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MINISTÈRE DE LA CULTURE

TRAVAUX SCIENTIFIQUES
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DE LUXEMBOURG

31

Proceedings of the 3rd European Bat Detector Workshop

16-20 August 1996 Larochette (Lux.)

Christine HARBUSCH & Jacques PIR (editors)

Luxembourg, 1999

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Contents - Sommaire - Inhalt

Foreword

50 participants from 15 different countries (from as far as Poland, Croatia, Estonia Tadjikistan and Azerbaijan Republic) attended the 3rd European Bat Detector Workshop convened from 17- 20th of August 1996 in Larochette in Luxembourg. After the Second Bat Detector Workshop held in Spain in August 1993 this meeting was confined to those who already had knowledge about bat detectors.

During this III. EBW new material and its application, results of surveying and monitoring methods for bats were presented as well as the use of computer programms analyzing recorded bat sounds. Evening excursions within different habitats showed the application of bat detector work in the field. During these three days at least 12 of the 19 bat species occuring in Luxembourg could be recorded, so that participants could familiarize with ultrasound calls of species which had been unknown for them up to then.

This meeting revealed the necessity of standardizing surveying and monitoring methods for bats. Only further development of an evident scientific methodology can lead to the target that bats as ecological key stone species are considered more consequently in landscape planning and biodiversity monitoring strategies. This is the major challenge for the organizing commitees of further European bat detector workshops.

We are indepted to all persons helping to organize the 3rd European Bat Detector Workshop in Luxembourg. We are especially grateful to the National Natural History Museum of Luxembourg for the financial and logistic support, and to the Minister of Culture for the financial support. We also like to thank the staff of Youth Hostel in Larochette, our private sponsors and last but not least the Organizing Commitee of the VII European Bat Research Symposium held in Veldhoven (especially P. Lina). All helped

to support this meeting to keep costs low, enabling a great number of partipants to attend the workshop.

Meanwile the European Bat Detector Workshops hopefully have become an institution to share the increasing knowledge about bat detector work, using the ultrasound emissions of our bat species in a more and more consequent way.

Luxembourg, July 1999

The Editors:

Christine HARBUSCH Jacques B. PIR

Trav. sci. Mus. nat. hist. nat. Lux. 31, 1999

Ballades dans l'inaudible
Univers acoustique des chiroptères d'Europe

par

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Abstract

During the last years a rapid development of the knowledge on the bat calls has been noticed. The instruments needed for this have become lighter in weight and financially accessible for a greater number of zoologists. Considering this evolution it became useful to produce a compilation of sound references and a guide to help naturalists using detectors. This is now available as compact disks together with a booklet produced by Catherine Bouchain and Jean Roché and published by Editions Sitelle and the Linnean Society of Lyon. As the items based only on heterodyne records are the most numerous, a whole disk is dedicated to this method with a detailed text to give aids in identifying those species for which the method is valuable. The second disk is dedicated to time expansion for 25 European bat species. The structures of the calls and their variability depending from behaviour or habitat are shown. These sound documents are coming with a booklet for use in the field and a volume giving details of the structures based on acustic analysis, illustrated by many graphs (spectral density, spectrographs,...). These documents being also destinated to a larger public this information is accompanied by an introduction to the knowledge on the echolocation of bats.

Résumé:

Ces dernières années ont connu un développement rapide des connaissances sur les cris des chauves-souris. Le matériel permettant d'y accéder est devenu léger et surtout financièrement accessible à un plus grand nombre de zoologistes. Dans un contexte il est apparu utile de faire un recueil de références sonores ainsi qu'un guide pour aider

les naturalistes qui emploient un détecteur. Ceci se présente sous la forme de disque compacts et de livres produits par Catherine Bouchain et Jean Roché et édités par les Editions Sitelle et la Société Linnéenne de Lyon. Comme les matériels fondés sur le seul principe de l'hétérodyne sont les plus nombreux un disque entier est consacré à cette technique ainsi qu'un texte détaillé pour aider à la détermination des espèces pour lesquelles cette méthode est valable. Le second disque est consacré à l'expansion dans le temps pour 25 espèces de chauves-souris européennes. Les structures des cris ainsi que leur variabilité selon le comportement et le milieu sont illustrées,. Ces documents sonores sont accompagnés d'un livret pour l'usage sur le terrain et d'un fascicule donnant le détail de leur structure fondé sur l'analyse acoustique illustré par de nombreux graphique (densité spectrale, spectrogramme...). Ces documents étant également proposés à un large public ces informations sont précédées d'une introduction à la connaissance de sonar des chiroptères.

Zusammenfassung

In den letzten Jahren war eine schnelle Entwicklung der Kenntnisse über die Rufe der Fledermäuse zu erkennen. Das dazu benötigte Material ist leichter und vor allem für eine größere Zahl von Zoologen finanziell erreichbarer geworden. In diesem Zusammenhang ist es nützlich geworden, eine Übersicht von Referenzrufen zusammenzustellen, sowie einen Führer, um den Fledermausforschern, die einen Detektor benutzen, zu helfen. Dieser präsentiert sich in Form einer CD und einer Broschüre, die von Catherine Bouchain und Jean Roché produziert wurden und vom Verlag Sitelle und der Linné-Gesellschaft von Lyon herausgegeben wurden. Da sehr viel Material auf dem einzigen Prinzip der Frequenzverschiebung (heterodyne) basiert, wurde eine ganze CD dieser Technik gewidmet, sowie ein detaillierter Text, der Hilfestellung für die Bestimmung der Arten gibt, für die die Methode anwendbar ist. Die zweite CD ist der Zeitdehnungstechnik für 25 europäische Arten gewidmet. Die Lautstrukturen und ihre Variabilität in Abhängigkeit von Verhalten und der Umgebung werden gezeigt. Diese Lautdokumente werden begleitet von einer Broschüre für den Gebrauch im Feld und einer Ausgabe, die Details über die Rufstrukturen basierend auf akustischen Anlysen gibt, und durch viele Graphiken (spektrale Dichte, Spektrographen,...) illustriert ist. Da diese Dokumente auch für ein breites Publikum gedacht sind, werden diese Informationen durch eine Einführung in die Kenntnisse über die Echoortung der Fledermäuse begleitet.

1 Introduction*

L'étude du système utilisé par les chauves-souris pour guider, avec habileté, leur vol dans l'obscurité absolue a débuté il y a tout juste deux siècles. Jusqu'à la dernière décennie les recherches le concernant sortaient peu des laboratoires du fait de la lourdeur de la technologie mise en oeuvre pour pénétrer le monde silencieux de ces animaux nocturnes. Depuis quelques années, il est devenu possible de rendre audible à notre oreille les émissions sonores des chauves-souris. Cette possibilité d'accès est due au développement d'appareillages légers, faciles à transporter et à mettre en oeuvre sur le terrain, là même où les chauves-souris sont actives. Ainsi tout un nouveau monde venait d'être découvert par les zoologistes en contact direct avec la nature. Cette nouvelle méthode d'observation a mis en évidence une grande variété de sons jusqu'alors quasiment inconnus. De plus il est devenu possible d'entendre et d'analyser facilement des séquences entières. Devant cette situation, il devient tentant pour le zoologiste d'essayer de reconnaître les espèces en présence. Pour cela il est nécessaire d'avoir des collections de cris émis par des chauves-souris dont l'espèce est rigoureusement déterminée. C'est dans cet esprit que les deux disques compacts ont été conçus sous le titre ***Ballades dans l'inaudible***. Ces enregistrements sont accompagnés d'une part par un livret destiné aux utilisateurs de détecteurs de chauves-souris afin de les guider pour la détermination des espèces et d'autre part, par un fascicule qui reprend les bases scientifiques de ce sonar animal et qui décrit les émissions des espèces figurant dans ces document sonores

Lors de la conception de ces disques compacts le souci pédagogique est resté présent à chaque étape de leur réalisation. Les deux techniques, hétérodynage et expansion temporelle, sont placées sur deux disques distincts car les zoologistes, selon le matériel en leur possession, utilisent l'une ou l'autre de ces méthodes. Pour chacun de ces deux disques une première partie est destinée à l'apprentissage de l'écoute en montrant les critères sur lesquels l'attention doit se porter. Dans la seconde partie les espèces sont illustrées en tant que telles. L'ordre choisi est issu d'une progression des structures acoustiques afin de rapprocher ce qui se ressemble pour faciliter les

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* Les illustrations sonores citées dans cet article correspondent aux deux disques de *Ballades dans l'inaudible*. I correspond au disque 1 "hétérodyne" et II au disque 2 "expansion de temps". Les numéros des séquences sont écrits en chiffres arabes.

comparaisons. Ce classement présente donc des différences avec ce que l'on trouve généralement dans les ouvrages sur les chiroptères. L'ordre de présentation "traditionnel" est repris dans **L'univers acoustique des chiroptères d'Europe** ainsi que pour la liste des espèces qui est incluse dans le coffret.

Cet ensemble de textes et de documents sonores sont édités par les Editions Sittelle avec le parrainage de la Société Linnéenne de Lyon. Le texte présenté ici est un résumé de cette documentation.

2 Techniques d'écoute

Les cris émis par les chiroptères sont constitués essentiellement de fréquences dites "ultrasonores" et de ce fait nous sont inaccessibles. Il est donc impératif de faire appel à un appareillage pour constater leur existence. Lorsqu'on enregistre un oiseau ou un amphibien il est facile de comparer le cri original et sa reproduction. En présence d'un cri de chauve-souris nous entendons une "image acoustique" issue de transformations du cri original. Le résultat varie selon la technique choisie et les paramètres retenus. Pour avoir une idée de ce que peuvent être les modifications apportées par les chaînes d'acquisition on peut écouter, par exemple, le cri ralenti 10 fois d'un rouge-gorge (II-25) et le comparer au chant bien connu de cet oiseau. Pour rendre audibles les ultrasons des chauves-souris il est nécessaire de les transformer. Il n'est pas possible de conserver à la fois l'échelle de temps et la structure intime des émissions sonores. Ainsi avec un système hétérodyne les images sonores obtenues sont synchrones avec les cris de l'animal, mais la structure est perdue. En revanche avec un expanseur de temps la structure est conservée mais l'échelle de temps est modifiée.

Il existe une troisième technique pour rendre audible les cris des chauves-souris : la division de fréquence. Cette méthode consiste à diminuer la fréquence des cris de l'animal par un diviseur tel que le quotient corresponde à une valeur de fréquence incluse dans les limites de l'oreille humaine. Avec un tel appareillage on prend en compte toutes les fréquences. L'échelle des temps est respectée mais l'image sonore des cris est plutôt simpliste car seule les fréquences les plus intenses apparaissent. Si ce système a l'avantage d'être à l'écoute de tout le spectre sonore, il perd en sensibilité. Cette technique étant peu utilisée par les zoologistes, elle n'a pas été illustrée dans les disques compactes présentés ici.

2.1 Hétérodynage

Le système hétérodyne est utilisé sur le terrain dès 1965 avec le détecteur Holgate. Actuellement il équipe la totalité des détecteurs. Avec cette technique les fréquences des cris de chauves-souris sont comparées à celles qui sont issues d'un oscillateur ajustable inclus dans le détecteur. En sortie on entend une image sonore représentant la différence entre les valeurs de ces deux fréquences. Ce procédé a l'avantage de respecter le temps mais les fréquences obtenues en sortie varient selon la valeur de fréquence choisie. Ainsi plus les deux fréquences en comparaison se rapprochent plus le son devient grave et même inaudible lorsque la différence s'annule. Dans cette situation, le "battement zéro" permet de connaître la fréquence principale de la chauve-souris observée. Ceci est illustré avec *Pipistrellus kuhlii* (I-3). Il s'agit d'une méthode simple d'estimer la fréquence principale. Les cris des chauves-souris ayant tous une modulation de leur fréquence pendant l'émission du cri, les hauteurs des sons entendus sont différentes si on aborde la fréquence principale en montant ou en descendant les valeurs affichées des fréquences sur le détecteur. Cette méthode est aussi sensible. Cet avantage est dû essentiellement au fait que l'on écoute dans une bande fréquentielle étroite et ainsi on filtre tout ce qui est sur les autres fréquences. Ceci permet aussi de sélectionner des fréquences pour privilégier l'écoute d'une espèce particulière.

Bien que simple, cette technique permet des observations intéressantes si l'on dispose d'un détecteur ayant un microphone de qualité et une échelle de fréquence suffisamment précise. Avec un certain entraînement on peut reconnaître la structure par balayage ascendant et descendant. Ainsi on peut entendre la différence entre un cri long en fréquence constante (*Rhinolophus hipposideros* I-1), un cri bref en fréquence quasi-constante (*Pipistrellus kuhlii* I-3) et un cri très modulé (*Myotis daubentonii* I-5). Dans ce dernier cas le son entendu est sensiblement constant car il n'est pas possible de faire le battement zéro en présence d'un cri bref fortement modulé en fréquence. En se plaçant sur une fréquence il est possible de détecter la présence d'animaux appartenant à des espèces différentes (*P. pipistrellus* et *P. kuhlii* I-4 ou *P. pipistrellus* et *Myotis daubentonii* I-6).

Cette méthode, qui respecte l'échelle de temps, est très utile pour déterminer le rythme d'émission. Ce paramètre est intéressant pour avoir une idée du comportement (séquences I-8 à 13).

En résumé, le système hétérodyne, très simple et très sensible, est une technique fondée sur la comparaison avec une fréquence de référence choisie par l'opérateur. De ce fait des cris ainsi enregistrés n'ont de valeur que si la fréquence de référence est notée immédiatement.

2.2 Expansion dans le temps*

L'expansion de temps consiste à enregistrer une séquence de cris de chauves-souris et à la rejouer avec un ralenti tel que le résultat soit audible. Ainsi les oscillations se retrouvent étalées dans le temps ce qui a pour effet d'abaisser leur fréquence. Ce fut la première technique utilisée pour obtenir l'intégrité des cris sonar des chiroptères au moyen d'un magnétophone. Avec cet appareillage on enregistre à une vitesse d'au moins 76 cm/s et on rejoue en faisant défiler la bande à 4,5 cm/s ce qui donne un ralenti de 16 fois. La famille des enregistreurs Racal est un exemple de ce type d'instrument. Si ces matériels donnent de bons résultats, leur poïds et le cortège d'accessoires nécessaires à leur bon fonctionnement (oscilloscopes, alimentation électrique etc.) constituent un handicap sérieux pour leur emploi sur le terrain. Avec le développement récent des détecteurs utilisant une mémoire RAM il devient possible d'enregistrer de brèves séquences et de les rejouer ralenties. Ce matériel léger associé avec un magnétophone à cassette permet d'aller sans contrainte là où les chauves-souris sont actives.

Ces divers matériel ont diverses possibilités pour ralentir. Ainsi avec un magnétophone les ralentis ne peuvent être que 8, 16 ou 32 fois. Le détecteur D980 de Pettersson Elektronik ne dispose actuellement que d'un ratio de 10 et les S350 et PUSP de Ultra Sound Devices des ratios : 2, 5, 10, 15, 20 et 50. Lorsqu'on enregistre avec ces matériels il est impératif d'indiquer le coefficient de ralentis sinon on risque de confondre pipistrelles et sérotines. Dans le disque dédié à l'expansion de temps le coefficient 10 a été retenu pour la simple raison que les enregistrements ont été obtenus avec un

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* Les exemples de cris expansés cités ici sont illustrés dans *L'univers acoustique des chiroptères d'Europe*

détecteur D980. Cependant un ralenti de 10 fois n'est pas le meilleur. En effet l'oreille humaine possède son optimum de sensibilité entre 1000 et 3000 Hz avec un maximum entre 1500 et 2000 Hz. La plupart des chiroptères ont des émissions entre 30 et 50 kHz. Ralenties 10 fois on obtient une fourchette de 3000 à 5000 Hz qui se situe sur des fréquences où la sensibilité auditive humaine décroît alors qu'avec un ralenti de 20 fois on se place entre 1500 et 2500 Hz où nos conditions d'écoute sont meilleures. De plus avec un ralenti de 20 fois la durée du cri enregistré double ce qui facilite l'estimation de la fréquence par notre oreille, en particulier en présence des cris très brefs des Vespertilionidés. Ces contraintes techniques montrent l'intérêt de connaître le coefficient du ralenti quand on écoute des cris obtenus par expansion de temps.

Le disque 2, "Expansion de temps" comporte un première partie destinée à l'apprentissage auditif pour la reconnaissance des cris ralentis 10 fois. Alors qu'avec un système hétérodyne on doit sans cesse comparer l'image sonore perçue avec une fréquence de référence, ici le cri est considéré dans sa totalité et l'éducation de l'oreille de l'observateur prend de ce fait une plus grande importance. En premier lieu l'attention est orientée sur la **fréquence**. Les trois premières séquences sont émises par *Pipistrellus kuhlii*, *P. pipistrellus* et *Miniopterus schreibersii*. Ces chauves-souris utilisent des cris de structure semblables : une fréquence très modulée en début et quasi constante ensuite mais la fréquence principale diffère (II-1 à 3). Ceci étant acquis on passe en deuxième lieu à la reconnaissance de la **structure**. Si celle des longs cris de fréquence constante comme ceux des rhinolophes (II-4) est facile à reconnaître, la tâche est plus difficile en présence de cris de Vespertilionidés. Une sélection de structure fondamentale est illustrée par les séquences II-5 à 15. On trouve successivement des cris d'*Hypsugo savii* ayant une durée de plus de 10 ms où la fréquence est quasi constante avec une faible modulation (II-5), des cris de *Pipistrellus kuhlii* émis sur des fréquences voisines (II-6). En début de ces derniers cris, la fréquence est modulée puis devient quasi constante. Ainsi progressivement on arrive aux structures complexes des cris sociaux (II-12 & 13) et on termine par des variations de structure quand l'animal émet des cris de détection et d'autres pour la localisation (II-14 & 15) tels que ceux de *Nyctalus leisleri* et de *P. pipistrellus*. La **durée** est aussi un paramètre utilisé pour décrire les émissions sonores (II-16 & 17). Dans quelques cas le caractère spécifique du cri apparaît dans la **répartition de l'énergie** au cours de l'émission (II-18 à

21). Le **rythme d'émission** des cris sonar apporte des informations qui concernent plus le comportement que l'espèce (II-22 & 23). Tous les exemples qui illustrent cette première partie doivent être écoutés attentivement afin de mieux percevoir les nuances des séquences de chacune des 25 espèces présentées dans la seconde partie du disque.

3 Emissions sonores des chiroptères

Avec les cétacés et quelques espèces d'oiseaux les chiroptères utilisent leur émissions sonores dans deux fonctions indépendantes, d'une part la communication et d'autre part la perception du milieu où ils vivent. Cette dualité conduit à deux démarches tout aussi indépendante pour leur étude.

3.1 Cris sociaux

La fonction d'un cri social est de transmettre une information d'un animal à un autre qui comprend le message. Les chauves-souris émettent leurs cris selon les usages traditionnels : appel du partenaire sexuel, menace envers un importun qui pénètre dans le gîte, avertissement à l'encontre d'une autre chauve-souris qui chasse dans le même espace alors que la densité des insectes en vol est insuffisante. Ces cris sociaux innés sont le reflet de l'espèce et de ce fait sont très utiles pour la détermination des espèces. Ceci est particulièrement valable pour distinguer *P. kuhlii* de *P. nathusii* qui ont des cris sonar très voisins tant dans leur structure que dans leurs fréquences (II-68 & II-71).

Parmi les cris enregistrés dans des colonies de parturition on remarque des émissions des jeunes qui sont les prémices des cris sonar de l'adulte. Dans la séquence II-28 obtenue dans une colonie de *Rhinolophus ferrumequinum*, on remarque des cris intenses en fréquence constante 20 kHz et des harmoniques dont l'intensité décroît avec leur rang. Au cours de leurs développement ces animaux concentrent progressivement leur énergie sur le 4^{e} harmonique qui seul subsiste chez l'adulte comme signal sonar.

3.2 Cris sonar

Avec cette fonction nous quittons la communication pour un système de perception de ce qui est autour de la chauve-souris. Dans ce contexte, la rigueur des lois de la physique est le cadre qui définit la structure des cris. Ceux-ci ont perdu leur mission de porteurs de message pour être des composants d'un sonar biologique. Ainsi la structure des cris sonar est avant tout le reflet d'un comportement avant d'être celui d'une espèce comme l'est un cri de communication. La chauve-souris "interroge" ce qui est devant elle. Elle adapte son cri à l'information recherchée. De plus elle tient compte d'autres paramètres : le milieu immédiat, sa vitesse et son type de vol. La trentaine d'espèces qui vivent en Europe exploitent des ressources alimentaires différentes : insectes en vol, posés sur le sol. Certaines chassent en espace très dégagé, d'autres en sous-bois. Ces différences éthologiques soulèvent des problèmes tout aussi différents qui se traduisent par des structures distinctes de cris sonar. De ce fait les espèces auront des signaux sonar d'autant plus différents que des différences apparaissent dans leur comportement. De cela il faut retenir que devant un cri sonar il faut simultanément associer l'espèce, le milieu et le comportement sinon le risque d'erreur d'interprétation est grand. Du fait de leur propriétés l'étude des signaux sonar est conduite selon une démarche qui leur est propre. Alors qu'en présence de cri sociaux on se limite à une simple description de la structure acoustique, avec les signaux sonar on utilise plus largement les outils mathématiques pour en déduire leurs propriétés : précision et résolution en distance et en angle, tolérance à l'effet Doppler...

4 Techniques d'analyse

Actuellement la seule analyse possible sur le terrain se limite à la mesure par hétérodynage de la fréquence principale. Pour aller au-delà, pour obtenir une représentation en temps et fréquence de la répartition de l'énergie du cri, il est nécessaire de faire un enregistrement, en général sur bande magnétique, en faisant appel à l'expansion de temps. Cette façon de faire préserve tout le détail qui constitue le cri, alors que l'hétérodynage ne restitue qu'une image imparfaite. Pendant longtemps le sonagraphe fut l'instrument essentiel pour analyser un son et obtenir, par filtrage successif, un sonagramme. Avec le développement de l'informatique il est facile et rapide d'obtenir des représentations graphiques. Comme lors de la restitution acoustique des ultrasons nous obtenons ici des résultats variables selon le choix des paramètres de calcul. En particulier lorsqu'on utilise les transformations de Fourier il n'est pas possible d'avoir simultanément une bonne résolution en temps et en fréquence. Un choix doit être fait selon la structure des cris. Sans entrer dans le détail, il est nécessaire en regardant une représentation graphique (sonagramme, spectrogramme, densité spectrale...) d'avoir présent à l'esprit les paramètres de calcul pour faire une interprétation correcte.

Ces techniques d'analyses sont nécessaires pour connaître la structure fine des cris dans sa totalité. C'est ainsi que l'on visualise comment la fréquence varie au cours de l'émission du cri par la chauve-souris et mieux percevoir les fréquences fortement modulées et celles qui sont quasi constantes. La densité spectrale donne l'importance relative de toutes les fréquences présentes alors qu'avec le système par hétérodyne une bande étroite seulement est examinée. Ces méthodes montrent également les harmoniques, permettent de distinguer les cris sonar dans un milieu très bruité ou lorsque des animaux de même espèces ou non chassent en même temps. Des exemples sont illustrés dans L'**Univers acoustique des chiroptères d'Europe.**

5 Sonar biologique

Nous sommes en présence d'une fonction de perception. Les cris sonar sont perpétuellement adaptés aux circonstances. Ainsi pour une espèce donnée on observe des variations dans les émissions sonores dont les structures dépendent à la fois du comportement et du milieu.

5.1 Influence du comportement

Selon l'activité les chauves-souris modifient la structure de leur cri de façon optimale. Le comportement le plus simple est le **vol de transit**. Il est illustré par le vespère de Savi (II-75) ou la sérotine commune (II-80). C'est un vol direct permettant à la chauve-souris de se déplacer depuis son gîte vers ses terrains de chasse. En espace sans obstacle le rythme d'émission est lent avec souvent moins de cinq cris par seconde. Ce type de vol est peu aisé à enregistrer car l'animal ne fait qu'un passage et disparaît. L'analyse des cris révèle des structures adaptées à la détection. Quand une chauve-souris chasse, elle reste dans un espace limité où en général elle vole en cercle. Ce **vol de chasse** est de ce fait plus facile à observer. L'animal restant dans le champ du détecteur pendant plusieurs minutes, il est alors possible d'utiliser l'hétérodynage par comparaison avec le contenu du CD I tout en étant très attentif à la valeur affichée qui elle seule donne un sens à ce qui est restitué par le détecteur. Dans ce contexte on reconnaît des cris de localisation. Leur bande fréquentielle plus large et leur fréquence principale plus élevée en comparaison avec les cris de détection traduisent une stratégie de chasse variant selon l'espèce. Cela peut conduire à la détermination de la chauve-souris entendue. La différence de structure des cris de détection et de localisation apparaît nettement dans la séquence II-9 émise par *Nyctalus noctula* qui alterne ces deux types d'émission sonore.

La poursuite et la capture de proie sont des actes importants dans le comportement des chauves-souris. Avec une durée inférieure à 200 ms, cet épisode est difficile à observer avec un système hétérodyne. L'accélération du rythme d'émission se traduit par un crépitement bref difficile à comparer avec la fréquence de référence. En revanche avec l'expansion de temps on peut distinguer le passage des cris de localisation à la poursuite dans les séquences II-39 avec un *Myotis capaccinii* ou II-70 avec *Pipistrellus nathusii*. Les cris émis pendant une poursuite sont peu utiles pour la détermination des espèces.

5.2 Influence du milieu

L'adaptation des cris au milieu est plus marquée lorsque les chauves-souris chassent. En effet pendant les vols de transit, quand l'animal se déplace directement vers son territoire de chasse, il choisit souvent une trajectoire éloignée des obstacles. De ce fait, il se place dans une situation où l'espace est dégagé. Dans ces conditions les cris sont constants dans leur structure. Il en est de même des poursuites quand prédateur et proie sont proches l'un de l'autre et dans ces conditions le milieu intervient peu.

Les variations les plus nettes apparaissent lorsque les chauves-souris chassent. Cependant il faut distinguer le cas où on met en premier le milieu et que l'on observe ce qu'émettent les animaux, de celui où l'on donne la priorité à un animal et que l'on suive les variation de ses cris selon le milieu où il vole.

Ainsi si on considère un milieu déterminé, une prairie par exemple, où chassent près du sol des animaux appartenant à des espèces différentes : *Myotis myotis* (II-29), *Hypsugo savii* (II-74) et *Eptesicus serotinus* (II-81), on remarque une certaine similitude. Le rythme lent du grand murin, la fréquence principale plus élevée pour le vespère peuvent être des critères de détermination avec une certaine expérience. Lorsque ce même grand murin vole en sous-bois (II-30) la fréquence principale passe de 29 à 32 kHz et le rythme est plus rapide. Il en est de même pour la sérotine. D'une façon générale lorsque le milieu est plus encombré le rythme s'accélère et la fréquence principale croît. De ces constatations il ressort que si on veut faire des comparaisons ou des statistiques sur des cris, on doit s'assurer non seulement qu'il s'agit de la même espèce mais aussi que le milieu et le comportement sont identiques.

6 Détermination des espèces

La finalité de ces études est de pouvoir identifier les espèces. L'observation visuelle étant difficile, souvent impossible, une telle méthode est séduisante d'autant plus que les chauves-souris ne sont pas manipulées ni capturées à l'aide de filet. De plus les espèces qui chassent à grande hauteur deviennent accessibles. Lorsqu'on écoute des cris sonar il faut prendre en compte simultanément : l'espèce, le comportement et le milieu. L'intérêt des disques associés à cette publication est d'illustrer la variabilité des émissions sonores. Un entraînement de l'oreille et l'expérience restent encore essentiels pour obtenir de bons résultats. Actuellement il n'existe pas encore de clés de détermination au cheminement simple car il est nécessaire d'associer les divers critères descriptifs des cris que sont : la fréquence principale, le rythme d'émission, la structure, la durée à ceux qui dépendent du milieu, du comportement. Cela doit se faire aussi en pensant qu'il existe des cas limites, comme le long d'une lisière ou d'une haie, où des espèces que l'on rencontre surtout dans les espaces dégagés peuvent venir chasser près du feuillage ou même entre les branchages et inversement.

Dans l'état actuel de la technologie mise à la disposition des zoologistes le problème de la détermination des espèces peut, en premier lieu, se faire par la méthode de l'hétérodynage. Celle-ci est la plus répandue et on la trouve sur les détecteurs les plus simples. Cependant pour pouvoir faire de bonnes observations il est nécessaire de disposer d'un système permettant d'ajuster la fréquence de comparaison à 1 kHz près. Cette possibilité se trouve les détecteurs équipés d'un affichage digital. Ce matériel en main il y a lieu de "se faire l'oreille" en comparant ce que l'on entend dans la nature avec les séquences du disque 1 "hétérodyne". Dans cet exercice il faut être très attentif au fait que les comparaisons sont valables que si la fréquence de référence est la même. Ceci étant maîtrisé le guide du fascicule **Ballades dans l'inaudible** permet, dans un premier temps, de reconnaître les espèces sans problèmes puis passer progressivement au cas plus difficile. Il ne faut pas vouloir déterminer à tout prix car nous manquons encore de recul. N'oublions pas qu'il n'est possible d'écouter confortablement les chauves-souris que depuis cinq ans alors qu'on le pratique depuis des siècles pour les oiseaux. De plus plusieurs animaux peuvent être présents sans qu'il soit possible de le constater.

La détermination par expansion de temps nécessite un investissement financier plus important. Cette méthode demande beaucoup d'expérience et de mémoire auditive si l'on veut faire de bonne détermination. Cependant elle offre l'avantage de pouvoir conserver l'observation sur un support magnétique. Ainsi il est possible d'écouter au calme et de comparer avec les séquences du disque 2 "expansion temporelle" en étant attentif au fait que le coefficient de ralenti soit le même. De plus il est possible de comparer ses propres observations avec celles d'autre zoologistes et éventuellement faire des analyses acoustiques. Le fascicule **Ballades dans l'inaudible** donne la démarche sur le terrain qu'il est utile de compléter par les informations et graphiques de **l'Univers acoustique des chiroptères d'Europe.** Ainsi la détermination de la plupart des espèces européennes devient possible.

7 Conclusions

Ainsi avec cette association textes et documents sonores nous espérons constituer une collection de référence des cris des chiroptères de la faune européenne dans des conditions de comportement et de milieu de vol bien défini. Ceci dans deux finalités possibles, d'une part aider le bon usage des détecteurs afin d'avoir des déterminations fiables et d'autre part faire connaître cette fonction sonar, si développée chez les chiroptères, aux naturalistes qui cherchent à comprendre ce qui se passe dans la nature.

8 Documents associés

Ballades dans l'inaudible par Michel Barataud

(2 CD et livret de 50 pages, descriptif de la méthode de détermination à l'aide d'un détecteur de chauves-souris; traduction anglaise: The world of bats; traduction allemande: Balladen aus einer unhörbaren Welt)

L'Univers acoustique des chiroptères d'Europe par Yves Tupinier

(130 pages, initiation à l'étude des cris sonar des chauves-souris et descriptions des émissions de 25 espèces européennes; traduction anglaise: European bats: their world of sound; traduction allemande: Die akustische Welt der europäischen Fledermäuse)

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Time expansion ultrasound detectors

by

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Abstract

A short overview of different ultrasound conversion techniques is given. The time expansion technique is unique in the sense that it preserves virtually all characteristics of the original signal. This technique is described in detail, as are some of the basics of digital signal processing. A few examples of bat calls recorded with both heterodyne and time expansion detectors are given. The sound samples are replayed and compared in order to illustrate the advantages of the time expansion technique. Some new methods to further enhance the usefulness of time expansion detectors are also presented.

Résumé

Une vue d'ensemble des différentes techniques de conversion des ultrasons est présentée. La technique d'expansion de temps est unique dans le sens où elle garde virtuellement toutes les caractéristiques du signal original. Cette technique est décrite en tous les détails, comme par exemple certaines informations fondamentales sur le traitement digitalisé du signal. Quelques tracés de cris de chauves-souris enregistrés sur les deux types de détecteur, hétérodyne et expansion de temps, sont présentés. Les échantillons de son sont repassés plusieurs fois et comparés pour illustrer les avantages de la technique d'expansion de temps. Quelques méthodes nouvelles permettant d'augmenter l'utilité des détecteurs à expansion de temps sont également présentées

Zusammenfassung

Es wird eine Zusammenfassung von verschiedenen Techniken der Ultraschall-Umwandlung gegeben. Die Zeitdehnungstechnik ist einzigartig in dem Sinne, dass sie fast alle Charakteristika des ursprünglichen Signals erhält. Diese Technik wird detailliert beschrieben, genauso wie einige Grundlagen der digitalen Signalverarbeitung. Einige Beispiele von Fledermausrufen, die mit heterodynen und Zeitdehnungs-Detektoren aufgenommen wurden, werden gezeigt. Die Lautbeispiele werden vorgestellt und verglichen, um die Vorteile der Zeitdehnungstechnik darzustellen. Einige neue Methoden, die die Nützlichkeit der Zeitdehnungsdetektoren weiter erhöhen, werden vorgestellt.

1 Introduction

Time expansion is a very useful method to transform ultrasound into audible sound, since it preserves virtually all characteristics of the original signal. A short overview of different ultrasound conversion techniques is given in this text, and time expansion is described in detail. Different implementations of the time expansion principle are discussed, and some methods to enhance the usefulness of time expansion ultrasound detectors are suggested.

2 Ultrasound conversion principles

The most common ultrasound conversion principles are heterodyning, frequency division and time expansion (see also Pettersson, 1993).

In a *heterodyne* detector, the ultrasonic signal is mixed with a reference signal, the frequency of which is adjustable, producing the sum and difference frequency of the two signals. Provided that the reference frequency ("the tuned frequency") is chosen close to the ultrasonic frequency, the difference frequency will be audible. Obviously this will make a range of frequencies, centered around the tuned frequency, audible. Consequently this is a narrowband technique.

One advantage of the heterodyne principle is its high sensitivity. Since a small portion of the entire ultrasonic frequency range is cut out and made audible, only a fraction of the full bandwidth noise will be made audible, resulting in a good signal to noise ratio.

The *frequency division* technique makes use of a digital frequency counter to reduce the frequency. As the name hints, the output frequency from a frequency division detector is a fixed fraction of the input frequency (e.g. one tenth). Since a digital frequency counter is capable of generating only two levels ("0" and "1") at its output, all amplitude levels of the original signal will result in the same fixed output level, provided that the amplitude of the input signal exceeds a preset threshold level. Consequently all amplitude information is lost in the basic frequency division detector.

There are, however, more advanced frequency division detectors, where the original signal amplitude is monitored and used to control the amplitude of the frequency division output signal. This *retained amplitude frequency division* principle provides more information than the basic principle.

The frequency division detector is a broadband device, in contrast to the heterodyne detector, so the entire ultrasonic frequency range is made audible, without tuning the detector. The sensitivity is lower, though. It should also be noted that working with more complex input signals may cause the frequency division detector to occasionally "lock" on a harmonic rather than the fundamental frequency. Obviously this will produce an output frequency higher than that expected.

The *time expansion* technique is different from other ultrasound conversion techniques in that it preserves virtually all characteristics of the original signal. The principle is similar to making a tape recording of the signal and then replaying this at reduced speed. If the time expansion factor is 10, a sequence of one second will take 10 seconds to replay, and all frequencies will be 10 times lower than they initially were. The fact that the original characteristics of the signal are preserved make time expanded signals ideal for sound analysis. Since the sounds are stretched out in time, it is also possible to hear details in the sounds not audible with other conversion systems, facilitating identification in the field.

Numerous examples could be given, demonstrating the advantages of the time expansion technique. E.g. the alternating pulses with different pitch from *Barabastella barbastellus* are easily heard in a time expansion detector. Pipistrellus pipistrellus and Pipistrellus nathusii both have an undulating portion in their respective calls. Using a time expansion detector they are easily told apart, since the high pitch chirp present only in the call from Pipistrellus nathusii is very evident.

3 Some fundamental issues in digital signal processing

Signal processing in general and digital signal processing in particular is a very large and rapidly evolving area. In this short summary only a few of the most fundamental issues are briefly discussed. For an in-depth discussion about this subject, the reader is referred to the extensive literature available, e.g. Proakis-Manolakis, Digital Signal Processing.

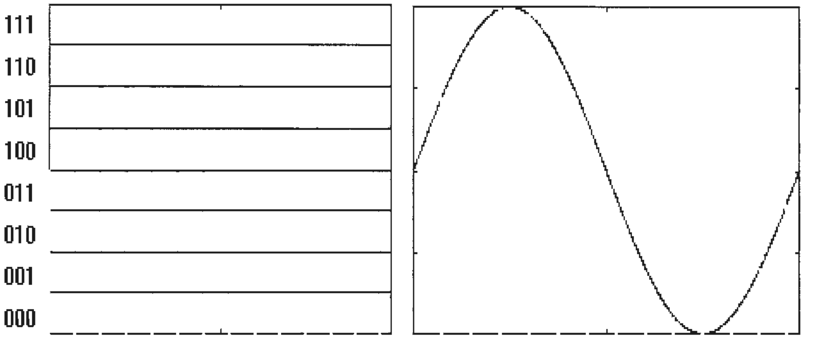
The storage medium in a time expansion bat detector is usually a digital memory, so the analog input signal must be converted into a digital signal. This process, which involves the steps *sampling*, *quantization* and *coding*, is taken care of by an Analog-to-Digital Converter (ADC).

Sampling of the analog signal means that it is sampled at (usually) regular intervals. The time between successive samples is referred to as the *sampling period.* At a sampling period of 1 ms, 1000 samples per second are taken. We say that the *sampling frequency* is 1000 Hz.

One interesting question is; how high a sampling frequency should be used (i.e. how close in time should samples be taken)? Obviously, the resemblance between the sampled signal and the original signal is better the higher the sampling frequency. On the other hand, a higher sampling frequency means that each second of the sampled signal will occupy a larger portion of the available memory, limiting the total storage time.

In order to be able to recover the original signal from the sampled signal, a sufficiently high sampling frequency must be used. The *sampling theorem* gives the theoretical lowest possible sampling frequency:

> ***The sampling frequency has to be at least twice as high as the highest frequency component in the signal.***



Resulting binary coded samples: 100, 101, 111, 111, 111, 110, 101, 011, 000, 000, 000, 001, 011

Fig. 1. Sampling, quantization and coding.

That means that an audio signal with a frequency content extending up to 20 kHz has to be sampled at least 40000 times per second. In practice, a higher sampling frequency is used (cf. digital audio equipment, where a sampling frequency of 44.1 or 48 kHz is used).

If the signal frequency is allowed to extend above *the Nyquist frequency,* f_N (half the sampling frequency), so called *aliasing* will occur. In such case the frequency of the sampled signal will be lower than that of the original signal.

Assume a sampling frequency of 20 kHz is used. The theoretical upper signal frequency limit is then 10 kHz. Applying a signal frequency of 12 kHz (2 kHz above f_N), will cause the signal frequency to be folded at the Nyquist frequency, resulting in a sampled signal with a frequency of 8 kHz (2 kHz below f_N).

Prior to sampling a signal, it should be low-pass filtered to ensure that any frequency components above f_N are sufficiently attenuated. This may require quite steep *anti-aliasing* filters. However, in many cases less steep filters are used, resulting in weak signal residues above the Nyquist frequency.

The effects of aliasing is demonstrated in the two spectrograms below. In Fig. 2 a) the result without an anti-aliasing filter is shown, while Fig. 2 b) shows the spectrogram after appropriate filtering of the signal. The displayed frequency range extends from 0 and up to f_N. The Nyquist frequency is 22050/2 = 11025 Hz, but here the frequency axis scaling has been changed to instead show the original frequencies, before the signal was time expanded 10 times. Note how the frequency components reaching above f_N are folded in Fig 2 a).

Fig. 2 a). A spectrogram showing a signal with aliasing.

Fig. 2 b). A spectrogram of the same signal as above, but after using a proper anti-aliasing filter.

It should be noted that when a signal is first captured with a time expansion detector, recorded and finally analyzed with a computer-based system, sampling will be made twice. The first time in the detector and the second time when feeding the signal into the computer (unless the samples were transferred digitally from the detector to the computer). It is of course possible that the two sampling frequencies are not identical. In such case aliasing may occur at different frequencies as a result of both sampling processes, creating a very complex spectrogram.

The value of each sample is represented by a value selected from a finite set of possible values. This is the *quantization* process. The difference between the original, unquantized value and the quantized value is called the *quantization error* or *quantization noise.* The latter term is justified by the fact that the error is random and thus has the appearance of noise. The smaller the quantization step, the smaller the error and consequently the lower the noise. A small quantization step is obtained by using a large number of quantization levels, i.e. many binary digits for the quantization.

It can be shown that the signal-to-quantization noise ratio (SQNR) for sinusoidal input signals is given by:

$$SQNR = 1.76 + 6.02n \quad \text{(dB)}$$

where n = number of bits used to quantize the signal

From the above it is clear that the SQNR increases approximately 6 dB for each extra bit used in the quantization process. A similar expression can be derived for other signal types as well.

4 Different implementations of the time expansion principle

4.1 High speed tape recorder

+	Long storage time
-	Large, heavy and expensive equipment required
	The tape has to be rewound before listening
	Requires separate microphone (and preferably also a bat detector)

A few decades ago, high speed instrumentation tape recorders were used for time expansion of ultrasonic signals. The high speed of the tape is required to obtain a sufficiently large bandwidth during recording. Obviously, it is necessary to use a microphone adapted for use at ultrasonic frequencies for this recording. It is also helpful to have a bat detector transforming the ultrasonic calls in real time (e.g. a heterodyne detector), to enable determining when to make recordings on the tape recorder for time expansion.

A typical time expansion sequence would be:

1. Make a recording at a certain (high) tape speed.
2. Stop the recording and rewind the tape.
3. Replay the recording at a lower tape speed.

All instruments performing time expansion store the signal temporarily in one way or the other. Using a magnetic tape as a storage medium has the advantage of allowing storage of comparatively long signal sequences.

Today there are alternatives to the reel-to-reel instrumentation tape recorder. These include modified VHS recorders as well as high sampling rate DAT recorders.

4.2 Digital memory

+	Inexpensive Instant replay Small Low weight
-	Limited storage time (typ. 10-20 seconds @ 150 kHz bandwidth)

The first time expansion bat detectors using digital memories as storage medium appeared on the market about 1985. Compared with the tape recorder approach, these are very compact and low weight units. The cost is also considerably lower. Since there is no tape to rewind, there is no delay between the recording and replay of the signal.

Most time expansion bat detectors are equipped with a second conversion system (e.g. a heterodyne system), and of course also an ultrasonic microphone, so no extra hardware is required.

The storage time is determined by the memory size and the sampling frequency, so at a given sampling frequency the storage time can be extended by simply adding more memory chips to the system. However, considering the capacity of the memories of today it is not practical to reach a storage time comparable to that of the high speed recording described above. The typical maximum storage time of commercially available time expansion detectors with digital memories is in the range 10-20 seconds at a bandwidth of 150 kHz (1996).

4.3 Computer and A/D card

+ Inexpensive
  Instant replay
  Programmable ⇒ operation can be easily changed
  Real time spectrogram of time expanded signal possible
  Long storage time

- Requires separate microphone (and preferably also a bat detector)

Using a computer equipped with a high speed data acquisition card makes it possible to use the computer's hard disk to store the signal. This enables storing (and time expanding) very long sound sequences. Most laptop or notebook computers of today come with a slot for PCMCIA cards allowing the data acquisition card to be plugged in, and with such a computer it is possible to use this technique in the field as well. In this context it should be emphasized that access to the computer's screen or keyboard is not necessary for the operation described above, meaning that the computer can be operated with the screen ”closed”, e.g. carried in a bag over the shoulder. Still this is a less mobile solution than a time expansion bat detector, and with the physical size and weight of the contemporary computers, this method will probably be used primarily in situations where long storage time is required.

An interesting extension to this idea, is to use the computer not only as a storage medium, but also to perform various types of sound analysis immediately after capturing the sounds. For example, it is possible to use the computer as a time expansion unit as outlined above and in addition to this have the spectrogram of the signal displayed at the same time the time expanded signal is replayed. Apart from the short delay between recording the signal and then replaying this in expanded time, this shows the spectrogram in real time. This function has been implemented and is available as an extension to the real time spectrogram analysis software BatSound (Pettersson Elektronik).

Since this is a computer-based solution, it is easy to adapt the system to different situations. Changing the sampling frequency, storage time, time expansion factor, pre-trigger conditions etc. is an easy matter. The performance of the system depends on the computer specifications and the speed of A/D cards available. Today there are 12 bit A/D PCMCIA cards with a sampling frequency of more than 330 kHz available. Provided that sufficiently steep anti-aliasing filters are used, this can give an effective bandwidth of up to about 150 kHz.

The resulting file size per second of recorded sound depends on the resolution (number of bits) and the sampling frequency. E.g. using 16 bits resolution (in practice this also applies to 12 bits) and a sampling frequency of 330 kHz results in a file size of 660 000 bytes per second. This means that a 1 minute recording will occupy about 38 Mb. A 2.4 Gb hard disk can, theoretically, hold about one full hour of recorded sounds. Such an extended recording time is of course primarily of interest when sounds are merely stored (rather than also having the sounds time expanded on the spot, which, considering the time it takes to replay the sound, would require quite a patient user!).

It should also be mentioned that gap-free sampling (sampling without occasionally loosing samples) directly to the hard disk at such high sampling rates requires high-performing computers and that it, in the case of slower computers, may be necessary to use the RAM for temporary storage of the sounds (before dumping it to the hard disk). This will of course impose some restrictions as to the length of each time expansion sequence.

Provided that the user already has a suitable computer at his/her disposal, the cost for this system is quite low, especially considering the potential capabilities of the system.

This technique can be expected to become increasingly common as computers become smaller and lighter, and the storage capacity increases.

5 Improving the time expansion system

5.1 Frequency selective triggering of the time expansion system

In all types of time expansion systems there has to be functions that control when to start and interrupt the recording to the memory (or tape). The simplest arrangement is to have two push-buttons, ”start” and ”stop”. This offers the user full control over the recording process.

Another common arrangement, suitable for more automated operation, involves using a level activated trigger. A button is pressed to start the recording to the memory (often a circular memory buffer). The recording continues until the input signal exceeds a certain threshold (an adjustable ”trigger level”). Depending on the so called pre-trigger conditions, the recording is interrupted immediately when the trigger condition is met, or a short time after this. Obviously, *any* sound with an amplitude exceeding the trigger level will trigger the system and interrupt the recording.

The latter arrangement can be extended to make the triggering system sensitive only to a limited frequency range. As mentioned above, the heterodyne system is a narrowband system which will produce an output signal only if the frequency of the input signal falls in a narrow frequency band, centered around the frequency to which the detector is tuned. Using the heterodyne output signal to trigger the time expansion system instead, results in a frequency selective trigger mechanism. Tuning the heterodyne system to e.g. 45 kHz would cause the time expansion system to trigger when sufficiently strong sounds with a frequency between approximately 40 and 50 kHz appear. It should be noted that the actual recording stored in the time expansion memory of course still is a broadband recording.

The advantage with such an arrangement is that the time expansion system can be made to capture the calls from certain species while rejecting others.

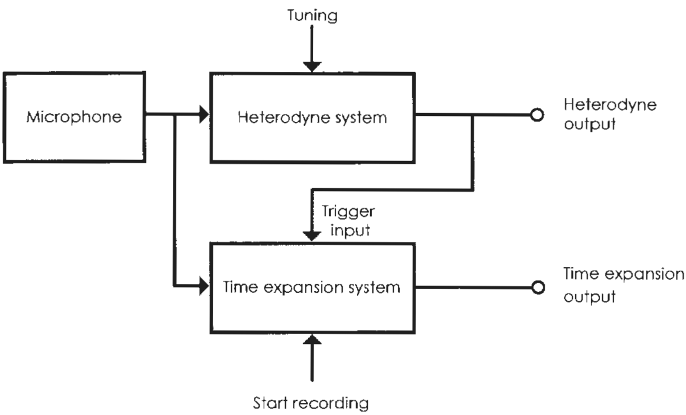


Fig. 3. Frequency selective triggering of the time expansion system.

5.2 Heterodyne analysis of the signal in the time expansion memory

Normally, the signal stored in the time expansion memory is replayed at a much lower rate than it was originally sampled at (otherwise the signal would not be audible). However, the signal in the memory is indeed the original signal and replaying it at the same rate it was sampled at is of course also possible, although we can't hear it then. However, feeding that signal to the heterodyne input of the detector (assuming the detector is equipped with both a time expansion and a heterodyne system) will make the signal audible again, provided that the heterodyne system is tuned properly. In fact, the stored signal can then be carefully analyzed by tuning the heterodyne system up and down, just as could be done when receiving a signal in real time, only that here the user has virtually unlimited time to tune carefully, check for harmonics etc. This can be useful to identify "difficult" species.

The technique can also be used by beginners who are in the process of learning to identify the different species from heterodyne transformed calls. Since the signal in the memory is replayed over and over again, the user is given much more time to learn the characteristics of each call type, compared with using a plain heterodyne detector.

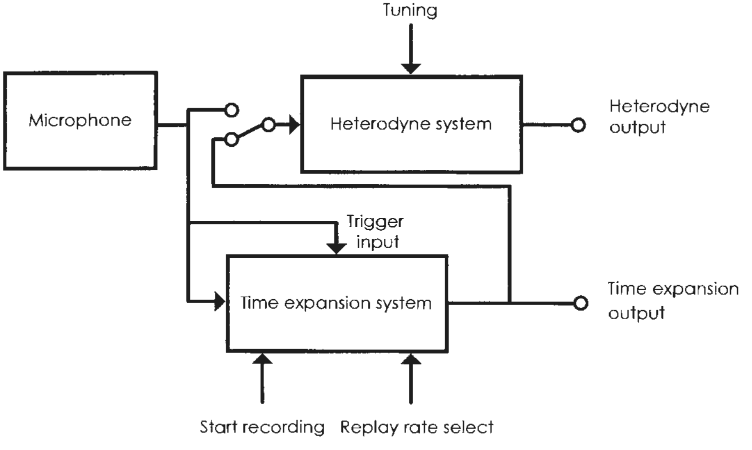


Fig. 4. Time expansion replay through the heterodyne system.

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Die Erfassung der Vorkommen der Nordfledermaus, *Eptesicus nilssonii*, in der Bundesrepublik Deutschland mit Hilfe von Ultraschall

Methodisches Vorgehen, Ergebnisse, Probleme

von

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Abstract:

During the last years the distribution of the Northern bat, Eptesicus nilssonii, in the Federal Republic of Germany was mostly clarified with the aid of ultrasound detectors. Organization of investigations, technique of recording, method of analysis, documentation of results and possibilities of confusion with other species are described and discussed. Also results of investigations about the geographic distribution of the Northern bat are shown and interpreted.

Résumé:

Pendant les dernières années la répartition de la sérotine de Nilsson, *Eptesicus nilssonii*, dans la République Fédérale d'Allemagne a été recensée avant tout à l'aide de détecteurs d'ultrason. L'organisation des recensements, la technique d'observation, la méthode d'analyses, la documentation des résultats et les possibilités de confusion avec d'autres espèces sont décrites et discutées. Les résultats des recensements de la répartition géographique de la sérotine de Nilsson sont également présentés et interprétés.

Zusammenfassung:

Die Verbreitung der Nordfledermaus, *Eptesicus nilssonii*, in der Bundesrepublik Deutschland wurde in den letzten Jahren mit Hilfe von Ultraschalldetektoren größtenteils geklärt. Organisation der Untersuchungen, Aufnahmetechnik, Analysemethode, Ergebnisdokumentation und Verwechslungsmöglichkeiten mit anderen Fledermausarten werden beschrieben und diskutiert. Ebenso werden die Untersuchungsergebnisse zur geographischen Verbreitung der Nordfledermaus dargelegt und interpretiert.

1 Einleitung

Es war der berühmte Heidedichter Hermann LÖNS, der mich veranlaßte, die Verbreitung der Nordfledermaus zu klären. LÖNS (1905, 1906) behauptete in seinen Arbeiten über die Säugetierfauna der ehemaligen Provinz Hannover, daß die Nordfledermaus im Herbst vom Norden her im Oberharz erschiene, dort nur von August an zu beobachten sei und den Harz im Frühjahr verlasse. Diese Aussage schien mir unwahrscheinlich zu sein. Ich bemühte mich daher um den Beweis, daß sich die Nordfledermaus während des ganzen Jahres im Harz aufhielt. Dieser Nachweis gelang mir erst mittels Ultraschalldetektor, mit dessen Hilfe ich im alten Oberbergamt in Clausthal-Zellerfeld eine schon lange bestehende Sommerkolonie der Nordfledermaus nachweisen konnte. Anschließend habe ich dann den Westharz mit dem Ultraschalldetektor nach der Nordfledermaus abgesucht und dort die Verbreitung dieser Art über das Sommerhalbjahr geklärt. Da es keine Hinweise auf einen Zuzug im Herbst aus dem Nordosten gab, hatte ich das erste Ziel, die Widerlegung der Angaben von LÖNS (1905, 1906), schon nach kurzer Zeit erreicht (SKIBA 1986).

Ein zufälliger Nachweis der Nordfledermaus 1984 in Beddelhausen/ Wittgensteiner Land (SKIBA & BELZ 1985) ließ ahnen, daß die Art auch noch anderenorts in den Mittelgebirgen vorkommen konnte. Seitdem habe ich systematisch nordfledermaushöffige Gebiete in der Bundesrepublik Deutschland abgesucht. Über die Vorgehensweise und Ergebnisse möchte ich in folgendem berichten.

2 Material und Methode

2.1 Organisation der Feldarbeit

In jedem Jahr habe ich eine bestimmte Region mehrere Tage aufgesucht und in vollen Nächten nach der Nordfledermaus abgesucht. Veranlassung zur Auswahl der Gebiete waren alte Angaben im Schrifttum, neue Zufallsfunde oder erfahrungsgemäß optimale Habitate. Die Gebiete wurden mit dem Kraftfahrzeug abgefahren oder zu Fuß begangen. Bevorzugt wurden wassernahe Siedlungsrandgebiete mit Quecksilberdampf-Lampen (HQL), deren Licht einen hohen Anteil an Ultraviolett-Strahlen enthält und dadurch auf Insekten anziehend wirkt. Die Untersuchungsrouten wurden für jede Nacht vorher festgelegt, und zwar repräsentativ für eine größere Region, da es die begrenzte Zeit nicht zuließ, jede Örtlichkeit abzusuchen.

2.2 Dokumentationsmethode von Ultraschall

Für die Feldarbeit wurde der Ultraschalldetektor Pettersson D 940 benutzt, der einen Frequenzwählerkanal und einen Frequenzteilerkanal besitzt sowie das Einsprechen von Kommentaren erlaubt, z.B. Beobachtungsumstände und eingestellte Frequenz. Die Dokumentation erfolgte auf Audiokassetten mittels Stereorecorder Sony WMD 6C unter Kopfhörerkontrolle. Dieser Stereorecorder hat einen von Hand einstellbaren Lautstärkeregler. Automatische Lautstärkeregler anderer Recordertypen erwiesen sich als weniger geeignet. Außerdem wurde in allen kritischen Fällen eine focussierbare 20 Watt-Lampe benutzt, um die Fledermäuse auch visuell im Flug beurteilen zu können. Nebenbei war diese Lampe ein erfolgreicher Schutz gegen aggressive Hunde, die geblendet und damit kampfunfähig gemacht wurden. In seltenen Fällen wurden auch ein Nachtsichtgerät und eine elektronenblitzbestückte 6x6-Kamera zur Dokumentation von Flugbildern eingesetzt.

2.3 Analysemethode von Ultraschall

Für die Analyse der Recorderaufnahmen diente ein digitales Oszilloskop mit Pretriggereinrichtung und Möglichkeit zur Zehnfachdehnung der Schirmbildanzeige. Mit Hilfe eines X-Y-Schreibers konnten die Bildschirmanzeigen dokumentiert werden. Die Auswertung der Bildschirmanzeigen erfolgte von Hand in folgender Weise (vgl. Abb. 1):

Frequenzverlauf des Einzelimpulses. Die Zahl der Wellen wurde auf die Zeiteinheit bezogen. Das Ablesen vom Bildschirm erfolgte der Genauigkeit halber in Zehnfachdehnung. Beispielsweise ergaben 2,9 Wellen/ms eine Frequenz in diesem Impulsabschnitt von 2,9 kHz. Unter Berücksichtigung der vorausgegangenen Zehnerteilung betrug dann die Originalfrequenz 29 kHz.

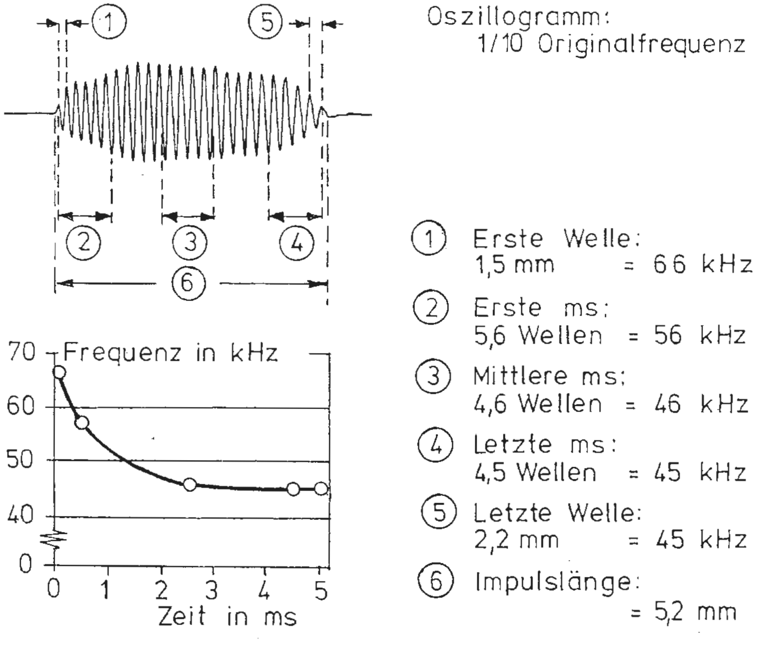


Abb. 1 Prinzip der Auswertung eines Oszillogramms am Beispiel eines Impulses der Zwergfledermaus - *Pipistrellus pipistrellus*.

Errechnung des gemittelten Verlaufs der Frequenzkurve für 10 statistisch repräsentativ ausgewählte Impulse und Errechnung der gemittelten Impulslänge.

Errechnung der zugehörigen Standardabweichung für die erste, mittlere und letzte ms der Frequenzkurve und für die Impulslänge.

Klassifizierung der Impulsabstände Impulsmitte bis Impulsmitte von 200 statistisch repräsentativ ausgewählten Impulsen in 10 ms-Klassen und Berechnung der mittleren Impulsrate in Impulsen/s.

Eine förmliche Spektralanalyse (Fast Fourier Transformation) wurde nicht durchgeführt. Als Ersatz für die Spektralanalyse diente die Kombination der Beurteilung von Frequenzverlauf des Einzelimpulses in Verbindung mit der Hüllkurve des Oszillogramms. Die Hauptfrequenz wurde bereits im Feld mittels Frequenzwähler ermittelt und auf Band eingesprochen.

Alle Ergebnisse (Frequenzverlauf mit Einzelangaben und Standardabweichung, Klassifizierung der Impulsabstände und Impulsrate) wurden abschließend übersichtlich in einer aus Vergleichsgründen standardisierten Grafik zusammengefaßt (Abb. 2).

2.4 Ultraschallinventar der Nordfledermaus

Die Identifikation der Nordfledermaus erfolgte aufgrund folgender Merkmale für freien Suchflug:

I m p u l s r e i h e n

Abstandsklassifizierung der Impulse: in der Regel befand sich ein Maximum in den 10 ms-Klassen um 200 oder 210 ms (gemessen Impulsmitte bis Impulsmitte). Oft ergaben sich zusätzliche Maxima in den 10 ms-Klassen um 300 - 330 ms, manchmal auch um 100 - 120 ms.

Impulsrate: etwa 4,0 - 5,5 (7,0) I/s.

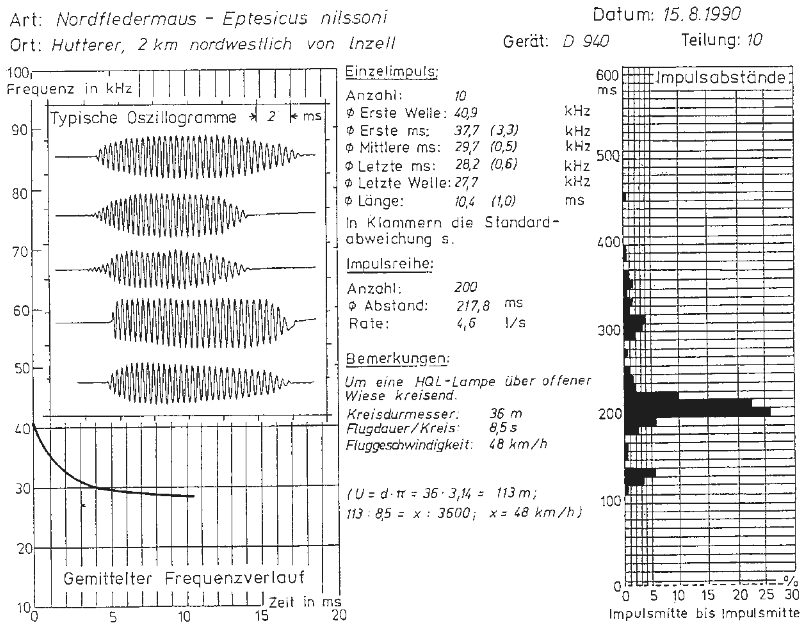


Abb. 2: Formblatt zur standardisierten Darstellung der Ergebnisse einer Ultraschallanalyse von Fledermaus-Rufreihen, hier am Beispiel einer Nordfledermaus - *Eptesicus nilssonii.*

Gleichmäßigkeit des Schall(druck)pegels: wechselnd zwischen verhältnismäßig gleichmäßig (seltener) und ungleichmäßig (häufiger).

Entfernung der Hörbarkeit: 50 - 70 m.

Subjektives Empfinden des Rhythmus: chrakteristisch, nicht so träge wie Zweifarbfledermaus (Vespertilio murinus), keine Aussetzer wie schneller Rhythmus der Breitflügelfledermaus (Eptesicus serotinus), ähnlich dem langsamen Rhythmus der Breitflügelfledermaus, jedoch in der Hauptfrequenz in der Regel 2 - 3 kHz höher, keine "tweet-chock"-Rufe wie Abendsegler (Nyctalus noctula), keine Quietschlaute und nicht so unregelmäßige Impulsabstände wie Kleinabendsegler (Nyctalus leisleri).

E i n z e l i m p u l s

Frequenzverlauf: Impulsbeginn 33 - 46 kHz, zu Beginn frequenzmoduliert, im letzten Impulsdrittel fast frequenzkonstant, Impulsende 26 - 30 kHz (Extremwerte 25 und 32 kHz).

Hauptfrequenz (Maximum nach FFT): etwa 29 kHz.

Schalldruckverlauf: In der Regel zu Beginn gleichmäßig zunehmend, im mittleren Bereich in der Regel konstant, am Schluß gleichmäßig abnehmend, also Hüllkurve des Oszillogramms symmetrisch.

Impulsdauer etwa 7 - 15 ms, Abweichungen ausnahmsweise möglich.

F a n g i m p u l s e

Typischer Impulsabstand 5 - 7 ms (Impulsmitte bis Impulsmitte), Impulsdauer 0,5 bis 2 ms, um 30 kHz; Impulsrate 140 - 200 I/s (vgl. Abb. 3). Kein "Schnurren" wie bei Abendsegler und Kleinabendsegler.

S o z i a l r u f e

Impulsdauer in der Regel etwa 30 ms, von 35 - 42 kHz (etwa Normalimpuls) auf etwa 14 kHz abfallend (vgl. Abb. 3). Im Detektor charakteristisch, aber nicht sehr laut hörbar. Mit Sozial- und Paarungsrufen von Abendsegler und Kleinabendsegler unverwechselbar.

Interindividuelle Abweichungen sind im Suchflug unter etwa gleichen Jagdbedingungen deutlich wahrnehmbar, jedoch im Vergleich zu einigen anderen Arten, z.B. zum Kleinabendsegler, verhältnismäßig gering. Intraindividuelle Unterschiede ergeben sich vorwiegend aus der Jagdsituation. Beispielsweise ist die Impulsrate beim Umkreisen einer Straßenleuchte in der Regel höher als beim Entlangfliegen an mehreren Straßenleuchten.

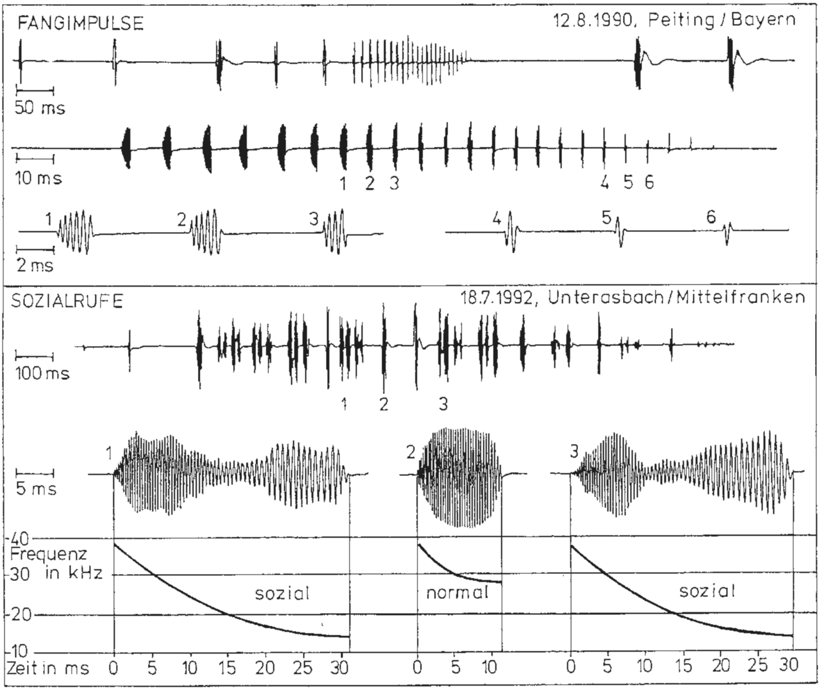
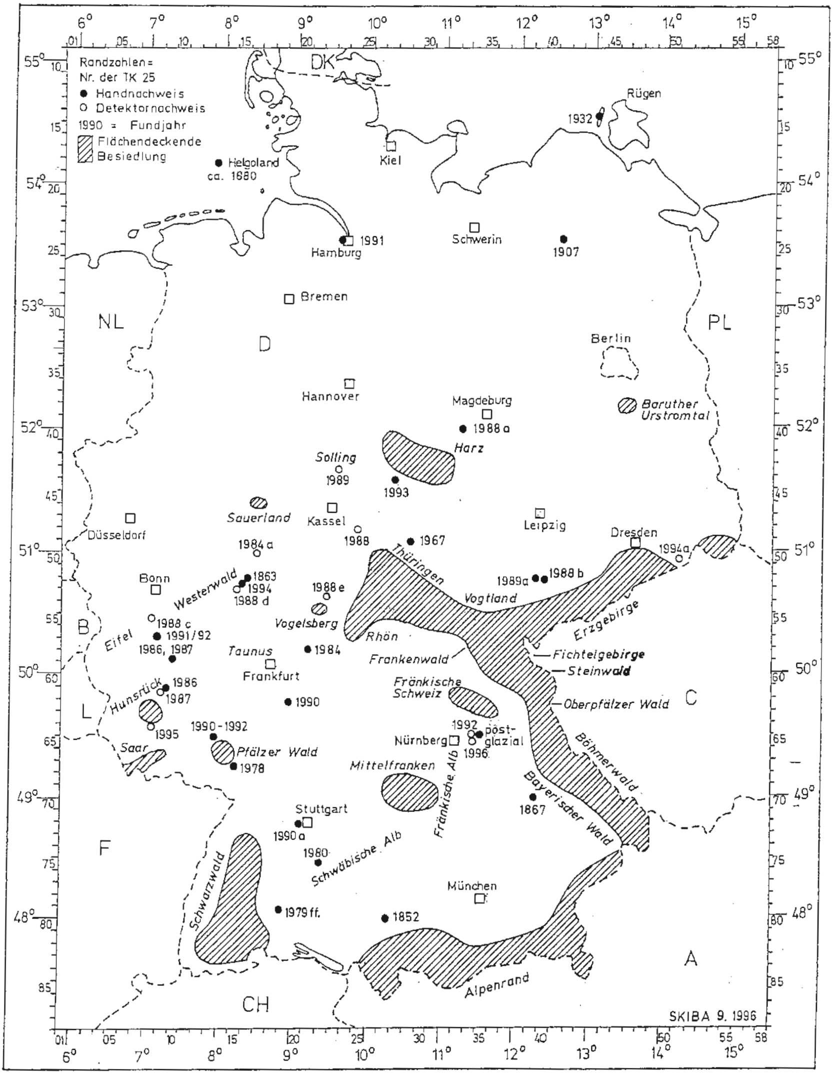


Abb. 3: Fangimpulse und Sozialrufe der Nordfledermaus-*Eptesicus nilssonii.*

Die Rufe sind bei sachgerechter Analyse der Rufreihen arttypisch. Außerdem wurden Größe (mittelgroß), Flugverhalten (Höhe 5 - 12 m; Geschwindigkeit 20 - 55 km/h, gewandter Flug) und sonstige Eigenarten, z.B. die dunklen Flughäute und die braune Grundfarbe, zur Artbestimmung mit herangezogen.

3 Ergebnisse

Die Übersichtskarte (Abb. 4) zeigt den heutigen Kenntnisstand über die Verbreitung der Nordfledermaus in der Bundesrepublik Deutschland. Der größte Teil der Verbreitung wurde dabei mittels Detektor geklärt. Spektakuläre Nachweise blieben dabei nicht aus:



Vorkommen der Nordfledermaus - Eptesicus nilssoni in der Bundesrepublik Deutschland.

Abb. 4: Verbreitung der Nordfledermaus - *Eptesicus nilssonii* in der Bundesrepublik Deutschland (Stand: 1.8.1996).

So wurden beispielsweise 1988 von WALTHER (HAENSEL & WALTHER 1990) etwa 50 km südlich von Berlin am Fläming Fragmente einer Nordfledermaus in einem Waldkauzgewölle gefunden. Durch Vermittlung von Herrn Dr. Haensel wurde ich 1989 in die damals noch bestehende Deutsche Demokratische Republik eingeschleust und konnte in der Nähe des Fundortes im Baruther Urstromtal die Nordfledermaus mehrfach mittels Detektor nachweisen. 1993 wurde das Vorkommen der Nordfledermaus dort auch durch Lebendfang von HAENSEL et al. (1994) bestätigt.

Im Frankenwald flog in Elbersreuth 1976 eine subadulte Nordfledermaus unbemerkt in den Koffer eines abreisebereiten Kurgastes und wurde nach Berlin transportiert, wo die Art bestimmt werden konnte und der Fund von KLAWITTER 1977 veröffentlicht wurde. Am Fundort und dessen näherer und weiterer Umgebung gelangen dann 1985 zahlreiche Detektornachweise, womit nachgewiesen war, daß die Nordfledermaus den Frankenwald bewohnt.

Für den Bayerischen Wald nannte TIEM (1906) Vorkommen bei Spiegelau in Heustadeln. Diese Vorkommen wurden später von ISSEL et al. (1977, S. 61) als nicht hinreichend belegt angesehen. Dort konnte ich die Nordfledermaus 1986 auf Anhieb als häufig nachweisen (SKIBA 1987).

Klarheit haben die Detektornachweise auch im Alpenvorland (SKIBA 1996a), im Schwarzwald (SKIBA 1990), in der Oberlausitz und im Zittauer Gebirge (SKIBA 1996) und in anderen Gebieten gebracht, zuletzt 1995 im Saarland (SKIBA 1997).

Nicht nachweisen konnte ich bisher die Nordfledermaus im Odenwald, im Taunus und im Bergischen Land, obwohl ringsherum Nachweise vorliegen. Auch eine sorgfältige Absuche der Märkischen Schweiz östlich von Berlin verlief erfolglos.

4 Diskussion

4.1 Verbreitung

Mit Hilfe der elektronischen Aufnahme und Analyse des Ultraschalls der Nordfledermaus konnte geklärt werden, daß diese Art als boreo-alpines Faunenelement in den deutschen Mittelgebirgen fast überall verbreitet ist und ausnahmsweise auch im Flachland vorkommt. Die Grenze der europäischen Verbreitung muß weiter westlich in Belgien, Luxemburg und Frankeich liegen, worauf erste Funde hinweisen. Es ist also an der Zeit, mit Hilfe der Ultraschalltechnik die Westgrenze der Nordfledermausvorkommen in diesen Ländern zu erkunden, um späterer Aussagen über die Populationsdynamik zu ermöglichen.

Nicht geklärt ist, ob der Bestand der Nordfledermaus in den letzten Jahrzehnten zugenommen hat oder nicht. Dies bleibt zukünftigen Vergleichsuntersuchungen vorbehalten. Es zeichnet sich jedoch schon jetzt ab, daß in geeigneten Habitaten, z.B. im Bayerischen Wald, im Harz und im Schwarzwald, die Art von der Installation der HQL-Lampen mit Ultraviolett abstrahlendem Licht und den dort sich sammelnden Insekten profitiert und die Siedlungsdichte dementsprechend örtlich zugenommen hat.

4.2 Methode und Fehlermöglichkeiten

Hinsichtlich des methodischen Vorgehens ist folgendes anzumerken:

In der Kette Aufnahmegerät - Recorder - Oszilloskop - X-Y-Schreiber sind Fehler möglich. Die Kontrolle mit Kalibriereinrichtungen und Stimmgabel ergab eine Fehlergröße, die sehr gering war und maximal bei etwa 0,2 kHz lag, also auf das Ergebnis keinen wesentlichen Einfluß hat. Die Kontrolle der subjektiven Ablesegenauigkeit erfolgte durch Wiederholung der Datenermittlung an den objektiv dokumentierten Oszillogrammen.

Zeitdehner wurden nicht benutzt. Ihre Anwendung hätte das Ergebnis nicht wesentlich verbessert. Lediglich die erste Welle im Frequenzverlauf eines frequenmodulierten Einzelimpulses liegt bei Anwendung von Zeitdehnern geringfügig in der Frequenz höher als bei der Anwendung des Teilersystems, bei dem die ersten Wellen - in der Regel die ersten zehn - verfahrensbedingt gemittelt werden. Die Ermittlung von Harmonischen (Obertönen) war nicht notwendig, da sie in der Regel für die Bestimmung der Art nicht wesentlich sind. Zudem ist es wegen der zeitlichen Begrenzung der Speicherung des originalen Ultraschalls schwierig, mit einem Zeitdehner bestimmte Ruftypen zu erfassen, z.B. Sozialrufe. Dazu kommt, daß durch das zeitgedehnte Abspielen Aufnahmezeit verloren geht. Mit dieser Aussage soll keinesfalls angezweifelt werden, daß die Zeitdehnung für die präzise wissenschaftliche Erfassung und Analyse der Rufe von großem Vorteil ist. Im vorliegenden Fall geht es aber lediglich anwendungsorientiert um die richtige Artbestimmung.

Ein Personalcomputer mit entsprechender Software wurde nicht benutzt, da zur Zeit keine auf die Analyse von Fledermausrufen ausgerichtete Software die Mittelung von 10 Impulsen mit Ausweisung der Standardabweichung zuläßt. Diese Mittelung ist jedoch für das richtige Ansprechen der Art von großer Bedeutung. Die automatische Abstandsklassierung läßt sich ebenfalls vielfach nicht anwenden, da oft Störgeräusche, z.B. durch Heuschrecken oder andere Fledermäuse, das Ergebnis verfälschen. Ich habe daher eine Handauswertung vorgezogen, werde aber möglicherweise zukünftig stärker den PC für die Auswertung benutzen.

Verwechslungsmöglichkeiten bestehen mit Breitflügelfledermaus (*Eptesicus serotinus*), Zweifarbfledermaus (*Vespertilio murinus*), Abendsegler (*Nyctalus noctula*) und Kleinabendsegler (*Nyctalus leisleri*). Folgende Unterschiede bestehen im wesentlichen (ausführliche Grafiken in SKIBA 1997):

Bei der Breitflügelfledermaus ist der Einzelimpuls im Schnitt kürzer und steiler moduliert als bei der Nordfledermaus und läuft bei etwa 24 - 26 kHz aus. Die Hauptfrequenz liegt in der Regel bei 25 bis 27 kHz. Die Impulsrate ist in der Regel höher als bei der Nordfledermaus, doch kann diese auch niedrig sein. Die Impulsabstandsmaxima liegen charakteristischerweise in der 10 ms-Klasse um 150 ms, ein zweites Maximum befindet sich manchmal in den Klassen um 270 - 300 ms. Subjektiv hört sich der Impulsrhythmus oft gleichmäßiger als bei der Nordfledermaus an, wobei im schnellen Rhythmus "Aussetzer" typisch sind.

Bei der Zweifarbfledermaus ist der Einzelimpuls im Schnitt wesentlich länger als bei der Nordfledermaus, verhältnismäßig flach moduliert und um

24 kHz auslaufend. Die Hauptfrequenz liegt häufig bei 24 - 25 kHz und damit tiefer als bei der Nordfledermaus. Die Impulsrate ist niedriger als bei der Nordfledermaus. Das Impulsabstandsmaximum liegt in der Regel im Bereich 260 - 350 ms, zusätzlich befindet sich manchmal ein Maximum bei 160 - 180 ms. Schallpegel und Impulsabstand können alternierend oder auch zeitweise verhältnismäßig gleichmäßig sein. Subjektiv ist der Rhythmus der Zweifarbfledermaus ähnlich dem der Nordfledermaus oder dem einer langsam rufenden Breitflügelfledermaus.

Beim Abendsegler ist die Hauptfrequenz unterschiedlich (etwa 18 - 25 kHz), die Impulse sind wesentlich länger und lauter als die der Nordfledermaus. Subjektiv hören sich die Rufe wie "tweet - chock" an. Wird der Frequenzwähler auf 18 - 20 kHz eingestellt, so hören sich die charakteristischen frequenztiefen Rufe wie laute Knalle oder dumpfe Schläge an. Sie sind eindeutige Unterscheidungsmerkmale zur Nordfledermaus und auch zum Kleinabendsegler.

Der Kleinabendsegler ruft leiser als der Abendsegler, auch wechselt seine Hauptfrequenz nicht so stark. Sie liegt bei etwa 24 - 26 kHz. Der Frequenzverlauf ist in der Regel flacher als bei der Nordfledermaus und endet meist bei 23 - 25 kHz, manchmal höher, sehr selten niedriger als 22 kHz. Das Ultraschallinventar des Kleinabendsegler ist auffallend variabel und kann im Tiefflug myotisartig sein. Die Impulse hören sich dann trocken prasselnd an. Im Höhenflug sind die Impulsabstände unregelmäßiger als bei der Nordfledermaus, entsprechend ist das Abstandsmaximum schwächer ausgebildet; in der Regel befindet sich ein flaches Maximum im Bereich von 210 - 290 ms, während die übrigen Impulse sich breit über die einzelnen Klassen verteilen. Subjektiv hören sich die Impulse des Kleinabendseglers oft typisch quietschend oder zwitschernd an, manchmal auch knall- oder explosionsartig, wenn der Kleinabendsegler mit verhältnismäßig hoher Geschwindigkeit vorbeifliegt.

Da der Kleinabendsegler die Frequenz seiner Rufe ständig wechselt, ist es möglich, daß ein e i n z e l n e r Impuls dem der Nordfledermaus ähnlich ist (vgl. WEID & HELVERSEN 1987). Eine fachgerechte Analyse von Fledermausrufen mit dem Ziel der Artbestimmung ist jedoch nur möglich, wenn Rufreihen analysiert und erforderlichenfalls miteinander verglichen werden. Dabei sind die Rufe des Kleinabendseglers objektiv und auch subjektiv nach dem Gehör so charakteristisch, daß Verwechslungen mit der

Nordfledermaus sicher vermieden werden können. Insofern schließe ich mich derselben Feststellung von ZING (1990 S. 286) an und kann der Auffassung von WEID & VON HELVERSEN (1987) und MERKEL-WALLNER et al. (1987) nicht zustimmen, daß mittels Ultraschall eine sichere Bestimmung der Nordfledermaus wegen Verwechslunggefahr mit dem Kleinabendsegler nicht möglich sein soll. Im übrigen unterscheiden sich beide Arten auch wesentlich durch charakteristische Sozialrufe und Unterschiede in der Art des Fluges.

5 Zusammenfassung

Zusammengefaßt zeigt sich, daß es mit Hilfe der Erfassung und Analyse von Ultraschall in den letzten Jahren möglich war, die Verbreitung der Nordfledermaus in der Bundesrepublik Deutschland zu klären. Eine sachgerechte Analyse der Ultraschallrufe ist auch ohne Zeitdehner und PC mittels Oszilloskop mit angeschlossenem X-Y-Schreiber oder Drucker möglich. Verbreitungschwerpunkte liegen in den Mittelgebirgen. Einzelnachweise verteilen sich über ganz Deutschland mit Ausnahme des Nordwesten. Es wird vermutet, daß sich die Vorkommen in Belgien, Luxemburg und Frankreich fortsetzen. Vorgeschlagen wird, hier die Westgrenze des Verbreitungsareals zu klären, um spätere Aussagen über die Populationsdynamik zu ermöglichen.

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Experience of bat monitoring with bat detectors in Estonia

by

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Key words: bats, monitoring methods, summer habitats.

Abstract

A modification of a bat monitoring method, the Route Counting Method (RCM), has been worked out and tested by the Estonian Bat Group in recent years . Our aims were the following: 1) to work out a simple method for bat census in summer habitats; 2) to estimate bat populations in chosen monitoring areas (so-called monitoring stations) in Estonia.

Three bat detectors (two of Skye Instruments SBR 1200, and one of Pettersson Elektronik D90A) and pocket-size tape recorders were used to record bat calls for further analysis.

The present Route Counting Method to monitor bat populations in summer habitats is based on counting of flying bats with bat detectors on monitoring routes. The method is a modification of a Line Transect Counting Method (LTC). On routes there are usually certain points where several bat species often concentrate to feed. In these waiting-points the observer stops for 3 minutes to record all species.

Quantitative results of observations are achieved by dividing the route into segments with length of 50 m (in case of Nyctalus noctula 100 m). Species will be recorded separately within each of these segments. Data of countings will be transformed into relative data, by extrapolating them per 10 km. Thus, the data of different routes become comparable. For correct determination of species, visual observations are required, for which light midsummer nights in June--beginning of July fit best. On the basis of counting data, the Route's Monitoring Index and the Mean Monitoring Index

will be calculated to quantitatively estimate the status of bat populations in monitoring areas.

The Route's Monitoring Index (RMI) presents the number of individuals + number of bat groups recorded per 10 km on a certain route. The Mean Monitoring Index (MMI) presents mean data of all routes studied. MMI values are quantitative estimations of bat populations for a larger area (e.g. Estonia). The MMI is only a relative index, which cannot be used to estimate exact bat numbers in certain habitats, as well as on the whole area of monitoring. On the basis of RMI-s collected from monitoring routes located in different parts of Estonia, the MMI has been calculated. The MMI value, mean of 20 routes studied in Estonia in 1993-1994, was 25.7 individuals and 7.2 groups of bats per 10 km. This is a quantitative estimate of bat populations in Estonia concerning the study period.

The present Route Counting Method is considered to be capable of quantitatively estimating the status of bat populations on a larger area. The Mean Monitoring Indices obtained from certain areas during subsequent years, or subsequent longer periods should show in which directions bat populations actually change. MMI-s will show these changes quantitatively. Considering the important cumulative content of MMI, it could be even dealt as the Main Monitoring Index.

Résumé

Une modification d'une méthode de surveillance de chauves-souris, la "Route Counting Method" (RCM) a été développée et testée par le Groupe Chiroptérologique Estonien pendant ces dernières années. Nos objectifs étaient les suivants: 1) de développer une méthode simple pour recenser les chauves-souris en été; 2) d'estimer les populations de chauves-souris dans des aires de surveillance sélectionnées (appelées stations de surveillance) en Estonie.

Trois détecteurs (deux de Skye Instruments SBR 1200, et un de Pettersson Elektronik D90A) ainsi que des magnétophones de poche ont été utilisés pour enregistrer les cris des chauves-souris en vue d'une analyse ultérieure.

La RCM destinée à surveiller les populations de chauves-souris retenue ici est basée sur le dénombrement des chauves-souris au vol à l'aide de détecteurs sur des routes de surveilance. La méthode est une modification de la "Line Transect Counting Method, LTC". Le long des routes, il y a toujours certains points où plusieurs espèces de chauves-souris se concentrent pour chasser. A ces points d'attente, l'observateur s'arrête pour 3 minutes et enregistre toutes les espèces.

Des résultats quantitatifs des observations sont obtenus en divisant la route dans des segments d'une longueur de 50 m (pour Nyctalus noctua 100 m). Les espèces seront enregistrées séparément à l'intérieur de ces segments. Les données du dénombrement sont transformées en chiffres relatifs, en extrapolant sur 10 km. Ainsi, les données des

différentes routes deviennent comparables. Pour pouvoir déterminer les espèces correctement, des observations visuelles sont indispensables, ce qui s'opère le mieux dans des nuits claires de juin à début juillet. Sur la base des données du dénombrement seront calculés l'Index de Surveillance de la Route (Route Monitoring Index, RMI) et l'Index Moyen de Surveillance (Main Monitoring Index, MMI) pour estimer le statut des populations de chauves-souris dans les aires étudiées.

L'index de surveillance de la route représente le nombre d'individus + le nombre de groupements de chauves-souris observés par 10 km pour une certaine route. L'index moyen de surveillance représente les données moyennes de toutes les routes étudiées. Les valeurs du MMI sont des estimations quantitatives des populations de chauves-souris pour une grande région comme l'Estonie. Le MMI n'est qu'un index relatif qui ne peut pas servir à estimer les nombres exacts de chauves-souris dans certains habitats, non plus dans l'ensemble de l'aire surveillée. Sur la base des RMIs collectés sur des routes de surveillance localisées dans différentes parties d'Estonie, le MMI a été calculé. La valeur du MMI, la moyenne de 20 routes étudiées en Estonie en 1993-1994, est de 25,7 individus et 7,2 groupements de chauves-souris par 10 km. Ceci est une estimation quantitative des populations de chauves-souris pour la période d'étude concernée.

La "Route Counting Method" présentée ici peut être considérée capable de fournir une estimation quantitative du statut des populations de chauves-souris à grande échelle. Les Indices moyens de surveillance obtenus dans certaines aires pendant plusieurs années consécutives, où des périodes consécutives plus longues, doivent mettre en évidence des tendances d'évolution des populations de chauves-souris. Les MMIs montreront ces changements de façon quantitative. Considérant le contenu cumulatif important du MMI, on pourrait même l'interpréter comme un Indice Général de Surveillance.

1 Introduction

A modification of a bat monitoring method, the Route Counting Method (RCM), has been worked out and implemented by the Estonian Bat Group in recent years (Masing 1994; Masing et al. 1994). Our aims were the following: 1) to work out a simple method for bat census in summer habitats, 2) to estimate relative number of bats in chosen monitoring areas (so-called monitoring stations) in Estonia. This paper is a summary of a more comprehensive work on the same subject (see Masing et al. in print).

2 Equipment

Three bat detectors (two of Skye Instruments SBR 1200 and one of Pettersson Elektronik D90A) were used. Pocket-size tape recorders were used to record bat calls for further analysis. Torches, notebooks and writing devices were used in field work. Topographical maps were used to mark monitoring routes, to calculate distances on the routes, and to put field observations on the maps.

3 Results

3.1 Description of the monitoring method

The present Route Counting Method for monitoring of bat populations in summer habitats is based on counting of flying bats with bat detectors on monitoring routes. The method is a modification of a Line Transect Counting Method (LTC), one of common bat census methods (Boonman 1996). The observer walks along a chosen (and mapped) route with bat detector in his hand. The route will contain several habitats: woods, parks, gardens, vicinity of houses, roads, and edges of water bodies). On routes there are usually certain points where several species of bats often concentrate when feeding. These points will be specially marked on the map. In these waiting-points the observer stops for 3 minutes to record all species passing by.

Quantitative results of observations are achieved by dividing the route into segments with a length of 50 m (in case of *Nyctalus noctula* 100 m). Every bat species will be recorded separately within each of these segments. Positive results will be recorded in two ways: 1) a single individual, 2) two or more individuals. The counting result is expressed by "number of individuals + number of bat groups" recorded on the route. Data of countings will be transformed into relative data, by extrapolating them per 10 km. Thus, the data of different routes become comparable. To get sufficiently correct data, the length of every monitoring route should be not less than 3000 m. Weather conditions are important: temperature not less than +8°C, wind speed up to 8 m/s, no heavy nor prolonged rain. To fit the period of maximum evening activity of bats, the route should be covered within two hours, which limits the route length to about 6000 m. The counting will start when it becomes quite dark, which is about one hour after sunset in midsummer in Estonia.

For correct determination of species visual observations are required, for what light midsummer nights in June - beginning of July fit best. At that time almost exclusively adult bats can be recorded, who then keep a quite sedentary life style.

On the basis of counting data, the Route's Monitoring Index and the Mean Monitoring Index will be calculated to quantitatively estimate the status of bat populations in monitoring areas.

The Route's Monitoring Index (RMI) presents the number of individuals + number of bat groups recorded per 10 km on a certain route.The Mean Monitoring Index (MMI) presents mean data of all routes studied. MMI values are quantitative estimates of bat populations for a larger area, e.g. Estonia. The MMI is only a relative index, which cannot be used to evaluate exact bat numbers in certain habitats, as well as on the whole area of monitoring.

3.2 Results obtained on monitoring routes in 1993-1994

The following seven bat species were identified on 20 monitoring routes studied in 1993-1994: *Myotis dasycneme, M. daubentoni, M. brandti/ mystacinus, Plecotus auritus, Pipistrellus nathusii, Eptesicus nilssoni* and *Nyctalus noctula.* Some bats could not be recognized on the basis of their calls heard from detectors. Midsummer light nights enabled to visually observe the size and flight behaviour of bats, what was important for correct identification of most species. In some cases mist-netting was carried out to ascertain the bat species.

Fig. 1 shows an example where counting results have been noted on the map, and on the basis of these results the RMI has been calculated. RMI-s of all 20 monitoring routes, as well as other details of the countings are presented elsewhere (Masing et al. in print). Maximum densities of bats were recorded near water bodies where the animals concentrated to feed. The highest level of RMI was obtained at Räpina where 58.5 individuals and 19.5 groups of bats were recorded per 10 km

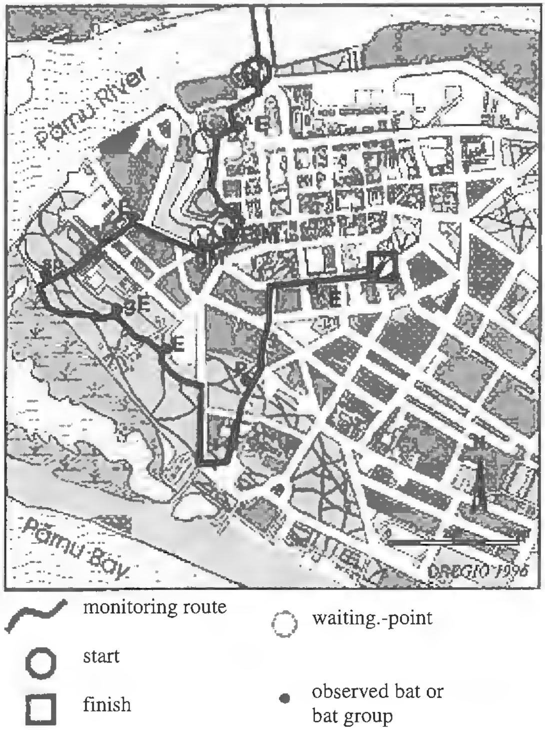

Fig. 1. An example of a mapped monitoring route in Pärnu together with the counting results (from Masing et al. in print).

Symbols used: E - *E. nilssoni, single*; gE - *E. nilssoni, group*; ^E - *E. nilssoni*, single near street-lamps; M - *M. daubentoni*, single; gM - *M. daubentoni*, group; P - *P. auritus*, single; sp - *Chiroptera species*, single.

Counting result, expressed in symbols (total number of recorded "individuals+groups" per species): E (5+1), M (1+1), P (1+0), sp (1+0) = 8+2

Counting result, transformed into Route's Monitoring Index ("individuals+groups" per species per 10 km, route length is 2600 m): E (19.2+3.8), M (3.8+3.8), P (3.8+0), sp (3.8+0) = 30.6+7.6

Table 1. Some results derived from bat countings on 20 monitoring routes in Estonia in 1993 and 1994 (from Masing et al. in print).

Total length of 20 routes is 83.6 km

Species	Index of Presence: no. and percentage of routes where the species was observed	Maximum estimation of species abundance: RMI = inds+groups per 10 km route, one selected route	Mean estimation of species abundance: MMI = inds+ groups per 10 km route, mean of 20 routes	Index of Grouping: percentage of bat groups taken from all observations (%)
M. dasycneme	4 20%	5.0+10.0	0.76+0.50	39.7
M. daubentoni	12 60%	2.4+9.8	1.44+1.57	52.2
M. brandti/ mystacinus	1 5%	1.4+0	0.07+0	0
P. auritus	2 10%	4.9+0	0.41+0	0
P. nathusii/ pipistrell.	6 30%	17.1+4.9	3.23+0.93	24.0
E. nilssoni	18 90%	30.7+8.0	15.60+3.83	19.7
N. noctula	7 35%	12.2+0	1.86+0.13	6.5
Chiroptera sp	12 60%	6.5+3.2	2.49+0.28	10.1
Summarized MMI for Estonia (data of all species together)			25.86+7.24 = 33.10 total observations/ 10 km	

On the basis of RMI-s, collected from the monitoring routes located in different parts of Estonia, the MMI has been calculated. The MMI value, mean of 20 routes studied in Estonia in 1993-1994, was 25.9 individuals and 7.2 groups of bats per 10 km (Table 1). This is a quantitative estimate of bat populations in Estonia concerning the study period. When counting of bats will be carried out on the same routes in the future, changes in values of RMI and MMI will reflect what is happening with bat populations.

4 Final remarks

The present Route Counting Method is considered to be capable of quantitatively estimating the status of bat populations on a larger area. The Mean Monitoring Indices obtained from certain areas during subsequent years, or subsequent longer periods should show in what directions bat populations actually change. MMI-s will show these changes quantitatively. Considering the important cumulative content of MMI, it could be even dealt as the Main Monitoring Index.

5 Acknowledgments

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Monitoring Bats in the Grand-Duchy of Luxembourg

by

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Abstract

The bat fauna of Luxembourg has been inventorized for the first time in a systematic way during the years 1991-1996.

The methods applied were the use of an ultrasound detector, model D980 (Petterson, S), the inspection of attics and mist-netting in feeding habitats and in front of mating or hibernating sites.

Until now, 19 species have been recorded. The distribution of these species and the best method to apply on the field work considering the time available and the surface to study are discussed.

It is shown that the results of such a brief survey are not sufficient to get a reliable knowledge on the status of the species.

Résumé

La faune des chauves-souris au Luxembourg a été recensée pour la première fois de façon systématique pendant les années 1991-1996.

Les méthodes utilisées comprenaient l'application d'un détecteur d'ultrasons, modèle D980 (Petterson, S), la prospection des greniers d'églises et la capture au filet dans les biotopes de chasse et devant les gîtes d'accouplement ou d'hibernation.

Jusqu'ici 19 espèces de chauves-souris ont été recensées. La répartition de ces espèces et la meilleure méthodologie à appliquer sur le terrain en fonction du temps disponible et de la superficie à prospecter sont expliquées.

Il est mis en évidence que les résultats d'un tel recensement sommaire ne sont pas suffisants pour permettre une définiton fiable du statut de chacune de ces espèces.

Zusammenfassung

Die Fledermausfauna Luxemburgs wurde während der Jahre 1991 bis 1996 zum ersten Mal in systematischer Form erfasst.

Die angewandten Methoden umfassen den Gebrauch eines Detektors, Modell D-980 (Pettersson, S), die Kontrolle von Kirchendächern und Netzfänge in Jagdbiotopen und vor Balz-und Winterquartieren.

Bislang wurden 19 Fledermausarten nachgewiesen. Die Verbreitung der Arten und die beste Erfassungsmethode im Gelände in Abhängigkeit von der verfügbaren Zeit und der Größe des Untersuchungsgebietes wird dargestellt.

Es wird deutlich gemacht, daß die Ergebnisse einer solchen umfassenden Untersuchung nicht ausreichend sind, um eine sichere Bestimmung der Bestandsdichte jeder Art zu erlauben.

1 Introduction

From the years 1991 to 1996, the summer distribution of the bat fauna of Luxembourg was investigated. This study was done on behalf of the National Museum of Natural History of Luxembourg. Before, no systematic surveys covering the whole of Luxembourg were done and data about the occurrence of bat species and their distribution were only known as a result of local studies or accidental findings. The first publication about bats in Luxembourg dates from 1869 by DE LA FONTAINE, followed by publications dealing only partly with bats in 1931 (V. FERRANT) and 1954 (A.M. HUSSON). Only in 1978 the first systematic investigations were done, including the check of summer roosts (mostly church lofts) and winter roosts. Also the publications of FAIRON et al. (1982) and PIR and ROESGEN (1987,1988) dealt with winter roosts checks. This recent investigation by the Museum was the first one to include the new technique of bat detector work. In fact, the bat detector was the main method of the study because a large part of the country had to be surveyed during a few months.

2 Material and Methods

In the subsequent years from 1991 to 1995, each fifth of the surface of the Grand-Duchy of Luxembourg was studied, i.e. approximately 500 km^2 per year. In 1996 an overall check was done to ascertain findings and cover the last missing grids. A grid of 5 X 5 km, orientated according to the luxembourgish Gauß-Krüger-System, was used. Every grid of the country was visited with the detector at 2 to 3 points, usually at potenially favourable bat biotopes. Areas of intensive agriculture are usually avoided by bats and were therefore only visited for comparing purposes. Highly profitable foraging areas such as ponds, lakes, or special wood lanes were used as control points in each year to check the level of bat activity in unfavourable nights.The investigations started with the onset of regular summer activities in late April and ended in September. Mist-netting was done until October. The nightly detector work started just before sunset and lastet according to weather and temperature conditions 3 - 4 hours. Nights with rain, temperatures below 10° C at sunset, or strong winds were avoided. The habitat features of the feeding area were noted to allow later interpretations about the preferred habitats of the bat species occuring in Luxembourg. These informations can help protecting special habitats. Further, obvious feeding strategies and interactivity or any special behaviour were noted.

2.1 The bat detector

The main method to study the summer occurrence of bat species and their use of hunting biotopes was the work with the bat detector. The PETTERSSON detector model D - 980 (PETTERSSON ELEKTRONIK AB, Sweden) was used. This detector applies the heterodyne method (H) and the frequency division method (FD) in one model. Also time expansion technique (TE) is included. For further explication of the techniques see the article of L. PETTERSSON in this issue (p. 21-34). The bats were identified in the field and only registered for later identification when no determination was possible. Unfortunatly no sound identification program could be used. In addition to the detector it was always tried to observe the bats with the help of a powerful torch to get information about their body size, color (if possible) and flight behaviour. Thus in most cases the identification of "difficult" species was possible.

The survey was done by point counts and by transect counts. During point counts, the area was checked by walking around and waiting for ultrasonic contacts. The minimum time spend at one point was 10 minutes, when no contact was made. Otherwise up to one hour was spend, depending on the species heard, their special behaviour and numbers of bats encountered.

Line transects were usually done along wood-edges, forest roads, streets along linear landscape elements such as brooks or lanes. Depending on their length, these transects were mostly driven by car with a maximum speed of 30 kmh.

The detector was always put on "FD" (mostly tuned to 45 kHz) in one channel and on "H" on the other channel. Thus all frequencies can be heared. The time expansion technique was frequently used. It proved to be essential for the identification of some bat species at critical hunting situations. For example to distinguish hunting *Eptesicus nilssonii* from *N. leisleri* or, on street lamps, *Eptesicus spec.* from *Nyctalus spec.* and *Vespertilio murinus,* or over water bodies *Myotis daubentonii* from *M. nattereri.* With more experience the TE became the main method used because of its more precise identification possibilities. This is especially true when using sound analysis programmes which allow the identification of most species at a very high level of confidence.

Not all bat species occuring in Luxembourg are easily identified by detector. They can be divided in three groups:

- Those having distinct and easily distinguishable ultrasounds, but emit their calls very weakly, such as the two Rhinolophid species.

- Those having distinct and loud ultrasounds such as the genera *Nyctalus, Eptesicus, Vespertilio* and *Pipistrellus*.

- Those with weak and rather similar ultrasounds within the genera such as the *Myotis* species and the *Plecotus* species.

Barbastella barbastellus has also distinctive ultrasounds which make it unmistakable, especially when using the TE mode. But with only 2 recent records from Luxembourg, the chance to encounter any individual is rather low!

The bats of group 1 can only be monitored by convential methods like roost controls. Their ultrasounds do not reach further than 5 m, thus making it impossible to monitor them systematically by detector.

The bats of group 2 are the easiest species to identify by detector. With some experience, all species can be identified in the field.

The species of group 3 make the most problems in identification. The ultrasounds of all *Myotis* species are to some extent similar and can be confused with each other, especially when they are hunting over water or in cluttered environment. When only short contact is made, even no identification can be possible. Here the use of the TE technique proves to be very helpful. Also visual observation can help to identifiy the species. For some species of the genus *Myotis*, the identification in mist-nets or in their roost remains the most confident solution.

2.2 Roost surveys

An other method used to assess the distribution of bats in Luxembourg was the systematic check of church lofts. This method should give an overview on the distribution of synanthropic bat species. Most of the accessible and potentially favourable church lofts in Luxembourg were checked, altogether 210. Due to the lack of time, small chapels and churches of modern architecture (flat roofs, no lofts,...) were assumed to be not favourable for larger nursery roosts and therefore not visited. Furthermore, suitable lofts of other buildings were checked, such as castles, schools, town houses or private houses where the owner complained about bats.

With this conventional method, important nursery roosts of *Myotis myotis*, *Myotis emarginatus*, *Eptesicus serotinus* and both *Plecotus species* could be found, in addition to a number of roosts of *Pipistrellus pipistrellus*, mostly in private houses. These results should have great influence on the conservation strategies for bats in Luxembourg, f.ex. the legal protection of nursery colonies in public buildings.

2.3 Mist-netting

In late summer and fall, the use of mist-nets in front of caves or mines revealed the occurrence of species that are not living in buildings or which are not or hardly possible to hear with bat detectors. Also the sexual activity and the reproductive status of these species could be seen. The use of mist-nets in the foraging areas proved not to be successful in relation to the time spend and the area to be surveyed.

The combination of all these methods used should garantee the highest possible success rate of species determination. Nevertheless the results have to be interpreted carefully when only determinations by detector could be done and no other method could be used to identify the species.

3 Results

The following bat species have been recorded in Luxembourg:

1 *Rhinolophus ferrumequinum* (SCHREBER, 1774)
2 *Rhinolophus hipposideros* (BECHSTEIN, 1800)
3 *Myotis daubentonii* (KUHL, 1818)
4 *Myotis brandtii* (EVERSMANN, 1845) *
5 *Myotis mystacinus* (KUHL, 1818)
6 *Myotis emarginatus* (GEOFRROY, 1806)
7 *Myotis nattereri* (KUHL, 1818)
8 *Myotis bechsteinii* (KUHL, 1818)
9 *Myotis myotis* (BORKHAUSEN, 1797)
10 *Nyctalus noctula* (SCHREBER, 1774)
11 *Nyctalus leisleri* (KUHL, 1818)
12 *Eptesicus serotinus* (SCHREBER, 1774)
13 *Eptesicus nilssonii* (KEYSERLING & BLASIUS, 1839) *
14 *Vespertilio murinus* LINNAEUS, 1758 *
15 *Pipistrellus pipistrellus* (SCHREBER, 1774)
16 *Pipistrellus nathusii* (KEYSERLING & BLASIUS, 1839) *
17 *Plecotus auritus* (LINNAEUS, 1758)
18 *Plecotus austriacus* (FISCHER, 1829)
19 *Barbastella barbastellus* (SCHREBER, 1774)

Altogether 19 bat species are identified in Luxembourg. Two of them, the Nathusius bat (*Pipistrellus nathusii*) and the Northern bat (*Eptesicus nilssonii*) were only identified by detector and parallel sight observations. All other species were, beside their identification by detector, also found in their roosts, caught in mist-nets or found dead and handed in to the Museum. The species marked with * were found for the first time in Luxembourg during this study.

In the following, some distribution details of the bat species of Luxembourg are given with special attention to the possibilities and drawbacks of their identification by bat-detector.

3.1 *Rhinolophus ferrumequinum* (SCHREBER, 1774) and *Rhinolophus hipposideros* (BECHSTEIN, 1800)

The greater horseshoe bat was already described in Luxembourg by De la Fontaine in 1869. In contrast to the former widespread distribution and abundance, nowadays it is only found in the Mosel valley in summer and few individuals are known from their winter roosts (PIR 1996).

Also the lesser horseshoe bat is known in Luxembourg since 1869 and was estimated to be a rather common species. A nursery roost existed in the Eisch valley. Form former 40 individuals in 1969, the colony got extinct by 1989. The only known individual during this inventory was found in 1992, but was never seen again since (ENGEL et al., 1993, HARBUSCH et al., 1999, in prep.)

Both spexies can hardly be heard by detector since their ultrasounds are emitted very lowly, although their frequencies are very typical and cannot be confused with other species. The only methods to systematically monitor both horseshoe bats are the conventional method of summer and winter roost checks (see also: RANSOME & HUTSON 1999).

3.2 *Myotis daubentonii* (KUHL, 1818)

Daubenton bats are widely distributed in Luxembourg and occur at almost every water body of sufficient size. But the species becomes more rare in the northern part of Luxembourg (Ösling), although the water quality of the brooks and their natural environments are good. One restricting factor could be the turbulences of fast running water which prevent successful echolocation. But also on calmer water and over dammed parts of brooks and rivers, findings of the Daubenton bat were scarce. The density of hunting Daubentons bats over the water bodies of the Ösling was always much lower than over those of the southern part of the country, the Gutland. This species can entirely be monitored by bat detector. The typical ultrasounds are easily recognizable and in cases of possible confusion with f.ex. the Natterer's bat, the use of the time expansion can help to identify the species. When using a strong torch, the typical hunting behaviour over the water surface can be observed.

3.3 *Myotis brandtii* (EVERSMANN, 1845) and *Myotis mystacinus* (KUHL, 1818)

To our actual knowledge, the two sibling species *Myotis brandtii* and *Myotis mystacinus* can not be separately identified by their ultrasounds. They therefore must be determined by other monitoring methods, based on the identification in the hand. For Luxembourg, there are only few findings of *M. brandtii*: one juvenile male found dead and two individuals captured by mist-nets in front of old mines in the southwest of Luxembourg. The knowledge about the distribution of this species is certainly incomplete.

The findings of identified *M. mystacinus* are more frequent than those *of M. brandtii*. The whiskered bat was captured in mist-nets in front of caves and mines in the central and western part of the country. Here, mostly males were captured.

All detector findings of the *Myotis mystacinus/brandtii* complex must remain unidentified. The distribution of this complex is more wide. It was mainly found along the small river of Sauer and some affluents. The environment of these water bodies is usually highly structured with old riparian trees or even woodland. In the northern part (Ösling), again only few individuals could be found.

3.4 *Myotis emarginatus* (GEOFRROY, 1806)

Due to the weak ultrasounds of the species and its rarity, the main method to reveal its distribution is the check of roosts. During the study, 6 roosts could be found or confirmed in the loft of churches or castles, 5 of them being nursery colonies. The species is concentrated to the climatically favourable regions of the Gutland, mostly following the river valleys.

3.5 *Myotis nattereri* (KUHL, 1818) and *Myotis bechsteinii* (KUHL, 1818)

For these two species, few information could be gathered during this study. Their ultrasounds are rather weak and do not allow easy findings. Both species are mainly tree-dwelling and thus hardly accessible by our methods used. Mist-netting revealed most data, showing that the two species occur in the southern part of Luxembourg. Probably *M. bechsteinii* is regularly occuring in the woodlands of the country. The monitoring of both species by detector requires a lot more time to be spend in the habitat.

3.6 *Myotis myotis* (BORKHAUSEN, 1797)

Most known roosts of the greater mouse-eared bat were found during this study. They are situated in church lofts or in lofts of castles. The summer distribution is confined to the Gutland with its more favourable climate. Detector findings were made mainly in the surroundings of colonies and when the bats used their typical loud and smacking ultrasounds (35kHz). All hunting biotopes were situated within deciduous woodlands.

3.7 *Nyctalus noctula* (SCHREBER, 1774) and *Nyctalus leisleri* (KUHL, 1818)

Both *Nyctalus* species produce loud and distinctive ultrasounds, thus allowing their identification up to 50 - 100 m distance to the observer. With some experience, the species are easily told apart from each other or similar calling species. They can be entirely monitored by detector, especially when taking into account their hidden, tree-dwelling lifestyle. Roosts in trees can be heard even without detector. In Luxembourg, the greater noctule is widespread and occurs mainly in the woodlands of the Gutland and along the valleys in the southern part of the Ösling. There are no findings in the northwestern and northern tip of the country, where intensive agriculture with open fields is the dominating feature of the landscape. There are no summer roosts or nursery roosts known.

The Leislers bat is a rather rare species in Luxembourg. Only a few findings scattered over the country are known. It seems to concentrate along the Mosel valley, where the only nursery roost was known (PEIFFER & PIR, 1994). This area is adjacent to the german country Saarland, where *N. leisleri* is much more widely distributed and not as rare (HARBUSCH, pers. data).

3.8 *Eptesicus serotinus* (SCHREBER, 1774) and *Eptesicus nilssonii* (KEYSERLING & BLASIUS, 1839)

The serotine is a widespread species, reaching rather high population levels. Its distribution is again confined to the southern part of the country. The submountainous regions of the Ösling with their rougher climate and hights above sea level of up to 600 m are clearly avoided. Only the southern parts of the Ösling are reached along the river valleys. The preferred foraging habitats of the serotine bat are cattle-grazed meadows adjacent to deciduous woods. At lower temperatures street-lamps are used for successful foraging. They usually hunt close (2-3 km) to their roosts in the villages.

The northern bat is an uncommon species. Only few findings are scattered over Luxembourg. They concentrate in regions with extensive deciduous woodlands.

Both species can be easily monitored by bat-detector. Their ultrasounds are loud and unmistakable. When they are hunting around street-lamps, longer sequences of ultrasounds have to be analysed in order not to confuse them with other species.

3.9 *Vespertilio murinus* LINNAEUS, 1758

There is only one finding of this species: a male was found in summer in a fissure of a house. No certain detector identification are known.

3.10 *Pipistrellus pipistrellus* (SCHREBER, 1774) and *Pipistrellus nathusii* (KEYSERLING & BLASIUS, 1839)

The common pipistrelle is widely distributed through Luxembourg and is the most common bat species. It does not seem to be endangered at the moment. Many types of biotopes are used by this bat, it even can be seen over open fields or vineyards. It only avoids some areas of the northwestern and northern parts of the country were intensive agriculture and villages with hardly any vegetation structures prevent successful hunting.

The Nathusius bat was only found in few individuals, mostly in the western part of Luxembourg. All findings were done near water bodies or in wet areas. There are no roosts known and all individuals were only identified by detector, but mostly could be compared with common pipistrelles hunting close to them.

Both pipistrelle species can be easily monitored by bat detector. Their ultrasounds are loud and can be distinguished with some experience. Especially during the mating season, their different social behaviour and social calls are obvious.

3.11 *Plecotus auritus* (LINNAEUS, 1758) and *Plecotus austriacus* (FISCHER, 1829)

The identification of the two long-eared bat species by detector is quite problematical. The observer has to be close to the hunting bats to hear their weak ultrasounds and he has to be rather experienced to tell the two species apart. The common long-eared bat also uses louder ultrasounds at special occasions, but a systematic survey by detector must remain uncomplete. The check of church lofts has brought much more information and in most cases certain identification of both species.

The common and the grey long-eared bat occur sympatrically in Luxembourg and can be found in all parts of the country. *Plecotus austriacus* is more common in the Ösling than *Pl. auritus*.

3.12 *Barbastella barbastellus* (SCHREBER, 1774)

The status of the barbastelle is unknown, but it is certainly a very rare and highly endangered species. Only at two times an idividual could be trapped by nist-netting in front of old mines along the Mosel valley. Although the ultrasounds of the species are unmistakable, especially when using the TE technique, no detector findings could be made.

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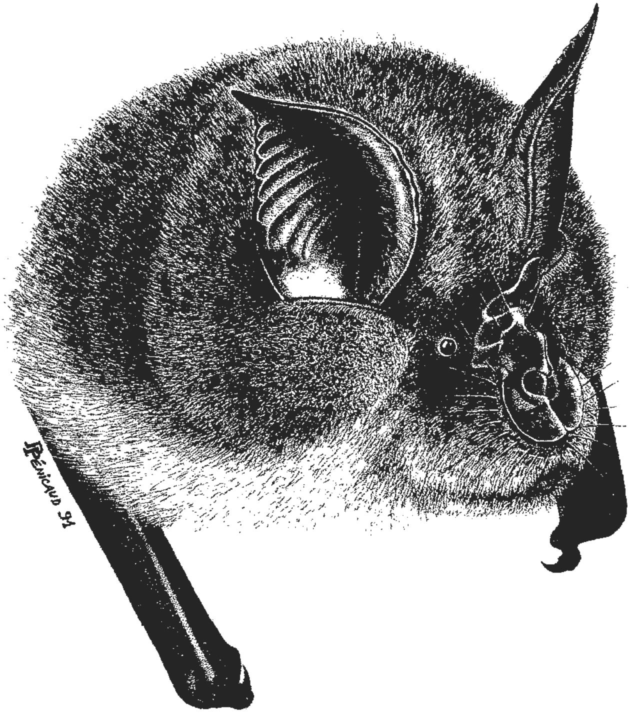

Rhinolophus hipposideros, dessin Philippe Pénicaud (©)

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Methods and theories of monitoring bats in Norway

by

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Abstract

For the last four years NØBI have been trying to develop and identify methods of monitoring bat populations with the use of ultrasound detectors. There are several factors making this difficult and especially the human error of data sampling must be studied carefully. There seems to be no simple solution for monitoring fluctuations in bat populations, and a lot of experimental work must be tried out first.

Temperature seems to have a strong impact on bat activity. However, bat activity really reflects insect availability. Summers are short in Northern Europe, and so are the nights. Bats need to gain strength from the previous winter, reproduce and prepare themselves for the coming winter during these short summers. The number of nights and hours in which foraging is possible will therefore strongly affect the population.

Rydell (1989) showed that *Eptesicus nilsonii* did not forage at temperatures lower than 6 °C. Furthermore, all bats in this study foraged at temperatures equal or above 10 °C. The number of nights with a temperature of ten degrees or more may then indicate the number of nights that are suitable for foraging. When calculating the number of nights for a number of consecutive summers, and compare this with an average, it is possible to use this for explaining, in part, population fluctuations. Of course, such a PFN index (= Potential Foraging Nights) cannot be used for comparing between different areas, but will allow monitoring a specific population through time.

I remains to check the threshold temperature for bat activity between regions and species to enable a more widely use of the method.

Résumé

Pendant les quatre dernières années la station NØBI a essayé de développer et de définir des méthodes de surveillance des populations de chauves-souris en utilisant des détecteurs à ultrasons. Quelques paramètres rendent difficile cette tâche et spécialement l'erreur humaine lors de la collecte de données doit être étudiée avec prudence. Il semble qu'il n'y ait aucune solution simple pour surveiller les fluctuations des populations de chauves-souris, ainsi un travail expérimental important doit être effectué d'abord.

La température semble avoir un impact primordial sur l'activité des chauves-souris. Cependant, l'activité des chauves-souris reflète en réalité la disponibilité des insectes. Les étés sont courts dans le Nord de l'Europe, les nuits de même. Les chauves-souris doivent reprendre leurs forces après l'hiver passé, se reproduire et se préparer à l'hiver suivant pendant ces étés de courte durée. Le nombre de nuits et d'heures pendant lesquelles la recherche de nourriture est possible aura donc un effet important sur la population.

Rydell (1989) a montré qu'*Eptesicus nilssonii* ne chassait pas à des températures de moins de 6 °C. En plus, toutes les chauves-souris de l'étude chassaient à des températures égales ou supérieures à 10 °C. Le nombre de nuits à une température de dix degrés ou plus pourrait alors indiquer le nombre de nuits favorables à la recherche de nourriture. En calculant le nombre de nuits pour une série d'étés consécutifs et en comparant ceci à une moyenne, il est possible d'utiliser ces résultats pour expliquer en partie les fluctuations des populations. Naturellement, un tel index PFN (= nuits potentielles de chasse) ne peut être utilisé pour comparer des régions différentes, mais permet par contre de surveiller une population spécifique dans le temps.

On n'a qu'à chercher la température minimale pour l'activité des chauves-souris selon les régions et les espèces pour permettre une utilisation plus généralisée de cette méthode.

Zusammenfassung

Während der letzten 4 Jahre hat die NØBI Station versucht, Monitoring-Methoden für Fledermauspopulationen mit Hilfe von Ultraschall-Detektoren zu entwickeln und festzustellen. Verschiedene Faktoren erschweren dies und insbesondere die menschliche Fehlerquelle bei der Erhebung von Daten muß sorfältig beachtet werden. Es scheint keine einfache Lösung zu geben, Fluktuationen in Fledermauspopulationen zu überwachen und viel experimentelle Arbeit muß zuvor ausprobiert werden.

Die Temperatur scheint den größten Einfluß auf die Aktivität der Fledermäuse zu haben. Trotzdem reflektiert die Fledermausaktivität die Verfügbarkeit von Insekten.

Die Sommer und auch die Nächte in Nordeuropa sind kurz. Fledermäuse müssen in diesen kurzen Sommern ihre Kräfte nach dem letzten Winter auffrischen, sich fortpflanzen und sich für den kommenden Winter vorbereiten. Die Anzahl der Nächte und Stunden, in denen eine Jagd möglich ist, hat somit einen wichtigen Einfluß auf die Population.

RYDELL (1989) zeigte, daß *Eptesicus nilssonii* nicht bei Temperaturen unter 6°C jagt. Weiterhin jagten alle Fledermäuse in dieser Studie nur bei Temperaturen von größer oder gleich 10 °C. Die Anzahl von Nächten mit einer Temperatur von 10°C oder mehr kann dann also die Nächte, die für einen Jagdflug günstig sind, anzeigen. Wenn man die Anzahl der Nächte für eine abfolgende Zahl von Sommern zählt und dies mit einem Durchschnitt vergleicht, so kann man dieses zur zumindest teilweisen Erklärung von Populationsschwankungen heranziehen. Natürlich kann solch ein PFN index (Potential foraging nights = potentielle Jagdnächte) nicht zum Vergleich zwischen verschiedenen Gebieten herangezogen werden, aber er wird es erlauben, eine spezifische Population über eine Zeit hinweg zu verfolgen.

Es bleibt zu untersuchen, wie der Grenzwert der Temperatur für Fledermausaktivität in verschiedenen Regionen und Arten lautet, um die Methode einer weiteren Nutzung zuführen zu können.

1 Introduction

For the past four years NØBI have been trying to develop and identify methods for monitoring bat populations with the use of ultrasound detectors. There are several factors making this difficult and especially the human error of data sampling must be studied carefully. It seems to be no simple solution for monitoring fluctuations in bat populations, and a lot of experimental work must be tried out first.

Several aspects of monitoring bat populations is already discussed in NØBI Brief 5 (Gjerde 1995c). Only new methods which already has not been described by other authors has been included in this article. These are:

- Survey methods
  - Reference transect
  - Surveying advertisement calling *Vespertilio murinus*
- Definitions
  - Observations
  - Urban and riparian habitat categories
  - Index for Potential Foraging Nights
- Filing bat observations

2 Survey methods

Several methods have been tested for surveying birds (e.g. Blondel *et al.* 1970, Reynolds *et al.* 1980, Burnham *et al.* 1981, Tilghman & Rusch 1981). Surveying bats, however, is somewhat more difficult and few adaptive methods have been developed due to the recent use of ultrasound detectors (Kunz 1988).

Methods in surveying transects by car, were initially developed by Ahlén (1980, 1981) and later adopted by Ahlén (1983), Haffner & Stutz (1986), Jüdes (1989) and Rydell (1991, 1992).

In our work, maps (1:5000) are being used in combination with aerial photographs. All uncertain field observations are recorded onto a magnetic tape for later identification, with the possible aid from specialists in mind. More recently a GPS[1] (model: Garmin 45) has been used to measure grid coordinates of observations in the field, enabling more efficient and rapid annotation of the records.

The examples and methods presented in this article is based on several different research projects.

2.1 Reference transects

During the summer of 1993 a township of Oslo was investigated for bats. At first the numbers recorded at the lake Østensjøvannet seemed to indicate a local movement to the eutrophic lake during lesser weather conditions and insect availability. The lake provides sufficient food despite the general decrease of insects elsewhere. However, this is difficult to confirm when observations in different areas are done on separate days with unlike/incomparable weather.

To test this a line transect was walked on the northeast side of Østensjøvannet in Oslo. This was done at several occasions during the beginning or end of the night when survey work also was being carried out in other areas. The results indicate that bats in an area do not move to better

[1]Global Positioning System

localities (like Østensjøvannet) during lesser weather conditions (Gjerde, in prep.).

2.2 Mapping advertisement calling *Vespertilio murinus*

In 1993 a project on mapping all advertisement calling *Vespertilio murinus* along the Norwegian coast from Halden to Stavanger was initiated (Gjerde 1995d, 1996a). Potential localities for *Vespertilio murinus* were visited from mid September and through November, initiating fieldwork 1-2 hours after sunset. Surveying was only carried out during good weather conditions, with no precipitation, little or no wind, and temperatures above +2°C. The ultrasound detector was fixed at 25 kHz to enable detection of foraging bats. It showed out to be most useful not using the detector when locating advertisement calling males.

The media were used to inform the public of the project. In these fora people were urged to call in their observations on *Vespertilio murinus* to NØBI's mobile phone number.

All old observations were collected through literature and observations by colleagues. Cities thought to be large enough to contain tall artificial structures were first listed. These structures were mapped by first checking with the local taxi drivers, police stations and fire departments. These had usually a fairly good knowledge of the local situation. At the same time I got a "triple check" of the city. These offices were contacted by phone before the cities were visited the first night. Potential localities discovered during the survey was added to the list, while unsuitable localities were crossed out. In the case of the cities of Drammen and Oslo, locals were not contacted. In Oslo, Kristiansand, Sandnes and Stavanger all tall buildings (9 stories or more) were mapped in daylight. At other cities the potential localities were checked during the trip to, and bat surveyed fro. In Drammen, however, the localities were not mapped prior to the survey at all due to the good aerial view while driving.

All pipes, churches, silos, tall apartment buildings, fortress', industrial buildings and cliffs over a certain height were checked. Some localities not exceeding this height were occasionally checked. An important part of the work was to get information from the care takers, and promote the project.

Natural habitats (cliffs) were surveyed as well.

A list of both natural and artificial localities were obtained from the County Environmental Departments, "Project Peregrine Falcon", "Project Eagle Owl" and a national climbing map.

Each potential locality were visited at least three times, every time for five minutes or more. When advertisement calling males were confirmed from a locality, it was visited no more. This due to our survey mainly register presence/absence.

Posters were hung up at potential localities where bats were not detected, with a request for observations. In addition the local newspapers were used, and in some cases a radio station.

A Pettersson D100 ultrasound detector was chosen, in contrast to the D980, since it had a loudspeaker. It was important to be able to hear the audible sounds from the advertisement calling males, as well as the search calls through the detector. Headphones were therefore not chosen.

3 Definitions

An observation is defined as a map reference at a point in time. If observations are clustered together, and not possible to distinguish on a map, they are regarded as one observation (observations less than 100 meters apart). This means that, e.g. an observation on three bats may be three encounters within a distance of 20-30 meters between each other. However, these will appear as one observation on a map. This way of interpreting observations is commonly in use by existing bat workers in Norway (e.g. Gjerde 1995a, b, c, Wergeland Krog 1995, Olsen *et al.* 1996).

The number of bats recorded is based on the number of individuals recorded simultaneously by visual and/or audible observations (e.g. **5** - 8). When additional bats are heard or seen, and the observer subjectively believes that these might be additional to the minimum number, but can not be certain, they are added as a second number to the observation (e.g. 5 - **8**). When a transect is being surveyed with a speed slower than the bat species flight speed, every new observation within a reasonable distance is added to the second number. When the speed of a transect is equal or higher than the species normal flight speed, every new encounter is regarded as a new specimen.

3.1 Habitat categories

The categories to the British Habitat Survey (Walsh et al., 1995) has been adapted in our work. However, the urban and riparian categories were to insufficient. Urban was categorized as one in the British Habitat Survey, while I during the SUM project divided urban into four subcategories (Gjerde, in prep.). I have divided riparian habitats into fast and slow flowing rivers (Gjerde 1993).

U Urban

Industrial parks/intersections/schools U1

This includes areas with little or no vegetation. Large buildings may occupy a large portion of the area, most of the remaining is of tarmac (roads, parking lots, storage areas etc.). This also includes highways, intersections and airports.

Down town apartment buildings U2

Buildings, often several stories tall, laying next to the street. Usually little or no vegetation on the side facing the street. Usually some vegetation on the back-side, often with a few trees, but not much ground vegetation.

Tall apartment buildings (8 stories or taller) U3

Tall buildings with good distance between them. Well maintained lawns with scattered trees. Reminds of parkland, but contains of usually somewhat less trees and usually no water, shrub or wild grass.

Housing estate/residential district U4

Private houses usually with a good maintained garden, consisting of hedgerows, lawns, trees (incl. fruit trees), shrubs, flowers, and others.

R Riparian

Rivers, slow flow (width)

A geological slow flowing river, where erosion goes basically horizontally. Usually resembles ponds and lakes in its flora and fauna.

Rivers, fast flow (width)

Rivers with vertical erosion due to a lower base level. Sand and stones along the shores and bottom.

The latter category has more recently been devided into two subcategories. The first subcategory contain vertical eroding rivers where the water does not brake the surface. In the second subcategory the water brakes from the surface, resulting in splashes and sprays (often called "whitewaters"). In this second subcategory floating objects, like e.g. insects, easily mix into the waterbody.

3.2 PFN-index

Temperature seems to have a strong impact on bat activity. However, bat activity really reflects insect availability. Summers are short in northern Europe, and so are the nights. Bats need to gain strength from the previous winter, reproduce, and prepare themselves for the coming winter during these short summers. The number of nights and hours in which foraging is possible will therefore, strongly effect the population.

Rydell (1989) proved that *Eptesicus nilssonii* did not forage at temperatures lower than 6°C. Furthermore, all bats in his study foraged at temperatures equal of, or above 10°C. The number of nights with a temperature of 10°C or more may indicate the number of nights that are suitable for foraging. When calculating the number of nights for a number of consecutive summers, and compare this with an average, it is possible to use this for explaining, in part, population fluctuations. Of course, such a PFN index (=Potential Foraging Nights) can not be used for comparing different areas, but will allow monitoring a specific population through time.

It remains to check the threshold temperature for bat activity between regions and species to enable a more widely use of the method.

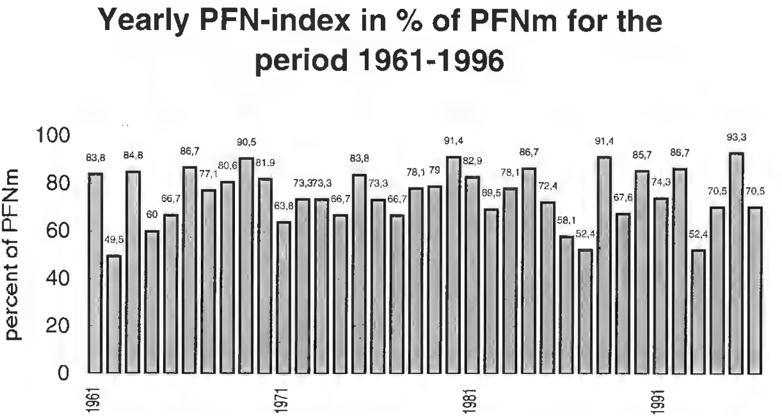

Figure 1. Yearly PFN-index measured at Blindern, Oslo.

Table I. Variation of PFN-index between some selected meteorological stations in Norway calculated for the period 1961 - 1990.

locality	municipality	longitute/latitude	m.a. s.l.	PFN m	PFN min	PFN max	PFN av
Blindern	Oslo	59°55'N 10°43'E	94	105	52	96	79
Kjevik	Kristiansand	58°12'N 08°04'E	12	147	53	98	69
Sola	Sola	58°53'N 05°38'E	7	165	48	94	72
Tønjum	Lærdal	61°03'N 07°31'E	36	152	38	91	56
Værnes	Stjørdal	63°27'N 10°56'E	12	135	26	85	54
Tromsø	Tromsø	69°39'N 18°55'E	100	81	5	40	22

Table 2. First date with night minimum temperature equal to or exceeding 10° C, measured during the period 1961-1990.

locality	earliest date	latest date
Oslo	15 April	5 June
Kjevik	15 April	8 June
Sola	19 March	13 June
Tønjum	6 February	19 June
Værnes	14 April	9 June
Tromsø	26 May	24 July

Table 3. Last date with night minimum below 10° C, measured during the period 1961-1990.

locality	earliest date	latest date
Oslo	23 August	2 November
Kjevik	17 September	2 November
Sola	17 September	9 November
Tønjum	4 September	1 December
Værnes	27 August	1 November
Tromsø	3 August	17 October

4 Filing bat observations

In 1994 a database, named "Bat-Base", was developed by Ola M. Wergeland Krog. The database was specially designed for bat records and related information.

In 1997 it was updated and modified by the author. Currently it is a national database containing around 2500 records. It is now managed by the newly established Norwegian Chiroptera Information Center (NIFF).

A print-out of the updated form is included in the appendix.

5 Epilogue

When fieldwork is being carried out using already available methods, strengths and faults usually become apparent. Minor faults in methods may be eliminated by small modifications. However, larger faults or lack of methods for a specific problem usually encourages the development of new methods, which in turn must be tested as well.

There has been established several working groups who are compiling information on methods in monitoring bat populations (Gjerde 1996b). Such a group was established during the 2nd European Bat Detector Workshop in Grazalema in 1993, with Ulrich Jüdes as chairman. The British Bat Conservation Trust is also developing such methods.

6 Acknowledgments

I would like to thank Stein Kristiansen from the Norwegian Meteorological Institute (DNMI) for comments and help in developing the PFN-index. Allyson Walsh at the University of Bristol has been kind enough to supply me with useful information on the British Habitat Survey, and Ola M. Wergeland Krog has allowed NIFF to take over the "Bat-Base".

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Bat-base

Reference/Source	Restrictions	Date rec.	Rec. no.
		30.09.1997	1051

Species	Observer	Date obs.	Obs. time	Number
Eptesicus nilssonii	Leif Gjerde	27.05.1994		1

Locality	Loc.	Grid system	UTM	
Frognerparken, southern pond		WGS84	NM95 44	NM94

Commune	County	Country
Oslo	Oslo	Norge

Obs. type	Activity	h.a.s.l.	Habitat 1
Bat detektor – visual	Hunting		Pond

Landscape	Habitat 2
Parkland	Parkland

Linear corridor, linkage habitat	Wind	Temp.
Stream		

Nearest construction	Cloudiness	
	1/8	

Notes

Frequency range 29-46 kHz. Faster rythm than E. nilssonii normally have. Difficult to find peak frequency (31-32 kHz). Observed the bats untill 2332. In the park from 2305 to 0030.

Norwegian National Database on bat observations

Records updated by:
Norsk Informasjonssenter for Flaggermus (NIFF), Postboks 247, N-2001 Lillestrøm.
Phone: + 47 922 10800. Fax: + 47 921 09000.

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Bat survey by car transects in Luxembourg

by

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Abstract

In one night, a car was driven with a speed of maximum 60 kmh on a transect of 50,6 km in total. Two bat detectors were used to count bats, one fixed to 25 kHz and one to 45 kHz. A total of 129 bats of 4 species were counted. The most frequent species was the common pipistrelle bat (Pipistrellus pipistrellus) with 103 encounts. It was mainly found in villages or over forest roads. 5 of 6 recordings of the serotine bat (Eptesicus serotinus) were made in or near villages. Only twice a noctule bat (Nyctalus noctula) and one Myotis species were registered.

Résumé

Pendant une seule nuit, une voiture était conduite avec une vitesse de 60 kmh au maximum sur un transect de 50,6 km au total. Deux detecteurs à ultrasons étaient utilisés, l'un fixé à 25 kHz, l'autre à 45 kHz. Au total, 129 chauves-souris ont pu être régistrées appartenant à 4 espèces. La pipistrelle commune (Pipistrellus pipistrellus) était l'espèce la plus frequente avec 103 registrations. Elle se trouvait surtout dans les villages ou au-dessus des chemins et routes forestiers. 5 sur 6 épreuves de la sérotine commune (Eptesicus serotinus) se faisaient dans ou en proximité des villages. Seulement deux fois, une noctule commune (Nyctalus noctula) et une espèce de Myotis ont été entendues.

Zusammenfassung

In einer Nacht wurde mit einem Auto mit einer maximalen Geschwindigkeit von 60 kmh ein Transekt mit einer Gesamtstrecke von 50,6 km abgefahren. Es wurden zwei Ultraschall-Detektoren benutzt, der eine wurde auf 25 kHz eingestellt, der andere auf 45 kHz. Insgesamt wurden 129 Fledermäuse aus 4 Arten gezählt. Die häufigste Art war die Zwergfledermaus (Pipistrellus pipistrellus) mit 103 Nachweisen. Sie wurde hauptsächlich in Siedlungen oder über Waldwegen nachgewiesen. 5 von 6 Nachweisen der Breitflügelfledermaus (Eptesicus serotinus) gelangen in oder in der

Nähe von Siedlungen. Nur zwei Mal wurde ein Großer Abendsegler (Nyctalus noctula) gehört und eine Myotis-Art.

1 Introduction

During the 3rd Bat Detectro Workshop, which was located in Luxembourg during August 1996, it was decided to carry out a survey of bats in the Grünewald forest. Due to a highway which was planned to be built through this forest, we wished to gather data on bat density and distribution within the forest.

This survey was our contribution to this work.

2 Methods

A car was driven when using two Pettersson D100 detectors. The detectors were pointing out each their window, thus one detector tuned at a fixed value of 45 kHz out the right hand side, closest to the vegetation, enabling better detectability of *Myotis* and *Pipistrellus* species. The other detector was pointing out the driver side, tuned at a fixed frequency of 25kHz to enable detection of "smacking" bat species.
A speed of maximum 60 km per hour was chosen, with a lower mean value. Every observation was noted on a Garmin GPS 45 instrument using the UTM grid system of WGS84. Time and distance from transect start was noted whenever possible.

3 Results

A total of 129 bats were counted during 50.6 km of transects on 19 August 1996. Sunrise was at 06:32 and sunset at 20:46 (calculated by the GPS)

Nyctalus noctula was only recorded twice in which both observations were within one hour after sunset. Five of six records of *Eptesicus serotinus* were made in, or near villages in the east and north, suggesting a preference for open and urban areas.

Table 1: Recorded species and individuals

species	no. ind.	bats/km
Pipistrellus pipistrellus (Pp)	103	2.0
Eptesicus serotinus (Es)	6	0.1
Nyctalus noctula (Nn)	2	0.0
Myotis sp. (M)	3	0.1
Unidentified	15	0.3

Table 2: Results of the specific transect.

	km	Es	Nn.	Pp	Pp/km	M	Ul	total	tot/km
Transect 1	5.6+	1	1	5	0.9	1	2	10	1.8
Transect 2	6.2-	3	1	4	0.6	0	1	9	1.5
Transect 3	10.2	1	0	16	1.6	1	8	26	2.5
Transect 4	4.2	0	0	11	2.6	0	0	11	2.6
Transect 5	1.0+	1	0	3	3.0	0	1	5	5.0
Transect 6	4.0	0	0	10	2.5	1	1	12	3.0
Transect 7	19.4	0	0	54	2.8	0	2	56	2.9
	50.6	6	2	103	2.0	3	15	129	2.5

Transect 1 2115-2129 C.R. 125, C.R. 126
Forest, west-east, asphalted road, crossroads near Petschbend (391.9 m.a.s.l.) - Stafelter - Spatzlay. Stop of transect at forest edge just west of Hostert.

Transect 2 2129-2140 C.R. 126a, C.R. 132
Forest edge and village in south (ca.1/3), agriculture (ca. 1/3), village (Ernster) - agriculture - new village.
South - north transect from crossroads west of Hostert, past Rameldange and through Ernster onward to village north of Ernster where E27 crosses through village.

Transect 3 2146-2157+ E27/N11
Forest with wide asphalted road.
Northeast to southwest. From village north of Ernster to Dommeldange.

Transect 4 2207-2220
Local forest dirtroad of soil and sand.
Dommeldange to crossroad C.R. 125/C.R.126

Transect 5 2220-2225+ C.R. 125
Forest with asphalted road.

Transect 6 2245-2252+ C.R. 124
Transect two km one way, with a return of same transect, totally 4 km. Forest road, asphalted.
Note slightly different results during transect to and fro.

Transect 7 2300-2342+ C.R.125, C.R. 126, N30 north, N30 south
Part of transect repeated (Stafelter north). Transect may be subdivided at 2.5, 6.7, 10.8 and 19.4 km.
All forest road on asphalt.

4 Discussion and conclusion

A one night survey is to little for any good analysis. Nevertheless it does give some indication and suggestions on the distribution pattern. Lower densities along the E27 would suggest these areas are less suitable for bats. This road would represent a more open area which is not preffered as a hunting habitat for *Pipistrellus*, and mortality by car accidents would be higher.

View-point	UTM	time	km	species	no.	annotations
199	02950.55065	2115	0	-		crossroad Heischler/ Asselscheuer
200	02952.55051	2118	1.0	Nn	1	
201	02960.55043	2119	2.0	Pp	1	
202	02964.55044	2121	2.5	M. Sp.	1	
203	02979.55043	2123	3.3			streetlamps
203			4.2	Pp	1	
204	02980.55044	2123	4.5	Pp	1	
204	02983.55045	2124	4.5	Ul	1	
206	02985.55045	2124	4.6	Pp	1	

View-point	UTM	time	km	species	no.	annotations
207	02987.55045	2125	5.0	Es		
208	02992.55046	2125		Pp	1	
209	02992.55046	2125	5.6	Ul	1	
		2129				short brake/crossroad
210	02999.55044	2129		Pp	1	
210		2129		Es	1	
211	02999.55044	2129		Pp	1	
212	03000.55044	2130		Pp	1	
213	03000.55046	2130		Pp	1	buzz
214	03002.55052	2131		Es	1	
215	03002.55053	2132	7.9	Es	1	
216	03004.55056	2132		Nn	1	
217	03005.55057	2133	8.4	Ul	1	
		2140	11.8			End of transect

218	03012.55083	2146	0			Start of transect
219	02993.55066	2149	2.9	Pp	1	
220	02992.55064	2149	3.0	Pp	1	
221	02991.55063	2150		M. Sp.	1	
221				Ul	1	
222	02988.55060	2150		Pp	2	
223	02986.55059	2150	4.0	Pp	1	
224	02984.55057	2151		Pp	2	
224				Ul	2	
225	02982.55054	2151		Pp	1	
226	02981.55053	2151		Pp	1	
227	02971.55041	2153	6.6	Pp	2	
228	02969.55039	2154		Pp	2	
229	02964.55036	2154		Pp	2	
230	02961.55034	2155		Ul	1	
231	02960.55033	2155		Pp	1	
231				Ul	1	
232	02951.55026	2156		Ul	3	
233	02940.55022	2157	10.2	Es	1	
						End of transect

		2207	0			Start of transect
234	02936.55023	2208	0.6	Pp	1	
235	02949.55035	2212	2.4	Pp	1	hunting
236	02951.55038	2214	2.8	Pp	2	

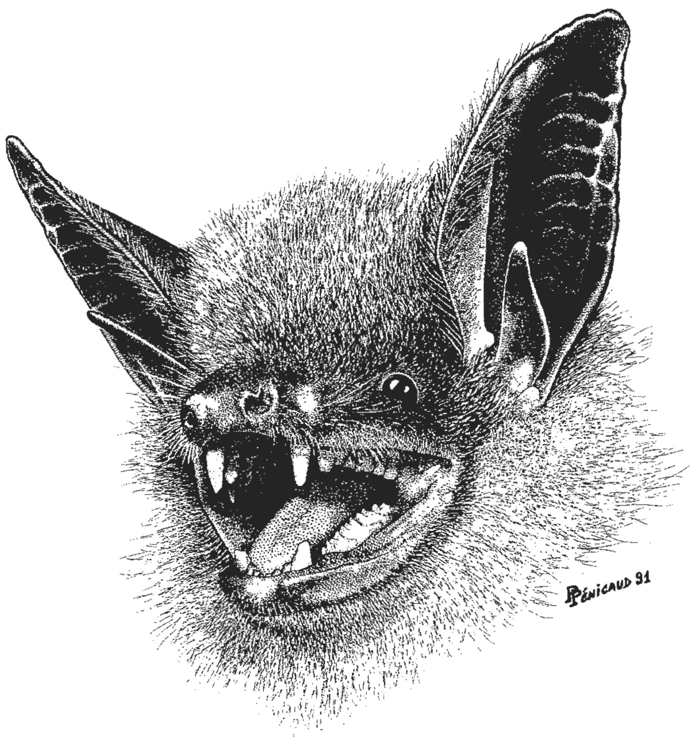
View-point	UTM	time	km	species	no.	annotations
237	02952.55044	2216	3.5	Pp	2	
238	02953.55047	2218	3.7	Pp	1-2	hunting
239	02953.55051	2220		Pp	2	
240	02952.55052	2220	4.2	Pp	2	crossroad
241	02950.55058	2224	5.0	Pp	3	
242	02950.55060	2224	5.2	Es	1	
242		2225	5.2	Ul	1	
						End of transect

		2245	0			Start of transect
243	02947.55063	2246		Pp	2	
244	02946.55064	2246		Pp	1	
245	02946.55062	2246		Pp	1	
246	02945.55060	2247	1.2	Pp	1	
247	02940.55058	2247		Pp	1	
248	02941.55061	2248	2.0			turn back
249	02940.55057	2250	2.4	Pp	1	
250	02943.55058	2250	2.8	Pp	1	
251	02945.55059	2251	3.0	Pp	1	
252	02947.55061	2251		Pp	1	
253	02948.55064	2252	3.6	Ul	1	
				M.sp.	1	
254		2252	3.6			End of transect

254	02950.55064	2300	0	Pp	1	Start of transect
255	02950.55056	2301	1.1	Pp	1	
256	02953.55051	2302	1.5	Pp	2	
257	02956.55049	2303	1.9	Pp	1	
258	02960.55045	2304	2.5	Pp	1	
259	02961.55045	2304		Pp	1	
260	02963.55052	2305		Pp	1	
261	02965.55053	2306	3.8	Pp	1	
261			3.8	Ul	1	
262	02966.55055	2306		Pp	2	
263	02964.55061	2307		Pp	1	
264	02964.55063	2307	5.0	Pp	2	
			6.7			End of transect

265	02966.55075	2311		B. Bufo	1	crossing road

View-point	UTM	time	km	species	no.	annotations
266	02965.55063	2312	8.4	Pp	1	
267	02965.55061	2313	8.7	Pp	1	
268	02965.55059	2313	8.9	Pp	3	
269	02966.55056	2313	9.2	Pp	2	
270	02962.55050	2315	10.0	Pp	2	
270		2315	10.0	Pp	1	
271	02960.55044	2316	10.8	Pp	1	stay to 2325
272	02951.55032	2328		Pp	2	
273	02954.55030	2329	12.6	Pp	1	
274	02954.55031	2329		Pp	1	
275	02954.55036	2330		Pp	2	
		2332	14.1	Pp	1	
		2333	14.4	Pp	1	
			15.1	Pp	2	
		2335	15.6	Pp	2	
		2335	16.0	Pp	1	
		2335	16.1	Pp	1	
		2337	16.7			Turn back
		2338	17.2	Pp	1	
276	02947.55051	2338	17.4	Pp	2	
		2339	17.7	Pp	2	
		2339	17.8	Ul	1	Es or Nn
		2339	17.9	Pp	1	
		2340	18.1	Pp	1	
		2340	18.3	Pp	2	
		2341	18.5	Pp	2	
		2342	18.7	Pp	4	
			19.4			End of transect



Myotis myotis, dessin Philippe Pénicaud (©)

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Feasibility of monitoring bats on transects with ultrasound detectors

by

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Abstract

In 1990 an experimental study was started to test if point and line counts along transects could be used for monitoring bats. Later, this was incorporated into the Dutch Mammal Monitoring Programme. In 1995 counts on 10 transects resulted in 1682 recorded presences of 9 species. Each transect of 13-17 km consists of 20 points and 20 lines in between, on which bats are recorded. Counts are performed monthly from April-September. Transport is usually by bicycle. Ultrasound detectors are tuned to approx. 40 kHz. Variables noted are presence, maximum number heard at one time and total number of registrations, for each point or line. Results from 6 transects have shown that all three variables are strongly correlated, but that presence showed the least variation. It is therefore preferred for monitoring purposes, but has the disadvantage of possible saturation (maximum is 100%). Results from points and lines were also strongly correlated, but variation at points was smaller.

Some species showed some seasonality in presence, resulting in variation being smaller in some months than in others. This differed between species, so counts in different months seem necessary. The maximum presence per season showed similar variation as the mean presence per season.

Results indicate that by using approx. 100 transects, differences between years of 20-40% (depending on species) or more can be detected. Monitoring bats this way, however, requires well-trained observers.

Résumé

En 1990, une étude expérimentale a été mise en place pour tester l'utilisation des dénombrements par points ou en ligne le long de transectes pour la surveillance des chauves-souris. Plus tard ceci a été incorporé dans le Projet Néerlandais de Surveillance des Mammifères. En 1995 des dénombrements de 10 transectes donnaient 1.682 présences constatées pour 9 espèces. Chaque transecte de 13-17 km comprenait 20 points et 20 lignes intercalées, où des chauves-souris ont été recensées. Les dénombrements s'opéraient mensuellement d'avril à septembre. Les déplacements se sont faits généralement en vélo. Les détecteurs d'ultrason étaient réglés à 40 kHz. Les paramètres notés étaient: la présence, le nombre maximal entendu au même moment et le nombre total des enregistrements pour chaque point ou ligne. Les résultats de 6 transectes ont montré que les trois paramètres sont étroitement correlés, mais que le paramètre 'présence' montre la moindre variation. Celle-ci est donc préférée pour les besoins de surveillances, bienqu'elle ait le désavantage d'une saturation possible (le maximum étant 100%). Les résultats des points et des lignes sont également étroitement correlés, mais la variation aux points est plus faible.

La présence de quelques espèces montre un certain effet de saison ce qui implique une variation plus faible dans certains mois que dans d'autres. Ceci différait selon les espèces, c'est pourquoi des dénombrements dans des mois différents semblent nécesaires. La présence maximale par saison montrait une variation similaire à la présence moyenne par saison.

Les résultats indiquent qu'en effectuant approximativement 100 transectes, des différences annuelles de 20-40% (dépendant des espèces) ou plus peuvent être trouvées. Cependant, la surveillance des chauves-souris par cette méthode nécessite des obervateurs compétents.

Zusammenfassung

Im Jahr 1990 wurde eine experimentelle Studie durchgeführt, um zu testen, ob Punkt- und Linienzählungen entlang Transekten zur Erfassung von Fledermäusen benutzt werden können. Diese Studie wurde später in das holländische Säugetier-Erfassungsprojekt aufgenommen. Im Jahre 1995 ergaben Zählungen auf 10 Transekten 1.682 Nachweise von 9 Arten. Jedes Transekt von 13-17 km Länge bestand aus 20 Punkten und 20 Linien dazwischen, auf denen Fledermäuse gezählt wurden. Die Zählungen wurden monatlich von April bis September durchgeführt. Als Transportmittel diente gewöhnlich ein Fahrrad. Die Ultraschall-Detektoren wurden auf ca. 40 kHz ausgerichtet. Als Variablen wurden für jeden Punkt oder jede Linie die Anwesenheit, maximale Anzahl der zur gleichen Zeit gehörten Tiere und die Gesamtzahl der Nachweise notiert. Die Ergebnisse von 6 Transekten haben gezeigt, dass alle drei Variablen streng korreliert sind, dass aber die Anwesenheit die geringste Variation zeigte. Sie wird deshalb für Erfassungszwecke bevorzugt, hat aber den

Nachteil einer möglichen Sättigung (maximal sind 100%). Die Ergebnisse von Punkten und Linien waren ebenfalls streng korreliert, aber die Variation bei Punkten war geringer.

Einige Arten zeigen jahreszeitliche Unterschiede in der Anwesenheit, daraus resultiert, dass die Variation in machen Monaten geringer als in anderen. Dies unterschied sich zwischen den Arten, so dass Zählungen in verschiedenen Monaten notwendig erscheinen. Die maximale Anwesenheit pro Jahreszeit zeigt eine ähnliche Variation wie die mittlere Anwesenheit pro Jahreszeit.

Die Ergebnisse zeigen, dass bei Anwendung von ca. 100 Transekten zwischen den Jahren Unterschiede von 20-40 % (abhängig von der Art) oder mehr gefunden werden können. Die Erfassung von Fledermäusen mit dieser Methode erfordert jedoch gut geschulte Beobachter.

1 Introduction

For monitoring bats different methods can be used. Counting hibernating bats can produce data for those species which can be observed and counted in accessable caves, military forts, ice-houses, cellars, etc. Species which during winter inhabit trees or houses are only rarely found there. These species, as well as some other species, can be monitored by using counts of bats leaving roosts. Such counts show the least variation if they concern maternity roosts before the juveniles are flying. They give only information on a limited part of the population, i.e. reproducing females. The rest of the population is thus not monitored. Also a species as the Nathusius Pipistrelle, which is only rarely reproducing in the Netherlands, can not be traced this way. To be able to trace developments in all species and all populations in the field, we decided to test the method of counting bats on points and lines using ultrasound detectors.

2 Methods

The first two transects were started in 1990, some more were started from 1992 onwards. Each transect has 20 points and 20 lines in between. We start counting on line 1 and finish with point 20. The total length of the transects is 13-17 km, transport is usually by bike. Counts were performed each month from April - September, i.e. 6 counts each year.

Points are chosen at places where we can expect bats of several species to occur. Points are usually chosen close to canals, ponds and lakes for species as Daubentons Bat and Pond Bat, or at edges in woodland. At each point bats are counted during 3 minutes. Up till 1997 bats were also counted on the lines in between the points.

Bats are counted as the number of bat-passes for each species, but more important also as the maximum number heard or observed at one time on each point or line. The ultrasound detector was tuned to approximately 40 khz. Thus most of the smaller species could be heard well, the larger species could be heard too, especially at close range. When such a larger species was heard, the detector was tuned to its maximum frequency to check its identity.

Counts were only performed when weather conditions were at least fair, thus windspeed less than 3 Beaufort, temperature at least 8°C and virtually no rain.

Counts were started approximately 1 hour after sunset.

The results for points and lines were treated separately. Three variables were used. The presence is the percentage of points or lines on which a species has been observed. The sum of maximums is the total of all maximum-estimates at each point or line and the sum of passes is the total of passes on all points or lines.

3 Results

3.1 Variables

It appeared that all three variables were strongly correlated, within all transects and within all species. This implies that their indication-value may be very similar. Even when tested against some other variables they appeared to be very similar in indication-value. Only the sum of all passes differed slightly, possibly due to the fact that a stationary bat when flying to and fro will produce more passes. In fact, the sum of passes is considered to tell more about differences between suitability of habitats, then about differences in population-level. Thus it seems rather inapropriate for monitoring purposes.

For monitoring purposes variables are particularly interesting if they show a low variation, because low variation means high reliability. It appeared that the presence, the percentage of points or lines on which a species occurred, showed the least variation, followed by the sum of maximums. This was valid for all species, both on points and lines, in all seasons. An example is shown in table 1 for the pipistrelle. The sum of passes showed by far the highest variation. As mentioned before, this implies that the sum of passes is the least appropriate for monitoring purposes.

Table 1: Relative standard deviation (rsd or CV) of variables used on point counts in the pipistrelle

presence	67
sum of max's	97
sum of passes	128

The presence appears to be the best variable to use, but has one disadvantage: it has the possibility of saturation. When a species has a very high density, there is the risk that they are encountered on all points or transects. From then on a further increase cannot be recorded anymore. Even though such a high level of occurrence has not yet been recorded in the Netherlands, we have decided to use presence and sum of maximums both in the future.

3.2 Points and lines

It appeared that the results from counts on points and lines were strongly correlated. It also appeared that variation was usually lower at points. This was especially so for species such as Daubentons bat and Pond bat, since points were on average closer to the water than lines. But it was true for other species as well.

So if one has to choose between counts on points or lines, points are slightly more suitable for monitoring purposes. In the Netherlands we initially preferred to do both, but since 1997 have skipped the counts on lines.

3.3 Seasonal variation

It appeared that some species showed slight differences in occurrence between months. This is shown in figure 1a and 1b for Noctule and Pipistrelle.

The Noctule bat shows a rather strong peak in occurrence (shown as bars) in summer, with low variation (shown as line) in July. This suggests that July is the better month to count this species, because of this lower variation. On the other hand the Pipistrelle was common in all months, but showed the least variation in June.

So it appears that different species show differences in optimal periods for counting, although June and July seem to have low variation in most species. Nonetheless it seems necessary to have counts in different months.

Figure 1 also shows that high occurrence does not necessarily mean low variation, and it is the low variation which is important for monitoring.

3.4 Maximum and mean

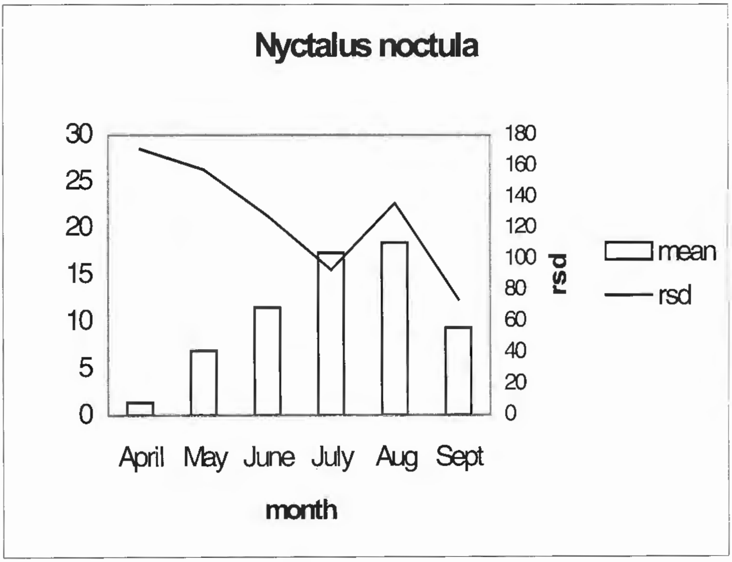
To determine an annual index in order to compare different years, it is common practice to use the mean of all counts in that year as the key-variable. It has been suggested that it might be better to use the maximum of occurrence in every year.

This could be tested on data gathered by Kees Mostert near Delft in the Netherlands. In 1993 he counted bats on a transect almost weekly. By so doing he produced a few counts each month. I took 5 random samples from those to have different monthly counts in one season. From each I determined both the mean and the maximum.

It appeared that the variation in mean and maximum showed very similar results (table 2). This implies that using the maximum does not produce a better annual index.

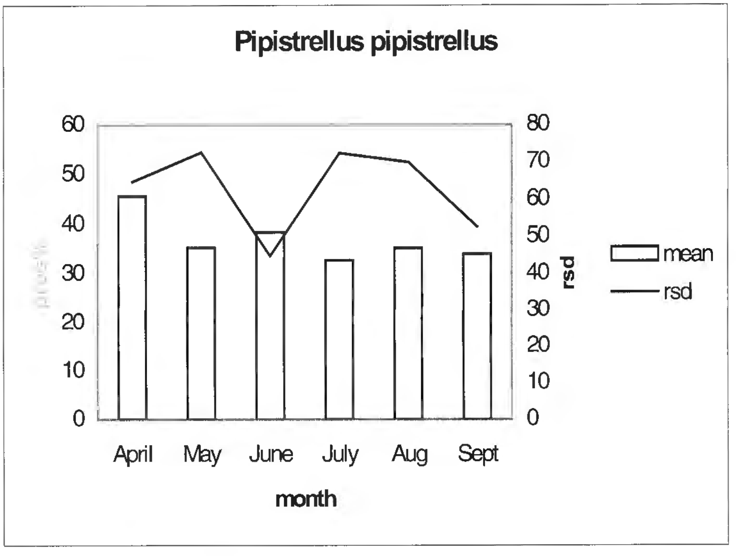
Table 2 Relative standard deviation (CV) of seasonal mean and maximum estimates for presence

	mean	maximum
M. daubentonii	31	31
M. dasycneme	224	224
P. pipistrellus	22	24
P. nathusii	8	16
N. noctula	69	71
E. serotinus	31	47



1a

Fig. 1: Seasonal variation in presence shown as mean (bars) and rsd (line) in Noctule (a) and Pipistrelle (b)



1b

3.5 Number of transects

To determine how many transects should be counted for producing valid trends, a simple model called STUD was used initially. This is based simply on the total variation found in the collected data. Our data were not sufficient for using more sophisticated models.

This model estimates the number of transects needed, based on the relative standard-deviation or RSD of the counting results, also called coëfficient of variation or CV. A chance of 5% that a result was unjustly considered a real difference was considered as acceptable. We also used a probability of 80% that a real difference is indeed found in the sample.

Figure 2 shows the relationship then between the variation in results (as rsd) and the number of transects needed to be able to find annual differences of 10%, 20% and 30%. It shows, as an example, that if the rsd in the counts is 50, we need at least 50 transects to be able to find a difference between years of 20%. It also shows that the lower the rsd (variation) is, the lower the observer effort or the higher the accuracy will be.

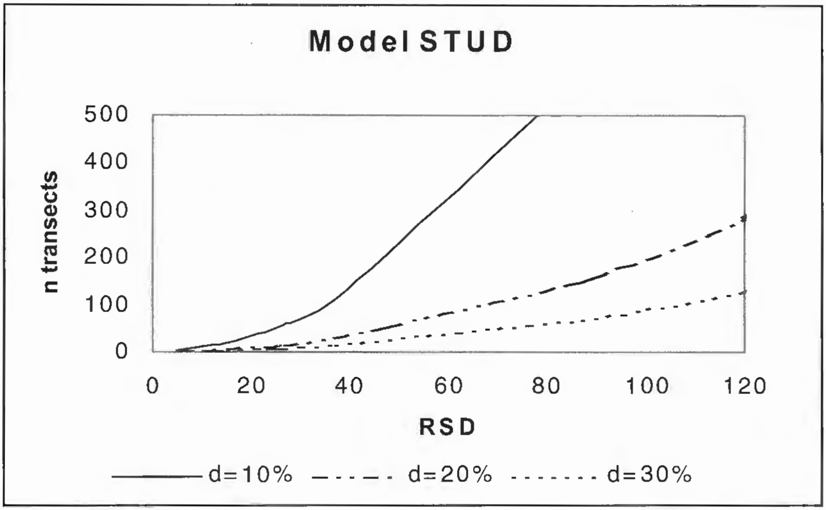


Fig. 2: Relationship between rsd, number of transects and trend detectability by using model STUD

Table 3 shows the results of using STUD for each species. It shows the species, the sample size and the number of transects needed to be able to find differences between years of 20%, 30% and 40%. For instance, if a difference of 20% between years is considered sufficient for Daubentons' bat, we can reach that goal with 93 transects.

Table 3 Number of transects needed for each species
Results are shown as sample size (n) and number of transects needed to detect annual differences of 20% (d=20), 30% and 40%. Only numbers of transects over 70 are shown.

	n	d=20	d=30	d=40
M. *cf.* mystacinus	8	152	69	
M. daubentonii	63	93		
M. dasycneme	55	358	160	91
P. pipistrellus	63	86		
P. nathusii	63	268	120	
N. noctula	63	333	149	85
E. serotinus	39	221	100	
P. auritus	16	317	142	81

With a smaller number of transects it will take more years to be able to discover trends.

Other studies with transect counts of bats (although a very limited number) show similar or somewhat smaller variations, so our data are best considered to be on the safe side.

3.6 Number of counts per season

Initially counts were performed monthly from April - September. Recently data of 8 transects were reanalyzed, indicating that results from counts in May, July and August produced very similar trends compared to results from all counts. We therefore decided to limit the counts to May, July and August.

3.7 Dutch Mammal Monitoring Programme

This method was adopted for one of the schemes in the Mammal Monitoring Programme in the Netherlands. Most schemes of this programme are now also incorporated in the National Network for Ecological Monitoring (NEM). For this network the Dutch National Statistical Service has issued guidelines for monitoring wildlife. For the number of transects or study plots needed it uses the rule of thumb that a number of 25-50 should be sufficient for detecting trends over a period of 5-10 years.

Unfortunately the transect counts are not incorporated in the NEM because of insufficient participants.

As a tool for analysis they provided the model TRIM, which is freely available through Internet (http://neon.vb.cbs.nl/sec_lmi_n/incpro/tri001pl.htm). We have tried to arouse the interest of other observers to cooperate with this scheme of transect counts. So far we have only managed to have counts on 14 transects with 9 species of bat. We will, however, put more effort in trying to increase this notably, by training and motivating more observers.

The first results, based on the model TRIM, seem to show that, so far, there are no sound indications of a trend in Pipistrelle and Daubenton's bat, but there seems to be a negative trend in Noctules (Figure 3). This shows the need for such a monitoring scheme.

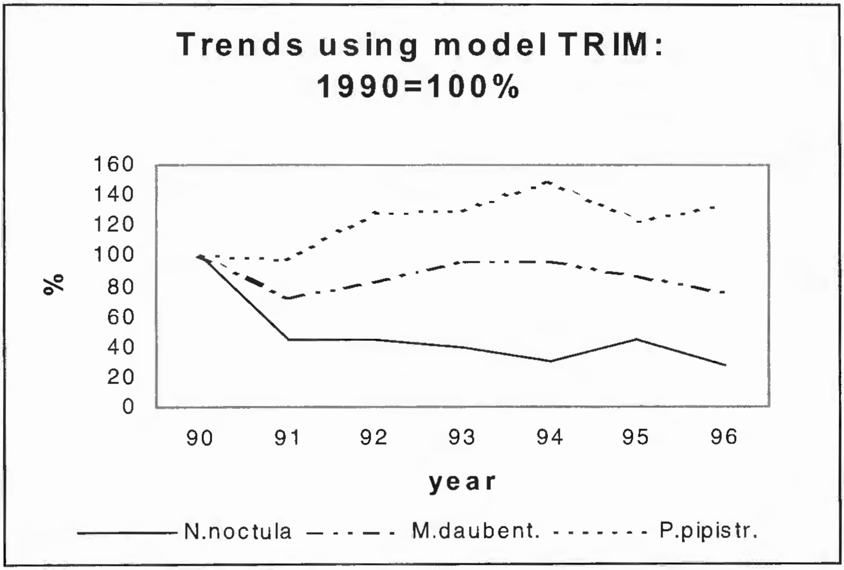


Fig. 3: Trends in three species of bat in the Netherlands calculated by model TRIM

It is only possible to have such a monitoring scheme in countries with only a limited number of species, which can reasonably be distinguished from one another by using ultrasound detectors. The Netherlands is such a country, especially the northern and western half of it. In other countries it may be more difficult, but why not give it a try?

Myotis daubentonii, dessin Philippe Pénicaud (©)

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The Bat Fauna of the 'Grünewald' forest in Luxembourg: a methodology approach.

by

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Summary:

Luxembourg authorities plan to cut the greatest ancient forest massif, the 'Grünewald' forest by a new motorway. To assess a maximum of faunistical data on forest dwelling bat species in this wood in a short time, different bat survey methods were used during summer 1996. The suitability of the different methods is analysed as the results and problems of this study are presented and discussed.

Résumé

Les autorités luxembourgeoises envisagent de construire une nouvelle autoroute à travers le plus grand et le plus ancien massif forestier, le 'Grünewald'. Pour recenser durant le laps de temps restant le maximum de données faunistiques sur les chauves-souris arboricoles, différentes méthodologies furent appliquées durant l'été 1996. L'aptitude de ces différentes méthodolies est dicutée face aux résultats et aux problèmes présentés.

Zusammenfassung:

Die Luxemburger Autoritäten planen eine neue Autobahn, die das älteste und größte zusammenhängende Waldgebiet des Landes, den Grünewald, zerschneiden wird. Um ein Maximum an faunistischen Daten über die waldbewohnenden Fledermäuse dieses Lebensraumes in dem verbleibendem Zeitraum zu erhalten, wurden während des Sommerhalbjahres 1996 eine Reihe verschiedener Fledermaus-Erfassungsmethoden angewandt. Die Eignung der verschiedenen Methoden wird im Rahmen der Vorstellung anhand von Ergebnissen und Problemen der Untersuchung diskutiert.

1 Introduction

Over one third of the surface of the Grand-Duchy of Luxembourg is covered by forests. North-eastern of the capital Luxembourg the greatest intact forest massif of our country is situated, an 'ancient wood' with some 3.100 ha surface of deciduous wood: the 'Grünewald' Forest.

Nevertheless Luxembourg authorities planned a new 17.5 km long highway connecting the north of our country with the capital, of which more than 12 km leads through this forest massif.

Nature protection NGO's introduced a complaint at the standing commitee of the Bern Convention in Strasbourg (F). To support this complaint with only scarce faunistical informations available, additional data on the occurence of bats as indicator species had to be investigated to be able to estimate the impact of the planned road on this habitat.

2 The 'Grünewald' forest

The 'Grünewald' is exposed to a continental climat with an annual mean temperature of 8,5°-9° C and a mean rain occurance of 750-800mm per year.

Representing a pronounced geological (Lias/Luxembourg Sandstone) and pedological homogeneity, the expected and actual vegetation of the 'Grünewald' is a *Fagion sylvaticae* forest.

The Grünewald-forest is dominated by natural vegetation of *Luzulo-Fagetum* and *Galio odorati-Fagetum.* More humid exposed valleys present thermophile *Quercetum*, *Carpinion betuli*, *Fraxino-Alnion* or *Tilio platyphyllis-Acerion pseudoplatani* vegetation (including trees of *Tilia cordata*, *Ulmus ssp.* and *Acer pseudoplatanus*) (Bode 1995).

Its outstanding importance lies in the fact that the 'Grünewald' is considered to be a relict from a historic old forest landscape in central Europe, a so-called 'ancient wood' (Bode 1995).

The ecological importance of a forest ecosystem like the 'Grünewald' is due to its high structural diversity of beech mixed forest presenting a great number of hunting habitats as well as an high average age of trees presenting a great number of tree holes as potential summer and winter roosts for endangered bat species (e.g. Frank 1997, Limpens & Bongers 1991).

3 Methods

Deciduous forests are of major importance for forest dwelling bats as summer roosts and hibernacula as well as hunting habitats. Linear forest structures may serve as orientation marks for commuting flights and flight paths and as marks for migration routes.

Mapping the occurence, the distribution and the habitat use of the bats of the 'Grünewald' forest, different methods were used. According to the variable bat activities different methodologies were applied and compared during this survey: mapping the potential tree roost intensity, bat detector field work, mist netting and looking for swarming bats in the early morning (Limpens et al. 1997).

3.1 Mapping potential tree roosts:

Due to the extention of the forest massif, six sample areas from 1.0 - 7.0 ha surface were chosen along the planned route of the motorway. One criteria to identify tree roost density in old forests (> 80-100 years) depends on the intensity of forestry culture in that area. Because all forest districts of the 'Grünewald' are managed in a more or less homogeneous way, this factor could be discarded choosing the sample area.

At the beginning of march 1996 all potential tree roosts (pic holes, crevices, rottenness cavities,...) within the selected sample areas were mapped by using binoculars when the trees were still leafless.

3.2 Mist netting bats in hunting habitats:

To mist net bats in their hunting habitats or on their flight paths allows to assess informations on bat species, sex determination, age and state of reproduction which are points of special interest for such a study.

During 7 evenings and nights 4-5 mist nets (all in all 96m^2) were installed simultaneously to catch bats in different habitats of the forest. All mist nets were tended within preferred hunting habitats (from ground up to 9 m height) as well as along or across supposed commuting and flight paths as forest edges, forest paths and vegetation gaps (Gaisler 1973, Tschapka 1998).

3.3 Bat detector survey:

Since the ongoing development of ultrasound detectors, survey work with bat detectors has gained more and more importance to determinate bat species by their characteristical ultrasonic sounds (Ahlén 1981, Weid & von Helversen 1987, Barataud 1996). Today the recent availability of time expansion ultrasound detectors, computer analysis programms and records of ultrasonic bat calls under different conditions (Barataud 1996) makes it possible to a certain extent to distinguish even between the more 'difficult' *Myotis*-species.

There are different ways of monitoring bats with ultrasound detectors, which rely on methods developed and used as standard in ornithology for bird survey and monitoring projects (Blondel 1975, Oelke 1980, Reynolds et al. 1980). A comparison of the different methods and references of bat monitoring is presented by Boonman (1996).

<u>Line Transect Counting Method (LTC):</u>

Along a random chosen line transect all contacts and bat passes notified by bat detector are counted revealing the Line Transect Indices (LTI), a measure instrument for bat abundance.

Problems occur when most chiropterologists choose non random line transects along roads, field- or forest paths, linear sructures as hedges, woodland edges, river and pond borders. According to Masing et al. (1998) these data should not be related with the LTC method but considered as an own Route Counting Method (RCM). By choosing the RCM the obtained indices must not be compared with those of other regions nor different habitats because the line transect was not chosen at random. This method is however suitable to monitor bat population within a region or a country.

Point Transect Counting Method (PTC):

At so-called counting points (random chosen stationary points within an area or on a line), all contacts and bat passes notified by bat detector are counted during an interval of 5 minutes, revealing the Point Transect Indices (PTI). If the transect points are chosen in a non-random way at places 'where several different bat species are expected', the obtained indices cannot be compared (s.o.).

Several groups composed by the participants of the III European Bat Detector workshop, surveyed 7 line transects along the planned route of the motorway in the 'Grünewald'. For this survey 9 Pettersson D980 (with time expansion), 2 Pettersson D960 and one Pettersson D200 bat detectors were used. A bat survey using the RCM by car transect was accomplished during this research project (Gjerde & Kovacic, in this issue).

3.4 Finding roosts by swarming activity:

During the roosting period in summer (may-august) most bat species are swarming in front of their roosting tree at dawn when returning from their hunting areas. Simultaneously several bats are circling around their roost landing and restarting from the roost entry in short periods.

Swarming bats around a roost can easily be detected by detector or by view at the first daylight. In the 'Grünewald' during five consecutive nights we tried to find occupied tree roosts by looking for swarming bats at dawn.

4 Results:

4.1 Mapping potential tree roosts

The results of mapping potential tree roosts are shown in tab. 1 (next page).

All tree holes were found in *Fagus sylvatica* (n=42); *Quercus robur* (n=15); *Quercus petrae* (n=1) and *Carpinus betulus* (n=1) trees.

Tab. 1.: Results of mapping potential tree roosts in 6 sample areas along the planned motorway in the 'Grünewald' forest.

Sample area Nr	surface (ha)	woodstock (trunks/ha)	circumference (cm)	mean circumference (cm)	tree roosts (trees/ha)
I	7,0 ha	84	92-260	176,0	3,0
II	1,5 ha	92	34-256	163,5	3,3
III	1,0 ha	96	54-244	131,0	9,0
IV	1,5 ha	90	81-223	156,5	3,3
V	1,5 ha	81	78-298	185,0	9,3
VI	1,5 ha	80	142-248	180,0	3,3
Mean	2,3 ha	87,2	34-298	165,3	5,2

Compared to reference values, Kneitz (1961) reports ca. 17 tree holes/ha in elder oak tree forests and Noecke (1990) gives a mean of even 10.7 tree roosts/ ha up to 21 potential tree roosts/ha. Our results show the extremly low density of potential tree roosts for bats within the sample areas of the 'Grünewald' forest (3.0 - 9.3 with a mean of 5.2 tree holes/ha, see tab. 1).

These results are surprising because the trees from all 6 sample areas represented an average age structure of >100 to 170 years, one major precondition to the genesis of tree holes suitable for bats as summer and winter roosts!

The reason for this surprisingly low number of potential tree roosts can only be due to a low time laps of development possibilities of tree holes, result of an intensive forestry management of the analysed wood.

4.2 Mist netting bats in hunting habitats

According to the results of low tree roost density in the forest, a high bat density during the mist netting campain could not be expected either. Only one single bat species, the Greater mouse-eared bat (*Myotis myotis*) could be recorded by netting in its characteristical hunting habitat within forest (Audet 1990, Arlettaz 1995).

The results of the netting survey method stands in a homogeneous forest habitat like the 'Grünewald', in no proportion to the time investigated in this survey method.

4.3 Bat detector survey

Mainly bat detector field work proved to be effective in mapping the repartition of bat species in the 'Grünewald' forest. At least 10 different bat species could be detected during a simultaneous bat transect count along the route of the planned motorway by the participants of the III European Bat Detector Workshop during the night of 18/19. August 1996. The recorded species are:

	Common name	Scientific name	Abbr.
▪	Noctule	*Nyctalus noctula* (Schreber, 1774)	**Nn**
▪	Leisler's bat	*Nyctalus leisleri* (Kuhl, 1817)	**Nl**
▪	Greater mouse-eared bat	*Myotis myotis* (Borkhausen, 1797)	**Mm**
▪	Natterer's bat	*Myotis nattereri* (Kuhl, 1817)	**Mn**
▪	Bechstein's bat	*Myotis bechsteinii* (Kuhl, 1817)	**Mb**
▪	Daubenton's bat	*Myotis daubentonii* (Kuhl, 1817)	**Md**
▪	Whiskered bat	*Myotis mystacinus* (Kuhl, 1817)	**My**
▪	Serotine bat	*Eptesicus serotinus* (Schreber, 1774)	**Es**
▪	Parti-coloured bat	*Vespertilio murinus* Linnaeus, 1578	**Vm**

- Pipistrelle *Pipistrellus pipistrellus* (Schreber, 1774) **Pp**
- *Myotis* cf *mystacinus/brandtii* **Mmb**

The Greater mouse-eared bat could be recorded at all 7 line transects, followed by *Nyctalus noctula* (6), *P. pipistrellus* (6) and *Myotis spec.* (6).

From 19 bat species living in Luxembourg at least 10 species could be recorded by bat detector survey. However it is supposed that bat detector survey under estimates some woodland species (e.g. *Plecotus auritus*, the small *Myotis*-species) which use low intensity echolocation calls in adaption to clutter within their hunting habitats (Walsh & Mayle 1991). The number of bat species living in the 'Grünewald' is supposed to be even higher, because of known nursing colonies of *M. emarginatus* in the surrounding villages nearby, a species known for foraging in deciduous forests (Krull et al. 1991).

Tab. 2: Bat species recorded at 7 different line transects (I-VII) along the route of the planned motorway in the 'Grünewald' forest.

Transect	Nn	Nl	Mm	Mn	Mb	Md	My	Mmb	Es	Vm	Pp	Ms	Ind	∑
I	X		X	X	X			X	X		X			7
II	X	X	X						X	(X)	X	X		5(6)
III	X		X								X	X	X	3(4)
IV	X		X				(X)				X	X		3(4)
V	X		X								X	X	X	3(4)
VI	X		X	X			(X)				X*	X		4(5)
VII			X	X	X	X		(X)	X			X		5(6)
∑	6	1	7	3	2	1	(2)	1(2)	3	(1)	6	6	2	

(* 45 kHz pipistrelle, and two pipistrelles with a maximum at 50 kHz)

For *Vespertilio murinus* it would have been the first record for Luxembourg. From the recorded bat call of *V. murinus* only 10 pulses could be evaluated, so we were unable to certify this species with 100 % certainty.

5 Conclusions:

The planned route of the motorway will cross one of the most important bat habitats in Luxembourg. Of the ten species recorded with certainty, three are highly endangered, four listed as endangered and two are listed as potentially endangered. Two of the species, *Myotis myotis* and *Myotis bechsteinii* are included in Annex II of the Habitats and Species Directive (92/43/CEE).

The impact of the motorway on estimated 12-13 bat species living in this forest will be quite devastating, particularly in the absence of a thorough Environment Impact Assessment. The construction of this motorway through a forest with a history of rich biodiversity, involves necessarily the isolation of some bat species from their feeding and roosting sites in the villages around the forest massif (*Myotis myotis, Myotis emarginatus*).

It can be said, that the 'Grünewald' is one of the richest chiropterazoenosis of Luxembourg, but with an extremly low individual density due to an intensive forestry management. The ecological potential of this forest could be increased to a large extent by a more sustainable woodland management. The change in forestry management includes:

- Conservation of all potential tree roosts in woodland;
- Higher average age of (deciduous) tree population;
- Creating special conservation zones without human activities in 5% of the wooded area;
- A main target should be a mean of 20 potential tree roosts (pic holes,...) per ha;
- Replanting new deciduous forest in intensive agriculture areas;
- Optimizing the knowledge of concerned forestry administration about forest dwelling bats as well as general public sensibilisation.

This way tree populations can develop a 'tree hole tradition' necessary to highly specified and endangered species like *Myotis bechsteinii*. In woodland mapping of potential tree roosts can be considered as a method complementary to standard methods as mist netting or detector field work.

6 Acknowledgements:

We are particular grateful to all participants of the III European Bat Detector Workshop in August 1996 in Larochette (Luxembourg), especially Prof. Dr. R. Skiba for analysing the bat calls *of V. murinus*. We thank Water and Forest Administration, Nature Protection Agency for their support during this study.

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The role of bats in landscape planning

by

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Abstract

Landscape planning is the most important planning instrument for nature conservation in Germany. One main objective is the protection and development of all animal and plant species in their natural habitats. The necessary basic information for implementing adequate conservation measures is obtained through habitat mapping. In addition, inventories are taken of different animal groups, for instance birds, dragonflies, and more recently of bats. This proceedure is necessary not only because bats belong to the most threatened groups of animals in Germany, but also because they are good indicators of those habitats which have a high value for other animal species.

For a comprehensive inventory of bats in a planning region, the application of different methods, for instance netting, inspection of attics and bat detector work, is necessary. Within any combination of methods, survey work with the bat detector will be a most important tool in gaining an understanding of the function of the different types of habitats as hunting areas, flight paths and roosts, and their interconnections

As an example of how data on bats can be integrated in planning, the local landscape plan for Bad Nenndorf is described. Here a total of 7 bat species were recorded, using a combination of methods. From the survey results, concrete measures for the protection of roosts, hunting habitats and flight paths could be arrived at and these could be implemented precisely within the landscape. In this way, requirements for the conservation of the bat fauna could be effectively integrated in landscape planning. In general, the comprehensive analysis of the bat fauna data reveals new aspects of landscape, which are not shown by a mere habitat survey, or by data on other animal species. This therefore enhances the possibilities for the conservation and development of the landscape.

Résumé

L'aménagement du territoire est l'instrument de planification le plus important pour la conservation de la nature en Allemagne. Un objectif est la sauvegarde et le développement de toutes les espèces animales et végétales dans leurs habitats naturels. Les informations fondamentales pour les mesures de conservation adéquates sont obtenues par la cartographie des biotopes. Ajoutés à cela, des inventaires sont effectués pour différents groupes d'animaux, p. ex. les oiseaux, les libellules et, récemment, les chauves-souris. Cette procédure est non seulement nécessaire parce que les chauves-souris comptent parmi les animaux les plus menacés en Allemagne, mais aussi parce qu'elles sont des indicateurs de biotopes à grande valeur pour d'autres espèces animales.
Pour réaliser un inventaire représentatif des chauves-souris d'une région à étudier, l'application de différentes méthodes est nécessaire, p.ex. la capture au filet, prospection des greniers et travail au détecteur. Cette dernière méthode est la plus importante pour arriver à comprendre la fonction des différents habitats, p. ex. terrain de chasse, couloirs de vol et gîtes, et comment ils sont reliés entre eux.
Comme example d'intégration des données chiroptérologiques dans l'aménagement du territoire, le plan paysager local de Bad Nenndorf est décrit. Au total, 7 espèces de chauves-souris ont été trouvées en utilisant une méthodologie combinée. A partir des résultats des recensements, des mesures concrètes pour la protection des gîtes, des habitats de chasse et des routes de vol ont pu être défini et celles-ci ont pu être effectués en détail sur le terrain. Ainsi les mesures requises pour la conservation de la fauna chiroptérologique ont pu être intégré efficacement dans le plan d'aménagement . Généralement, une analyse détaillée des donnés concernant la faune chiroptérologique révèle des aspects nouvaux du paysage qui ne sont pas mis en évidence par un simple recensement d'habitat ou par les donnés sur d'autres espèces animales. Ceci augmente ainsi les possibilités pour la conservation et le développement du paysage.

Zusammenfassung

Die Landschaftsplanung ist das wichtigste Planungsinstrument für den Naturschutz in Deutschland. Ein Hauptziel ist der Schutz und die Entwicklung aller Tier- und Pflanzenarten in ihren natürlichen Habitaten. Das notwendige Basiswissen zur Umsetzung geeigneter Schutzmassnahmen wird durch Habitatkartierungen erhalten. Zusätzlich werden Kartierungen verschiedener Tiergruppen, z.B. von Vögeln, Libellen, und seit kurzem auch von Fledermäusen gemacht. Dieses Vorgehen ist notwendig, nicht nur weil Fledermäuse zu den bedrohten Tiergruppen in Deutschland zählen, sondern auch weil sie gute Indikatoren für solche Habitate sind, die auch für andere Tierarten grosse Bedeutung haben.

Für eine umfassende Kartierung von Fledermäusen in einem Planungsraum ist die Anwendung verschiedener Methoden notwendig, zum Beispiel Netzfang, die Kontrolle von Dachböden oder die Detektorarbeit. Innerhalb jeder Kombination von Methoden ist die Erfassungsarbeit mit dem Detektor ein wichtiges Werkzeug, um die Funktion der verschiedenen Habitate, so wie Jagdgebiete, Flugstrassen, Quartiere und ihre Verbindungen untereinander, verstehen zu lernen. Als ein Beispiel, wie Fledermausdaten in die Planung integriert werden können, wird der Landschaftsplan von Bad Nenndorf beschrieben. Hier wurden 7 Fledermausarten durch die Kombination verschiedener Methoden nachgewiesen. Ausgehend von den Erfassungsergebnissen konnten konkrete Massnahmen für den Schutz von Quartieren, Jagdgebieten und Flugstrassen formuliert werden und sie konnten in der Landschaft präzise umgesetzt werden. Auf diese Art und Weise konnten Anforderungen für den Fledermausschutz effizient in die Landschaftsplanung integriert werden. Allgemein gesagt enthüllt die umfassende Analyse der Fledermausdaten neue Aspekte in der Landschaft, die durch eine blosse Habitaterfassung oder durch Daten über andere Tierarten nicht aufgezeigt werden. Dies fördert somit die Möglichkeiten für den Schutz und die Entwicklung der Landschaft.

1 Introduction

In Germany, as in many other European countries, landscape planning is the core planning instrument in nature conservation. The implementation of the legal responsibility to protect animal and plant species, and to develop and protect their natural habitats, is a prominent goal in the landscape planning process.

A systematic survey of nature and landscape parameters is the basis to any landscape planning. Besides a general survey of vegetation (habitats) additional data on the occurrence of a selected group of animal species are also assessed. Which animal species should be included in the planning process is subject of the current discussion in Germany and other European countries. European bats are a highly threatened group of species, and at the same time are suitable indicator species for complex functional relations within the landscape (Brinkmann et al., 1996; Helmer & Limpens, 1988; Limpens & Kapteyn, 1991; Limpens et al., 1989; 1997). Therefore, in our opinion, the role of bats in the process of landscape planning should be developed more strongly.

To stimulate the integration of the study of bats in landscape planning, several workshops were organised where planning authorities, planning agencies and bat experts discussed the possibilities and limitations of using bat data in landscape planning, as well as the minimal methodical requirements required from bat survey work for landscape planning (BRINKMANN ET AL. 1996). With this article we attempt to summarize and highlight some of the results of these interesting and fruitfull discussions.

2 Bat surveys for landscape planning - landscape planning for bat conservation

Because, in the course of their circadian as well as their annual life cycle, bats are obliged to use different parts of the landscape as hunting habitats, flight paths, summer roosts and hibernacula, they are well suited to demonstrate the functional relations between these different parts of the landscape. Knowledge of these dynamic relations is of utmost importance for establishing conservational concepts on a landscape ecological basis. The assessment of the more static vegetational structure of the landscape alone does not provide this quality of knowledge (BRINKMANN 1998; RIECKEN 1992).

In some of their functional habitat requirements some bat species are linked to habitats which are also important for other threatened species. Because of its high requirements for the structural diversity of the hunting habitat, the Bechstein's bat (*Myotis bechsteini)* is almost never found in forests which are not of high natural quality, and therefore can considered to be a 'primeval forest bat' (SCHLAPP 1990). A similar indicator of diversity function can be asumed for Leisler's bat (*Nyctalus leisleri)* and Natterer's bat (*Myotis nattereri*).

Besides needing high quality of the hunting habitat, forest dwelling bats are also dependent on a sufficient number of tree holes for their summer and winter roosts, a resource which usually common only in older forests (e.g. LIMPENS & BONGERS 1991; LIMPENS ET AL., 1991; 1997; POTT-DÖRFER 1993).

However, it is not only their suitability as indicators, but also their rarity within Germany, that requires attention to be given to bats in the landscape planning process (for Lower Saxony e.g. HECKENROTH 1991; for Germany e.g. NOWAK, BLAB & BLESS 1994). This legal requirement follows the Agreement on the Conservation of Bats in Europe (Bonn

Convention), the EC's Flora and Fauna Habitat Directive, as well as the German federal laws on nature conservation (Bundesnaturschutzgesetz) and the conservation of species (Bundesartenschutzverordnung) where most of the native bat species are ranked as endangered species.

Integration of data on bats in the planning process provides the opportunity to prepare and structure concrete measures for bat conservation. Since efficient bat conservation measures, especially on a local scale, must concentrate on roost sites, flight paths, hunting areas and their functional connections, landscape planning in which landscape ecological relations are integrated can be a very important tool in bat conservation.

Existing and proposed land use determines the resulting structure of the landscape and the quality of habitats for bats. Effective conservation strategies must influence local land use such as agriculture, forestry or urban development. This is the main objective of landscape planning - to point out the important elements of the natural system and the resulting requirements for nature conservation and landscape management. These two factors must be included when considering the existing land use as well as the land use planning process.

3 Tasks and procedures of landscape planning in Germany in relation to bat survey work

Landscape planning is based on the Federal Nature Protection Act (Bundesnaturschutzgesetz), introduced in 1976. Because of the federal structure of Germany, this law is detailed in nature protection acts at state level. Therefore the system of landscape planning somewhat differs between different states, but in general we have the following four levels (table 1).

Table 1: The four levels of landscape planning in Germany and the relationship to spatial comprehensive planning (taken from KIEMSTEDT 1994)

Planning area	Spatial Comprehensive Planning	Landscape Planning	Scale (metric)
State	State Spatial Plan	Landscape Programm	1 : 500000 to 1 : 200000
Regional District/ County	Regional Plan	Regional Landscape Plan	1 : 50000 to 1 : 25000
Community	Land Use Plan	Landscape Plan	1 : 10000 to 1 : 5000
Part of the Community	Master Plan	Open Space Master Plan	1 : 2500 to 1 : 1000

The requirements and measures of nature protection and landscape management are laid out in a landscape programme at the state level, in a regional landscape plan for individual regions, and in a landscape plan at the local level. The open space master plan provides information for a part of a community e.g. one village and its surroundings in the community.

Landscape planning is a hierarchical planning system. The measures and requirements of nature protection and landscape management in theory become increasingly specific from the state level, down to the community level (KIEMSTEDT 1994).

Planning can be viewed as the basis for nature conservation work done by nature protection authorities. For example, it provides background information for the selection of nature reserves. Landscape planning is also the basis where information on nature protection is contributed to comprehensive planning. Comprehensive planning has to co-ordinate the various land use demands at different administrative levels. It is a legal requirement that demands of nature protection are incorporated in the process (KIEMSTEDT 1994).

Landscape planning focuses on **three main issues**, the planning for:

- Species and habitat protection
- Nature and landscape related recreation
- Soil, water, air and climate.

In the landscape planning process the parts of the planning area which have an importance for the overall nature potential have to be determined. For species and habitat protection, the necessary basic information is obtained through habitat mapping. In addition, inventories are taken of different animal groups, for instance of birds, dragonflies and more recently of bats. By analysing the correlation between the different types of land use and the occurrence of species, the resulting impact on nature, both for species and their habitats, can be shown. This information is needed to develop a planning concept in which the objectives for nature protection and landscape management are incorporated. Then those planning measures and requirements, which are necessary to achieve the planning objectives can be defined.

These general steps of landscape planning need to be considered, when a bat survey as a part of a landscape plan, is planned (table 2).

Table 2: Methodical steps for bat survey as part of a landscape plan

planning process	the role of bat conservation
1. Definition of the problem	Is there a need of bat conservation in the planning area?
2. Inventory and analysis	⇒ selection of methods, depending on scale and structure of the landscape ⇒ survey work ⇒ documentation
3. Planning concept	objectives of bat conservation
4. Plan of action	methods and extend of bat conservation

4 Bat survey methods

In mapping the distribution, occurrence and habitat use of bats, a whole range of methods are available (see table 3. & fig. 4). All differ in terms of investment of labour, equipment and the level of training needed, as well as in selectiveness, effectivenes, completeness and efficiency regarding the species that can be recorded, the period in the year that they can be used, the types of habitat use (roosting, commuting, hunting) that can be recorded, the types of roosts that can be found, and the accuracy of the observed numbers (for reviews see e.g: LIMPENS ET AL., 1997; LIMPENS & BONGERS IN PREP; LIMPENS & ROSCHEN IN PREP).

For a comprehensive inventory of bats in a planning region, in most cases a combined application of different methods, e.g. netting, inspection of attics and lofts and a bat detector survey, is necessary (LIMPENS & ROSCHEN 1996). Which methods are to be used and which survey intensity is required, is dependant on the goals of the survey work, and the requirement of specific data relevant to the planning process and possible conflicts in the planning area (BRINKMANN ET AL., 1996). Within any combination of methods, survey work with the bat detector (LIMPENS, 1993) is an important tool in gaining an understanding of the function of the different types of habitats as hunting areas, flight paths or roosts, and their interconnections (LIMPENS & ROSCHEN IN PREP; LIMPENS ET AL. IN PREP;).

5 An example: a bat survey for a local landscape plan

In this chapter, an example of the integration of data on bats in a local landscape plan is described (BRINKMANN 1995). The survey and analysis were carried out in 1994 and 1995 for the landscape plan Bad Nenndorf (FELS, LUCKWALD & WIEBUSCH 1995). Besides a survey of the biotopes/habitats, also bats, birds, amphibians, reptiles, grasshoppers, dragonflies, and butterflies were also studied.

Table 3: Effective survey methods for the different bat species (adapted from BRINKMANN et al, 1996; LIMPENS & ROSCHEN, in prep.; LIMPENS et al. 1997, in prep.)

Methods and Species	auditive and visual survey with a detector	roost finding by searching for swarming bats	survey of advertising territorial males	netting in hunting habitats	netting at underground	inspection of attics & lofts	inspection of bird & bat-	inspection of hibernacula	publicity work
Rhinolophus ferrumequinum	o	o	-	o	o	++	-	++	o
Rhinolophus hipposideros	o	o	-	o	o	++	-	++	o
M. brandti/mystacinus	++	++	-	++	o	o	++	++	o
Myotis mystacinus	(+)	++	-	++	o	o	++	(+)	o
Myotis brandtii	(+)	+	-	++	o	o	++	(+)	o
Myotis emarginatus	o	o	-	o	++	++	o	++	o
Myotis nattereri	o	o	-	o	++	o	++	++	o
Myotis bechteini	o	o	-	o	++	o	++	o	o
Myotis myotis	o	o	-	o	++	++	o	++	++
Myotis daubentonii	++	++	-	o	++	o	++	++	o
Myotis dasycneme	++	++	-	o	++	o	o	++	o
P. nathusii/pipistrellus	++	++	++	o	o	o	o	o	++
Pipistrellus pipistrellus	++	++	++	o	o	(o)	o	-	(+)
Pipistrellus nathusii	++	++	++	o	o	(o)	++	-	(+)
Nyctalus noctula	++	++	++	o	o	o	++	o	o
Nyctalus leisleri	++	++	++	o	o	o	++	o?	o
Eptesicus serotinus	++	++	-	o	o	o	o	o	++
Eptesicus nilssoni	++	++	-	o	o	o	o	o	++
Vespertilio murinus	++	o	++	o	o	o	o	o	+
Barbastella barbastellus	++	o	-	o	o	o	o	++	o
P. auritus/austriacus	o	++	o	++	++	++	o	++	++
Plecotus auritus	(o)	++	(o)	++	++	++	++	(+)	(+)
Plecotus austriacus	(o)	++	(o)	++	++	++	o	(+)	(+)

++ = effective o = possible - = not suitable ( ) = identification difficult/impossible

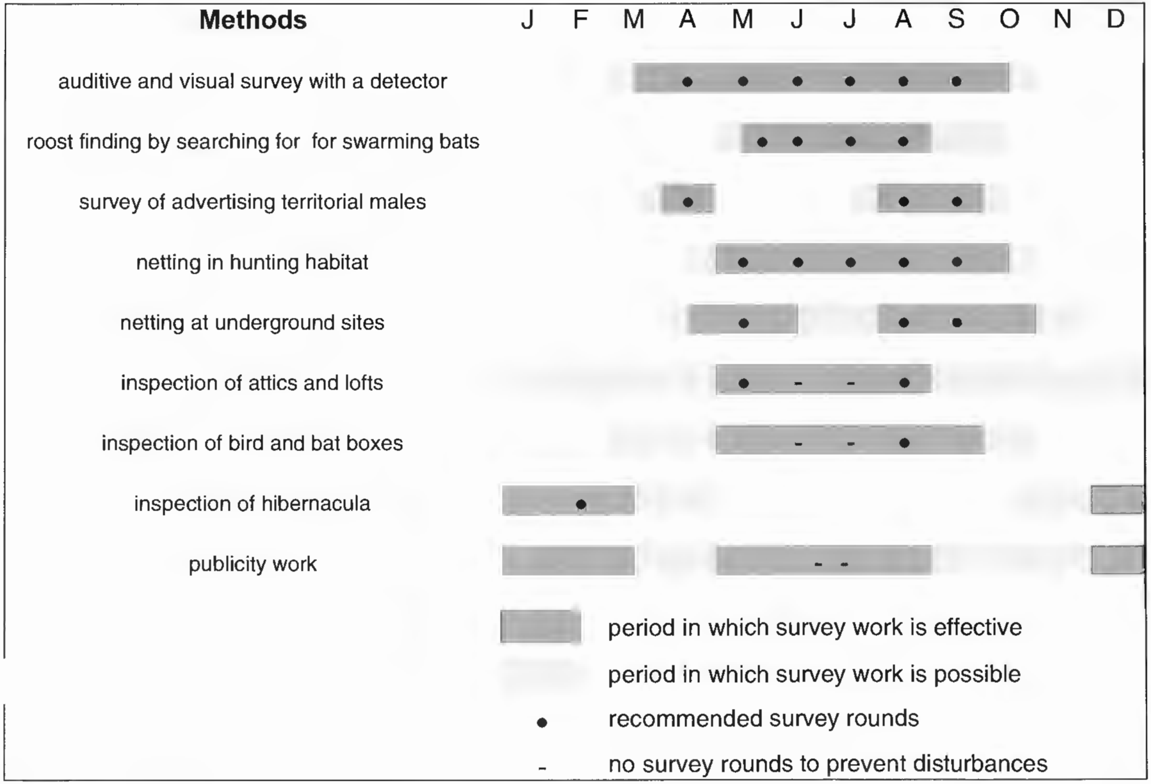

Fig. 4: Periods for bat inventories depending on the method

5.1 Planning area and planning tasks

The communitiy Bad Nenndorf is situated about 30 km west of Hannover in Lower-Saxony, and covers an area of about 55 square kilometres. The landscape is characterised by the gradient of the northern German low lands to higher hill and mountain landscapes. Large parts of the planning area are very open and under intensive agricultural use. In parts of the landscape, mainly in the riverbank areas, a small scale structured landscape still exists, with hedges, tree lines and patches of trees. The villages too have highly structured of trees and orchards, especially at the village edges. The north part of the area is dominated by a larger, well-structured forest, the 'Haster Wald'.

The goals of the chiropterological part of the landscape analysis were to find out:

- which are the important habitats for bats?
- which are the important connections (flight paths) between them?
- which habitats are threatened and in which ways?
- which measures can be taken to improve the situation for the bat fauna?

5.2 Methods and results

In a selection of areas, each representing one part of the landscape in the overall planning area, the bat fauna was surveyed, using a combination of methods as described in chapter 5. Inspection of hibernacula, and netting in front of underground sites, was not carried out because there are no suitable underground sites present in the area. An overview of the used methods and survey results is presented in fig. 5.

A total of 7 bat species were recorded in the survey areas, with highest numbers of records for the common Pipistrelle (*Pipistrellus pipistrellus*). Nursery roosts of this species were found mainly in villages with good connections to preferred hunting habitats near the rivers and in valleys (Rodenberger Aue) or well structured forest areas. In these situations flight paths, as a seperate functional habitat element, could also be observed.

Methods and Species	auditive and visual survey with a detector	roost finding by searching for swarming bats	netting in hunting habitats	inspection of bird & bat-boxes	inspection of attics & lofts	publicity work
Number of excursions	21	10	5	1	2	2
Myotis daubentoni	**HH**	**R**	**HH**	-	-	**HH**
Myotis mystacinus	-	-	**FP**	-	**NR**	**NR**
M. brandti/ mystacinus	**HH**	-	-	-	-	-
Myotis bechsteini	-	-	-	**R**	-	-
Nyctalus noctula	**HH**	-	**HH**	-	-	-
Pipistrellus nathusii	-	-	-	**R**	-	-
Pipistrellus pipistrellus	**HH/FP**	**NR**	**HH**	-	**R**	**HH/R**
Eptesicus serotinus	**HH/FP**	**NR**	-	-	**R**	**HH**
$\sum$ species	**5**	**3**	**4**	**2**	**3**	**4**

Fig. 5: Used methods and survey results (Hunting habitat, **HH**, Flight path, **FP**, Roost, **R** and nursery roost; **NR**).

A nursery roost of Serotine bat (*Eptesicus serotinus*) again is situated in a house which is also close to suitable hunting habitats. Foraging Serotines were mainly observed at forest edges, and at the richly tree-structered edges of the villages.

A nursery roost of Whiskered bat (Myotis mystacinus) was found in a house at the very edge of forest (Haster Wald). Its hunting grounds are predominantly situated inside this well structured and humid forest.

The value of this forest is illustrated by the fact that the recorded roosts of Daubenton's bat (*M. daubentonii*) and Bechsteins's bat (*M. bechsteinii*) are also within this forest.

Bechstein's bat is clearly a rare species, and was found only once. Daubenton's bat, however, was observed hunting in larger numbers over all suitable water surfaces in the research areas. The Noctule (*Nyctalus noctula*) was observed only in its hunting habitat.

5.3 Results in planning

Based on the studies of the bat fauna, a large number of areas and their importance to nature conservation could be identified. These were especially some of the forest areas, the orchards and the riverbank areas, which are structured with hedges and trees and appear to be hunting habitats of great importance. In this landscape connective elements, like hedges, alleys and tree lines, were shown to be important as flight paths, roosts and hunting habitats for the pipistrelles.

With this knowledge conservational measures for these identified roosts and important bat feeding grounds can be integrated in the landscape plan.

Proposals for the improvement of the bat habitats are:

- in cultivated fields and grassland
- creation of more diverse habitats along paths and field edges
- turning cultivated land back into grassland
- preservation/planting of woodland elements as: single trees, groups of trees, copses, tree lines, alleys and hedges
- in forests
- preservation of those forests which are predominately deciduous
- transformation of coniferous forests into deciduous forests
- preservation of forests with a good numbers of old and dead trees
- standing and running water
- planting and designing the shoreline in a natural way
- creation of new ponds
- residential areas
- construction and maintenance of green spaces
- design of village outskirts to include fruit trees and orchards

5.4 Discussion

- **methods and results**

Besides the seven recorded species, some additional bat species can be expected to occur. In a forest structured in a similar way to the Haster Wald, but in a neighbouring area, TAAKE (1992) also netted Brown long-eared bat (*Plecotus auritus*), Brandt's bat (*Myotis brandtii*), Natterer's bat (*M. nattereri*) and Greater mouse-eared bat (*M. myotis*).

The first three species are especially difficult to observe in their hunting habitat with the detector. If more netting activities had been performed, these species might have also been found within our survey area.

The survey intensity was relatively low in the forest area. We have therefore probably found only some part of the existing tree roosts. For instance, for Bechstein's bat, it is probable that, besides the roost found in a bird box, numerous other roosts in trees are used (e.g. WOLZ 1986, FUHRMANN & GODMANN 1994). For Noctules, which are known to have a large home range, it is possible that their roosts are outside the survey area (e.g. KRONWITTER 1988, HEISE 1985).

In general, the work with the detector can be seen as the basic survey tool, which must be complemented by various other methods (see fig. 5; LIMPENS & ROSCHEN IN PREP.).

Because of the high effort and labour costs, only selected areas which represented the overall landscape were studied. Extrapolation of the results is therefore a neccessary step for the analysis of the situation for the whole of the planning area. Such extrapolation, however, will bring in uncertainties we have to be able to identify and deal with.

- **results in planning**

The resulting plans shows us how, based on these data, new aspects of advantage to wildlife can be integrated in planning. Measures for roost conservation can only be implemented effectively when roosts are known. At a somewhat lower level, this also applies to hunting habitats and flight paths.

From the analysis, a concept for the conservation and development of parts of the community can be developed, in which measures, like planting a new hedge, can be precisely implemented within the area. A comprehensive analysis of the different functional habitats and their interconnections reveals aspects of landscape which are not shown by a mere habitat survey or by data on other animal species and which thus enhance the possibilities for better conservation and development of the landscape.

Many of the requirements for nature conservation, like more holow trees in forests, are also important for other animal species. In this way the data on the bat fauna can support the argumentation for particular concrete measures.

The general popularity of bats is growing. This is undoubtedly the result of the active public relations work of the many bat groups in Europe. Measures for bat conservation and for the development of the necessary habitats are therefore becoming more and more well-accepted. Bats can thus, by their positive image, support discussion and implementation of positive nature conservation measures.

In general the surveying of bats can be seen as an important part of landscape planning. Their integration in future landscape planning is therefore of utmost importance.

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National Museum of Natural History of Luxembourg
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