWAAB, 1997). In the rest of France, some 10 – 11'000 individuals were censused in 1995 (ROUÉ, 1997). In the east and south-east of Germany, some 600 lesser horseshoe bats are counted in winter roosts, and half of this number is found in summer roosts (M. Biedermann, 1997, pers. com., H. Geiger, pers. com., OHLENDORF, 1997b, A. Zahn, pers. com.). Austria still reports some strong populations, especially in Carinthia and Styria. In total, several thousand individuals are reported (SPITZENBERGER, 1997, G. Reiter, pers. com.). Both have found populations with steep downward trends and also roosts with population recoveries. In the south of Poland, less than 500 animals are known and the populations are estimated to total about twice this number of individuals (Kokurewicz, pers. com.). In the Czech Republic the total population comprises some 3800 animals (Gaisler, pers. com.). A discontinuous distribution is documented with some trends of recent population recoveries (GAISLER, 1997). Countries in eastern Europe still harbour large lesser horseshoe bat populations, although some signs of decreasing numbers are reported there, too. In many countries of southern Europe, little information exists about the current status and the demographic tendencies of this species. In general they seem to be common, but there are also many reports of lost colonies.

[Figure 1]

[Figure 2]

Switzerland

There are numerous data attesting to population crashes in Switzerland between the 1950s–70s (see the example in Fig. 2). However, according to our enquiry, at least eight Swiss cantons still harbour the species at present (1999). These are the cantons of Bern (BE), Grisons (GR), Fribourg (FR), Neuchâtel (NE), Obwalden (OW), St. Gallen (SG), Solothurn (SO) and Valais (VS). Fig. 3 shows the distribution of 39 known nursery colonies active from 1990 to 1999, whereas Table 1 presents a list of these nursery colonies during the past 10 years, with the high-test number of adult animals counted and recent demographic trends. The total number of adult lesser horseshoe bats counted in all roosts is about 1400 animals. We estimate the actual population size to be about 2000 adult animals, some 1.5 times as many animals as the number counted in the nursery roosts.

Although many caves have been controlled during winter time in Switzerland, only few winter roosts (with mostly single lesser horseshoe bats) have been found. Because small caves and crevices are available in large numbers in the alpine area, the census of bats in winter roosts cannot be used to estimate population size in this area.

32 out of 39 colonies seem to be aggregated as clusters of colonies which could represent separate populations (marked with circles in Fig. 4). More than 95% of the animals are found within these four main populations. All but one of the larger colonies are situated within these clusters (Fig. 5).

As regards population trends within those 39 nurseries, 31% showed a recent increase in number, 15% appeared stable, whereas 10% were decreasing; it should be noted, however, that 44% ($n = 17$) of all nursery sites did not yield data precise enough to estimate population tendencies (Table 2). When considering only the sites with sufficient data to document exact trends ($n = 22$), we found that 55% of them exhibited an overall population increase, 27% seemed stable, whereas 18% only ex-

hibited a marked decrease. These results suggest that some populations might well be undergoing a positive development, as exemplified by a maternity roost in Obwalden (Fig. 6).

[Figure 3] / [Table 1]

[Figure 4] / [Figure 5]

[Table 2] / [Figure 6]

Potential causes of the decline and evaluation of their relevance

The evaluations by bat experts matched each other, demonstrating concording views about the possible origins of decline. A list of the most relevant factors, according to the questionnaire sent out, is given in Table 3. Comments to the eight possible factors are given in the next paragraph. In Table 4 suggestions for priorities in conservation research are listed, ranked according to the number of times it was mentioned by the Swiss regional bat experts.

[Table 3]

[Table 4]

We present now the comments of two of us (FB & RA) about possible causes of decline, separating the factors in two main classes: abiotic and biotic factors, although both clearly interact and may correlate.

The signification of the symbols (in brackets) is as follows:

- a priori not a relevant factor
- factor that might play / have played some role but further evaluation is required
- factor ranked as a major potential cause of decline.

The sections 'Comment' presents a justification of our classification into one of these three categories.

Abiotic factors

Pesticides (•••)

The extensive use of pesticides began during the period of World War II, particularly in agriculture. Many animal species began to decrease soon after, as exemplified by raptors (*Falco peregrinus*, *Accipiter nisus*, etc.) that were heavily contaminated by organochlorined pesticides (DDT, etc.). Horseshoe bats may have faced the same problem. Yet, the raptors have now largely recovered in Europe, including Switzerland, whereas there has not been such a dramatic increase in horseshoe bat populations. It should be pointed out that a slower population recovery in bats may be due to their lower reproductive rate. The effects of pesticides may be the contamination of the food chain (abiotic) and/or a decreasing food availability (biotic, discussed in next section).

Comment: The hypothesis that pesticides may be responsible for the decline of the lesser horseshoe bat is appealing as it typically represents a global effect. Recent investigations have shown that some pesticides act as hormones and can then potentially interfere with reproductive ability. If pesticides are the main factor of decline, we would expect to observe population recoveries unless pesticides especially harmful to horseshoes are still in use. A research project exists in this field in Switzerland, but conclusive results are not yet available. The main problem is that even if one finds a correlative evidence of a relationship between environment contamination and bat population status, the causality is not demonstrated. Also, this would raise the question whether the incriminated pesticides still persist in the environment and therefore constitute a permanent source of contamination.

Changes in the physical structure of habitats (•••)

Lesser horseshoe bats exploit cultivated landscapes such as farmland or woodland (BONTADINA et al., 1999), two types of habitats which have faced dramatic modifications since World War II. Traditional insect-rich meadowland and pastureland have been changed into crops, whereas forest patches, hedgerows and single trees have been systematically eradicated. This has resulted in a loss of overall habitat diversity and

connection, whilst rendering the overall landscape more homogeneous. Moreover, cattle and small domestic animals were banned from Swiss forests early this century, which certainly implied further losses in vegetation patchiness and vertical structure within woodlands. A direct influence of this is of course a global drop in the available insect prey biomass (see biotic factors).

Comment: Habitat changes are ranked among the probable major factors of decline. However, as many areas still harbour highly structured landscapes but no lesser horseshoe bats any more, habitat destruction may explain the extinction of local populations, but certainly not the whole phenomenon of the decline of lesser horseshoes across most of Western Europe. Regarding the changes in woodlands, they may have been largely underestimated. Major changes in farming practices could have had a large scale impact on lesser horseshoe bats.

Loss of roosts and roost deterioration (••)

Lesser horseshoes in Switzerland used to roost in large lofts (attics, mostly during the summer) and in underground cavities (mostly outside the summer). The renovation of buildings and a decrease in mining activity may have reduced the number or quality of roosts available to bats (e.g. through the insulation of roofs, which deteriorates thermic conditions).

Comment: Loss of roosts and roost alteration could have played a role locally, but they would hardly be able to explain the widespread decrease of the species in western Europe.

Climate changes (••)

Fluctuations in climate may cause alterations in distribution and population sizes; a climatic optimum actually took place in the late 1940s and early 1950s, i.e. just before lesser horseshoes began to decline.

Comment: The decrease of *R. hipposideros* took place almost simultaneously in much of western Europe. This supports the hypothesis of a

global effect. If global warming starts to affect earth, we should soon expect a population recovery. If climate is the main factor, there are no special measures to implement for species conservation. However, the fact that *R. hipposideros* was an abundant species in Switzerland early this century, when the climate was not significantly warmer than today, contradicts the scenario of a great thermic dependence as a single acting factor.

Biotic factors

Food shortage (••)

The availability of insect prey to bats has certainly decreased significantly in the past decades in most of western Europe. This is thought to be mainly due to habitat transformation (farmland into human settlements), the use of pesticides (dramatic drop in insect prey biomass; for contamination see abiotic factors), changes in agriculture (meadows into crops, pastures into arable land) and silviculture (deciduous into coniferous trees), among others. As a result, many relevant habitats no longer exist or do not provide enough insect biomass. This may have affected lesser horseshoes.

Comment: As food is usually the most important condition for species existence and reproduction, this hypothesis should be given a high priority. However, little is known about insect availability in the past. It is noteworthy that lesser horseshoe bats have gone extinct in areas where changes in food supply have certainly been slight and this factor cannot explain the complete disappearance of some populations.

Competition against other species (•)

Recent investigations have suggested that some bat populations have probably dramatically increased in the past decades, presumably as a consequence of foraging upon insects attracted by street lamps. This is possibly the case of pipistrelle bats, whose diet appears similar to that of lesser horseshoes. As European bat communities appear saturated (due to most ecological niches being already occupied), it is difficult to

imagine that one species could substantially increase in number without affecting the demography of others using convergent resources (see ARLETTAZ et al., 2000).

Comment: This hypothesis would benefit from a deeper evaluation. However, it remains to be shown how it can account for the recent positive populations trends observed in several lesser horseshoe bat populations? The only possibility would be that white lamps particularly attractive for some bats have progressively been replaced by orange bulbs, which do not offer such favourable foraging conditions, but this seems contradicted by observations.

Genetic inbreeding (•)

A lack of exchanges between colonies and populations could cause some genetic inbreeding.

Comment: Genetic bottlenecks could play some detrimental role within local populations close to extinction, but they would certainly not be able to eventually cause the extinction of a population, which was still panmictic in the 1950s.

Diseases (•)

Pathogens suddenly introduced into a population, particularly when they are of alien origin, may provoke rapid extinctions through sudden, massive mortality.

Comment: Diseases usually decimate populations quickly, whereas the decline of *R. hipposideros* has been progressive. Moreover, pathogens tend to affect all populations similarly, but several populations have remained almost unaltered to date.

Predation, including human disturbance (•)

Predation and human disturbance may well explain some population crashes at a local scale but certainly not the wider global population decline of *R. hipposideros*.

Research recommendations

Referring to our list of potential causes of population decline (Table 3), and considering the convergent views of regional bat experts for the evaluation of the factors possibly involved, we propose the following research topics (Table 5):

- Resource exploitation, subdivided in two sections: use of space, and trophic & foraging ecology
- Contamination by pesticides
- Population dynamics
- Roost conditions
- Climate change
- Population genetics
- Colonisation potential

A proposal for a conservation research program in Switzerland

The main goals of the proposed research are the following: 1) To understand the causes of regression of *R. hipposideros*, as far as possible [One constraint is, that an experimental approach is hardly applicable on that threatened and rare species, therefore we shall mostly rely on a comparative approach], 2) to find out the key factors which may currently be responsible for the survival of the remnant colonies and 3) to propose an efficient conservation scheme for this endangered species in Switzerland, which would include both, the protection of remnant colonies and their management, so as to elicit an increase in population size, and a progressive recolonisation of lost areas.

The research program has been divided into two chronological phases (phase I and II, Table 5), the first one being subdivided into two priorities (phase I.1, phase I.2). The first two topics (resources exploitation and pesticides) are the most relevant and therefore, both are included in phase I as priority actions. The development of refined monitoring methods for long-term population dynamics surveys must also be placed in phase I.1, as much of the work depends on accurate moni-

toring. Altogether, this first phase is planned over three years. It is our opinion, that planning of the second phase will have to be submitted for reevaluation, once the first phase has been completed.

Since most of the research methods involved (e.g. electronic techniques, manipulations of the animals, statistical analysis, etc.) require scientific skills in the field of bat research, most work will have to be carried out by reputable bat biologists. However, some projects would offer opportunities for students to familiarise themselves with bat fieldwork.

We propose that every project is considered separately, from an organisational viewpoint, with an attributed team and supervisors. The latter will be responsible for planning the research, coordinating the activities, and contributing to data analysis and publication.

The following sections highlights the research topics, planned methods and approximate time schedules, in greater detail.

Resource exploitation

Use of space (revealed by radio-tracking) - phase I

- Habitat selection (i.e. habitat use vs. availability) in different regions
- Use of microhabitat: preferred vs. avoided vegetation structure
- Home range use in relation to landscape structure and connectivity
- Roost use and availability in relation to landscape structure and connectivity

Trophic and foraging ecology - phase I

- Diet vs. insect prey biomass availability according to habitat and region

Use of space - phase II

- General habitat profile and comparative landscape evolution
(possibly including comparisons with foreign populations)

Description of work (phase I)

The study of resource exploitation in phase I is aimed at comparing different regions and various population dynamics.

As regards radio-tracking, we propose to tag six lesser horseshoe bats in each of the four main populations. Data on habitat use and spatial behaviour of two animals should be collected in spring, summer and autumn at given locations. In order to widen the database to enable the

comparison of resource exploitation in healthy vs. remnant populations, further data from relict colonies should be collected. One – two animals will be radio-tracked at 4-6 sites, if possible.

Individual bats will be captured with mist nets outside the roosts across their traditional flight lines in order to minimise disturbance at colony roosts. We shall use the lightest and smallest radio-tags available on the market and avoid marking heavily pregnant females. In any case, the weight of tags should not exceed 10% of body mass (BONTADINA et al., 1999; a pilot study conducted on 12 lesser horseshoe bats).

In the intensively studied regions, food availability will be assessed by insect trapping within foraging grounds of the species, using various sampling methods (light traps, sticky traps, etc.). Diet will be studied by means of faecal analysis. Diet selection will be investigated by comparing diet composition with insect availability.

Time schedule

We are planning to collect the data above during the spring, summer and autumn of 2001/02. Winters will be devoted to data compilation and analyses.

Pesticide contamination

There is already an ongoing extensive research project on that subject at the moment. The idea is to see whether pesticide contamination correlates with the decline of lesser horseshoe bat populations. Results have been presented at the Bat Conference 1999 and are expected to be reported in full form in the next time. Any further project on pesticides will depend on the results of that study.

Population dynamics

Marking and methodological tests - phase I

- Development of refined monitoring methods enabling the estimation of sex ratios, and the proportion of yearlings and other age classes within populations
- Development of a safe method enabling young bats to be marked.

Population dynamics and modelling - phase II

- Collection of data on life history traits and fitness parameters
- Prospective and predictive modelling of population dynamics

Description of work (phase I)

Various techniques will be evaluated with the aim of minimising sampling effort (and thus colony disturbance) whilst getting reliable basic population data: maximum number of adults and youngs in a nursery roost, sex ratios, mean or median date of birth, growth of young and, possibly, the reproductive success of mothers.

It is proposed that as a control experiment, a yearling cohort should be ring-marked in one nursery colony, whereas a similar cohort will be captured, but not ringed, in another colony (control). The behaviour of the young bats before and after ringing will then be monitored using IR video cameras at both sites, and their behaviour compared.

Time schedule

This module, one year in duration, should be started in the first year. The results will serve to establish a standard protocol for monitoring all nursery roosts in the country.

Roost conditions

There is an ongoing research project at the moment aiming to compare roost structure and climatic conditions in different attics occupied by lesser horseshoes in the Grisons. Results could be presented at the next Bat Conference, following which any new project on roost conditions will be formulated.

Overall climatic effects

- Long-term evaluation of possible climatic changes in different areas of Switzerland.

Description of work (phase I)

Various Swiss regions showing different demographic trends of *R. hippo-sideros* will be compared from a climatic perspective: Valais, Grisons, Berner Oberland as regards the alpine arc, but also areas of the Swiss Plateau and Jura mountains. Seasonal subgroups should be analysed,

looking for statistical trends in precipitation and temperature. The extant data collected by the Swiss Meteorological Institute (SMA) since 1930(50) will be available for use.

Time schedule

This is part of the second stage of phase I according to the ranking of research topics. Data are delivered as spreadsheets by the SMA; analysis could be performed by a student, for instance in geography, but supervision will be necessary and must be funded.

Population genetics

Any project on that topic will be reconsidered once the first phase is completed.

Colonisation potential / release experiments

The need for such a research as well as the methods will be considered when the first phase is completed.

Accompanying measures

We list here some non research activities which will have to be developed in parallel with, and complement to, the research activities. They are usually carried out either by the Coordination centres or the local bat workers (RFE/CR).

Public campaign

- Nation-wide public campaign to locate new horseshoe bat roosts
- Regional enquiries and/or calls complementary to the nation-wide action

Description of work (phase I)

Successful public calls and enquiries in Obwalden and the Berner Oberland have shown that such actions are well worth the additional effort. Horseshoe bats in particular are very suitable as an enquiry target through the mass media's as they are easily recognisable due to their unique morphology. We propose that our two Coordination centres (KOF & CCO) launch the national public campaign. Under the super-

vision of the centres, the RFE/CR could take over the operations in the various regions, relaying information in the regional/local medias. Along with the aim of finding new roosts, the campaign would also be used to provide information on the threat to lesser horseshoe bats and on the planned conservation project. The strategy should be discussed together with the Centres and the RFE/CR. An internet site as well as a target-group approach must be envisaged.

Time schedule

It would be advantageous to carry out the enquiry as soon as possible, so that the following research project could benefit from the results.

Monitoring program

In order to facilitate the collection of long-term data on population dynamics, the protocols for population monitoring have to be standardised. The following should be considered:

- Establishment of a minimum monitoring scheme (number of bats present, number of adults vs. young, etc.)
- Focus on the future demographic evolution of nursery colonies
- As far as possible, collection of parameters relating to life history traits and fitness
- Use of this refined monitoring as a tool for control of implementation actions

Description of work

Data collection on population dynamics should, from the outset, considering the need for long-term population surveys and modelling. We propose to establish a working group (in which RFE/CR will be included) with the task to elaborate a common, standardised monitoring scheme. Also, a monitoring centre should collect the data, analyse it on a nation-wide level, provide overviews and, finally, send the results back to the local responsibles. The monitoring scheme should be, as far as possible, Euro-compatible.

Permanent contact and exchange with people in charge of the population dynamics project will be required so as to optimise the improvements in survey methods and efficiency.

Time schedule

A minimum monitoring scheme should be implemented and co-ordinated from the start of the whole project. Fine surveys are expected to be performed every second year.

Action plan

The action plan itself consists of the implementation of all conservation recommendations drawn from the research results. The implementation of the action plan is primarily the responsibility of the RFE/CR. But, according to conservation needs, this may require the enrolment of additional personal and additional funding. Appropriate implementation may also require some clarification of the legal basis for the conservation measures proposed.

Description of work (phase I)

The conclusions from the various research projects should be put into action as soon as they become available.

Time schedule

In order to be able to carry out crucial conservation actions and / or to save time in implementing recommended actions, we must keep the option of carrying out management measures open, even if research work is ongoing.

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Literature list

On the following web site we provide a list of about 700 references (status at Nov. 2000) on lesser horseshoe bats:

<http://www.rhinolophus.net/ref.html>

The list may be downloaded, too.



Fig. 1: Distribution of the lesser horseshoe bat in Europe. The recent distribution is shaded. The dotted line depicts the northern border of the distribution of the species before World War II (after Ohlendorf 1997b).

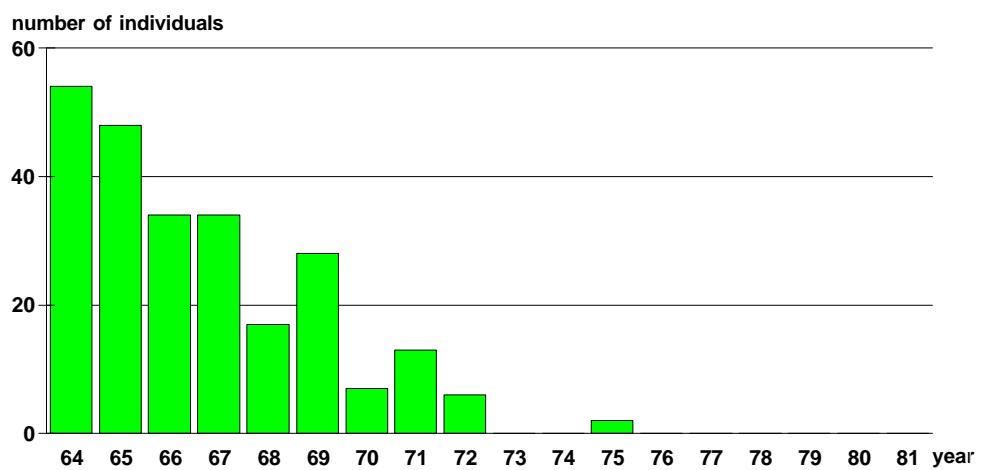


Fig. 2: An example of population decrease at one winter roost in Switzerland (number of individuals, after Arlettaz et al. 1998).

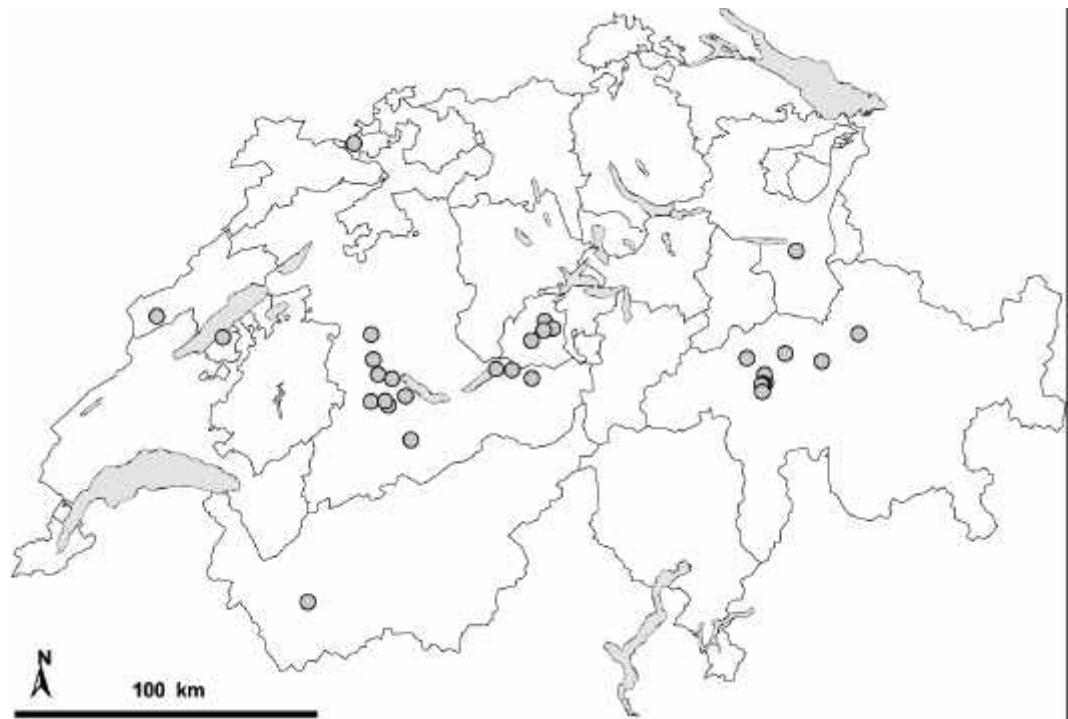


Fig. 3: Distribution of 39 known nursery roosts of *Rhinolophus hipposideros* in Switzerland in 1990-2000.

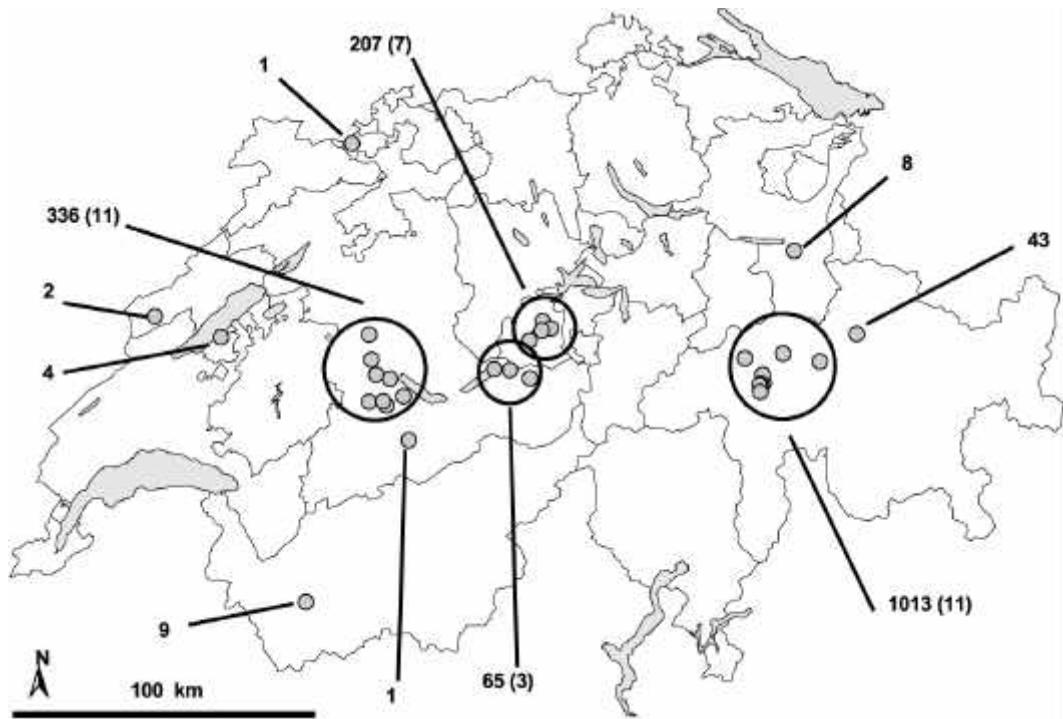


Fig. 4: Distribution of the 39 nursery colonies known in Switzerland in the year 2000. The four clusters of colonies sheltering the largest populations are depicted by circles. The numbers show the maximum number of adult animals counted (number of colonies in brackets).

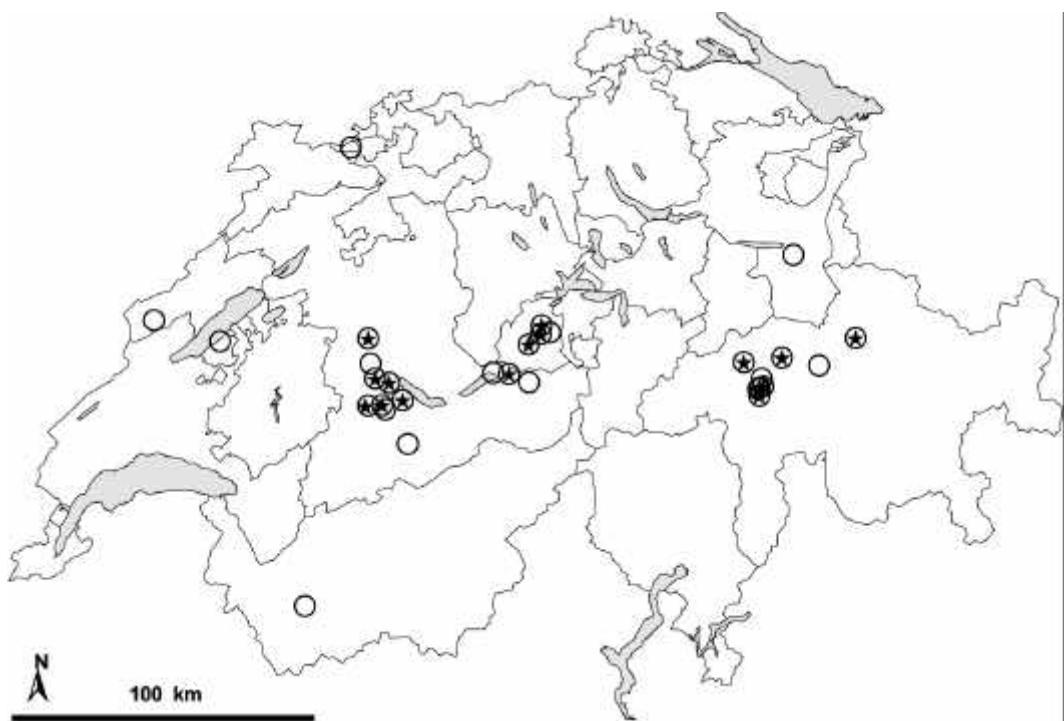


Fig. 5: 22 out of 39 nursery colonies of *Rhinolophus hipposideros* shelter more than 20 individuals each (marked with stars). The largest nursery colonies are situated in the core distribution areas (see Fig. 5).

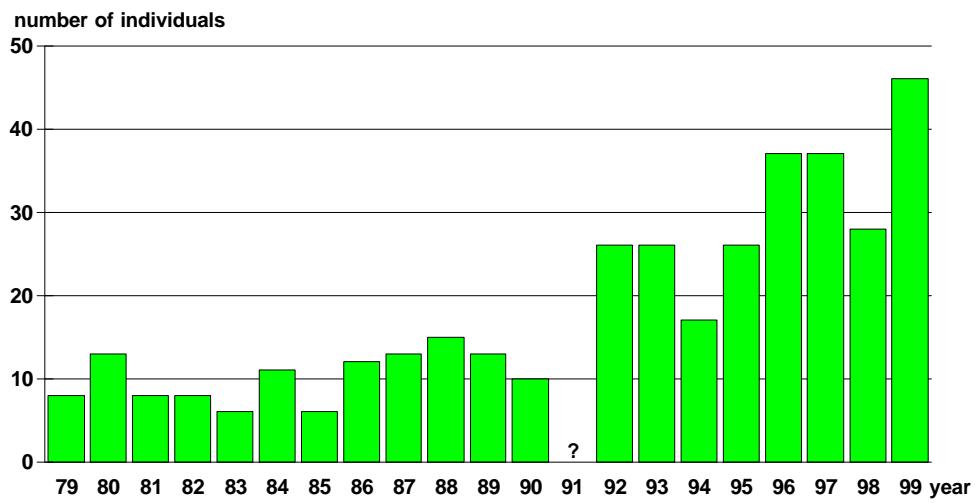


Fig. 6: Example of a recently increasing population: maximum number of individuals censused since 1979 at one maternity roost in Obwalden (data by Alex Theiler).

Table 1: List of the 39 nursery roosts of *Rhinolophus hipposideros* known in Switzerland from 1990 to 2000. The last four roosts of the Canton BE could not be confirmed as nursery roosts in the most recent years.

Canton	Community	max. adults	max. juve- niles	prop. juv. / ad.	year of count	trend
SG	Flums	8		0%	1995	down
SO	Kleinlützel	1		0%	1997	
FR	Estavayer-le-lac	4	3	75%	1999	(stable)
NE	St-Sulpice	2			1990	down
GR	Camuns	20	8	40%	1999	stable
GR	Castiel	43	11	26%	1999	up
GR	Cumbel	11	8	73%	2000	down
GR	Uors-Peiden	120	64	44%	2000	
GR	Uors-Peiden	53	15	28%	1999	stable
GR	Uors-Peiden	150	66	44%	2000	up
GR	Surcasti	166	59	36%	2000	up
GR	St. Martin	245	50	20%	2000	up
GR	Tomils/Tumegl	8			1999	stable
GR	Valendas	24	17	71%	2000	up
GR	Valendas	52	23	44%	2000	up
GR	Waltensburg	121	25	21%	1999	
BE	Blumenstein	75	36	48 %	2000	up
BE	Erlenbach	62	7	11 %	2000	up
BE	Brienzwiler	42	5	12 %	2000	
BE	Daerstetten	19			1998	
BE	Diemtigen	16	10	63 %	2000	
BE	Brienz	11			1999	
BE	Burgistein	40	30	75 %	2000	
BE	Daerstetten	35	11	31 %	2000	
BE	Toffen	30	15	50 %	2000	up
BE	Amsoldingen	25	20	80 %	2000	up
BE	Wimmis	60	20	33 %	2000	
BE	Erlenbach ?	3			1995	
BE	Kandergrund ?	1			1999	
BE	Meiringen ?	12			1999	stable
BE	Wimmis ?	1			1998	down
OW	Giswil	20	16		1999	stable
OW	Giswil	23	6		1999	
OW	Giswil	31			1998	
OW	Giswil	54	33	61%	2000	
OW	Sarnen	30			1997	
OW	St. Niklausen	3	1		1997	
OW	Sachseln	46			1999	up
VS	Le Châble	9			2000	up
total	39 nursery colonies	1676	559			

Table 2: Population trends in 39 nursery colonies from 1990-2000

Population trend	Number of colonies total N (%)	Number of sites with data (%)
Up	12 (31%)	12 (55%)
Stable	6 (15%)	6 (27%)
Down	4 (10%)	4 (18%)
Missing data	17 (44%)	
Total	39 (100%)	22 (100%)

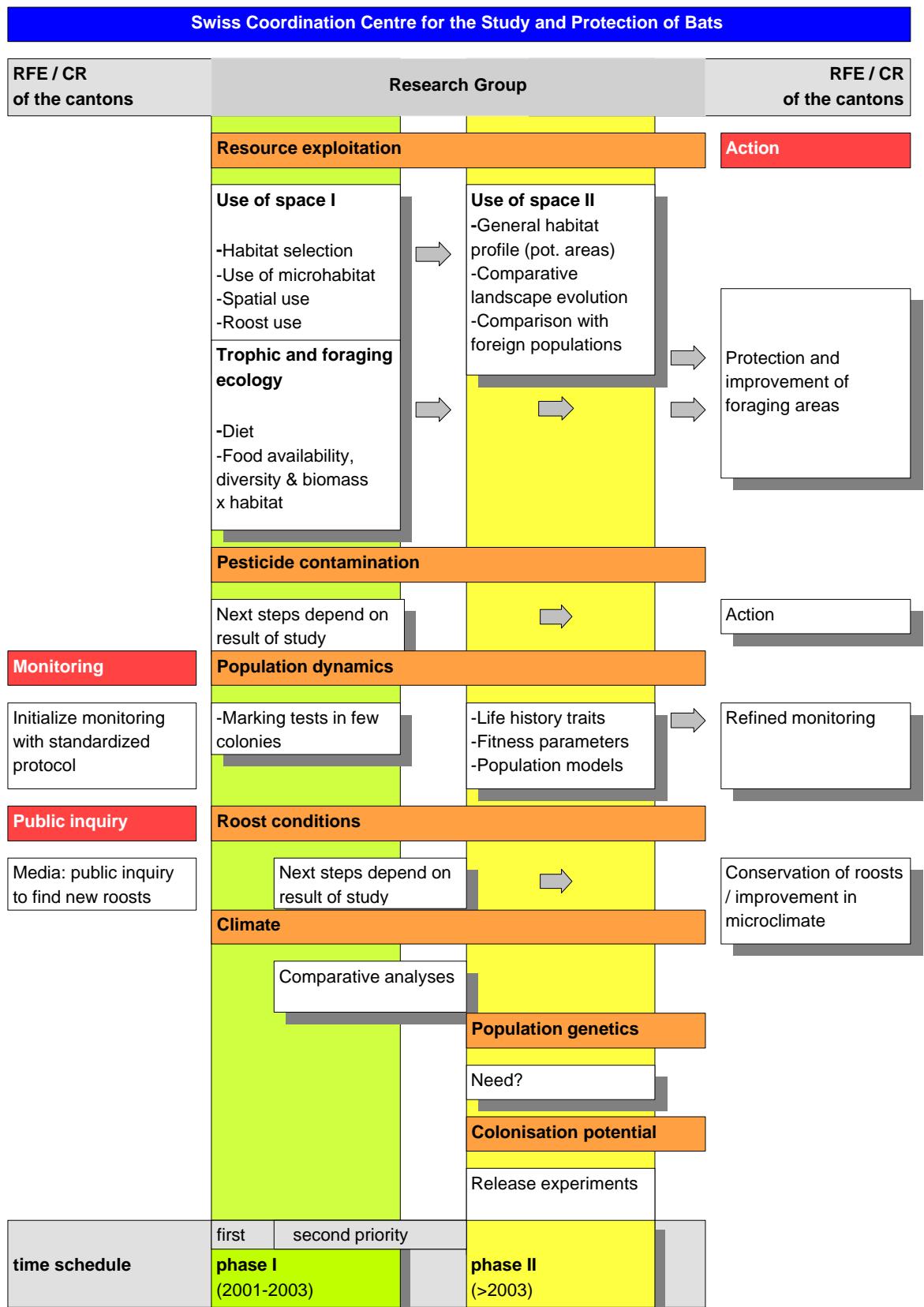
Table 3. Potential causes of regression of the lesser horseshoe bats in Switzerland. Replies from an enquiry submitted to 12 regional bat experts; factors were scored according to an interval scale ranging from 0 (irrelevant factor) to 5 (very relevant factor). Averaged scores were listed in decreasing order.

	Average rank
<i>A. Abiotic factors</i>	
Pesticides	4.0
Changes in the physical structure of habitats	3.1
Loss of roosts and roost deterioration	1.2
Climate changes	0.4
<i>B. Biotic factors</i>	
Food shortage	3.4
Competition against other species	0.8
Genetic inbreeding	0.4
Diseases	0.2
Predation, including human disturbance	0.0

Table 4. Suggestions for priorities in conservation research proposed by 11 regional bat experts; the proposed topics are ranked with respect to the number of mentions.

	number of counts
Habitat use	8
Diet	4
Roost availability/function	4
Identification of potential foraging habitats	3
Comparative landscape evolution	3
Pesticide analysis of faeces/tissues	3
Pesticide analysis of potential prey	3
Connection of roosts	2
Comparison with foreign colony (optimum)	2
Spatial use around nurseries	2
Protection and improvement of foraging areas	2
Landscape analysis around nurseries	2
Structure and microclimate of roosts	2
Changes in climate	1
Finding of new colonies	1
Monitoring colonies	1
Genetic variability within and between colonies	1
Conservation of existing colonies	1
Recolonisation of roosts	1
Reproduction success/body mass and condition/mortality	1
Legal situation for protection of sites	1

Table 5: Overview of the proposed projects.



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