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SURVIS: a fully-automated aerial baiting system for the distribution of vaccine baits for wildlife

SURVIS: ein vollautomatisches System zur Flugauslage von Impfstoffködern

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Summary

Large-scale oral vaccination of wildlife against rabies using aerial bait distribution has been successfully used to control terrestrial wildlife rabies in Europe and North America. A technical milestone to large-scale oral rabies vaccination campaigns in Europe was the development of fully-automated, computer-supported and cost-efficient technology for aerial distribution of baits like the SURVIS -system. Each bait released is recorded by the control unit through a sensor, with the exact location, time and date of release and subsequently the collected data can be evaluated, e. g. in GIS programmes. Thus, bait delivery systems like SURVIS are an important management tool for flight services and the responsible authorities for the optimization and evaluation of oral vaccination campaigns of wildlife against rabies or the control of other relevant wildlife diseases targeted by oral baits.

Keywords: rabies, vaccine, bait distribution, GIS

Zusammenfassung

Die großflächige Flugzeugauslage von Impfködern wird seit Jahren erfolgreich bei der Bekämpfung der sylvatischen Tollwut in Europa und Nordamerika eingesetzt. Ein technischer Meilenstein auf diesem Weg in Europa war die Entwicklung einer vollautomatischen, computergestützten und kostengünstigen Technologie für die automatisierte Auslage von Impfködern per Flugzeug wie zum Beispiel das SURVIS-System. Jeder abgeworfene Köder wird durch einen Sensor erfasst, wobei die genaue Position, die Zeit und das Datum des Abwurfes gespeichert werden. Die Daten können anschließend in Geografischen Informationssystemen bezüglich Köderverteilung und -dichte analysiert werden. So sind Auslagesysteme wie SURVIS ein wichtiges Instrument für Flugdienstleister und zuständige Veterinärbehörden zur Optimierung und Evaluierung der oralen Immunsierungskampagne gegen Tollwut oder sonstige Wildtierseuchen.

Schlüsselwörter: Tollwut, orale Immunisierung, Köderauslage, GIS

Introduction

Oral rabies vaccination (ORV) of wildlife against rabies is nowadays the method of choice in terrestrial wildlife rabies management in Europe and North America. Since the first field trials in Switzerland in 1978 the method has constantly been adapted and optimized, including bait distribution systems. In the early days, baits were predominantly distributed by hand with the assistance of local hunters and forest rangers (Steck et al., 1982; Schneider et al., 1983). Although hand distribution of baits offers certain advantages, it is extremely labour intensive and is therefore unsuitable when baits are to be distributed in extended rural areas like large forested areas. Also, the distribution of baits in highly inaccessible areas like swamps is problematic. Moreover, in areas where baits were distributed twice annually over a period of many years an increasing weariness and subsequent reluctance of the hunters involved to participate in subsequent ORV campaigns became evident (Müller and Schlüter, 1998). Hence, it was necessary to look for alternatives to the existing bait distribution system. The introduction of aerial bait distribution did not only solve the above-mentioned problems, but also resulted in a qualitative improvement of bait distribution – with higher bait-uptake and immunization rates in the fox population (Müller et al., 1993). Furthermore, it was demonstrated that aerial baiting of large areas is feasible at low costs (Johnston et al., 1988).

Actually, already in the late 1950s large-scale aerial baiting techniques were developed (Batcheler et al., 1967). During these campaigns toxic baits were distributed in order to poison animals like ground squirrels, rabbits and possums (Wade, 1965; Marsch, 1967; Godfrey, 1973). In first aerial campaigns distributing oral rabies vaccine baits targeting foxes a crew of at least three persons was required; one pilot, one navigator and at least one baiter (Bachmann et al., 1990; Finley, 1998). The baits were dropped manually through a pipe or loaded on a conveyor system after which the baits exited the aircraft. Sometimes an electronic metronome was used to provide a rough estimate of the bait density (Rosatte, 2011). Dropping baits from the plane under such conditions often caused deviations of the planned bait distribution pattern and targeted bait density. For example, if 20 baits are to be released at uniform intervals per kilometre, at a ground speed of 180–200 km per hour it is necessary to drop one bait every second. A difference of only 0.5 seconds will result in the bait being 50% out of position. Also, flight speed is never constant but depends on wind velocity and direction, causing additional local uncontrollable changes in the required bait density (MacInnes et al., 2001). Poor visibility due to bad weather also hindered effective bait distribution by causing deviations from the set flight path and consequently the bait distribution pattern. Finally, the manual dropping of baits has a negative impact on the cost of distribution due to additional personnel required and consequently reduced bait carrying capacity of the planes. Unfortunately, some of these potential drawbacks could not be assessed because the actual flight route and bait distribution pattern (incl. bait density) was not documented and could not be compared with the planned flight route and bait density. A new approach was therefore required to overcome these and other problems associated with aerial bait distribution. In 1994, a concept for automated aerial delivery of baits was developed in Germany by the University of Stuttgart, Flight Service Magdeburg and IDT Biologika GmbH (formerly Impfstoffwerk Dessau-Tornau GmbH) (Anonymous, 2002). This concept became the fully-automated satellite-navigated and computer-supported SURVIS-system. In this paper, the SURVIS-system will be described together with its potentials in terms of analyzing the obtained data.

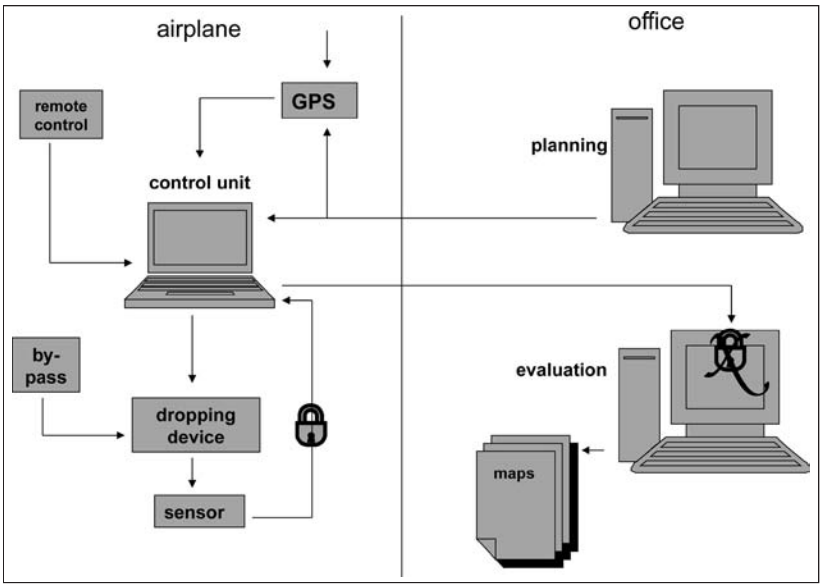

FIGURE 1: *Flow chart of the SURVIS-system and its components (see text for explanation).*

SURVIS-system

SURVIS comprises a Global Positioning System (GPS) receiver, a computer-based control unit (laptop) and a dropping device equipped with a sensor for registration of bait droppings; all segments/equipment are linked (Fig. 1).

The actual dropping device is a lightweight compact unit (approximately 5 kg) measuring 35 x 35 x 30 cm. Its compact dimensions allow it to be installed at any desired position in the aircraft. With this system it is necessary to insert the baits in a flexible foil tube that is pulled into the dropping device (Fig. 2A). For constant release of baits from the foil tube it is lifted over a curved surface and subsequently cut open by rotating blades. To prevent the baits from being damaged by the blades, a "metal-tongue" is pushed between the baits and the top of the foil tube. Any released bait activates a sensor (Fig. 2B) that halts the dropping device until the control unit issues a signal to drop the next bait to leave the aircraft through the dropping shaft.

The first step in the preparation of the aerial distribution of a vaccination campaign is determining the most cost-effective flight path within the vaccination area that is subsequently programmed into the computer – taking e. g., load capacity, distance between flight lines, total flight distance and return flight without pay load into account. Before

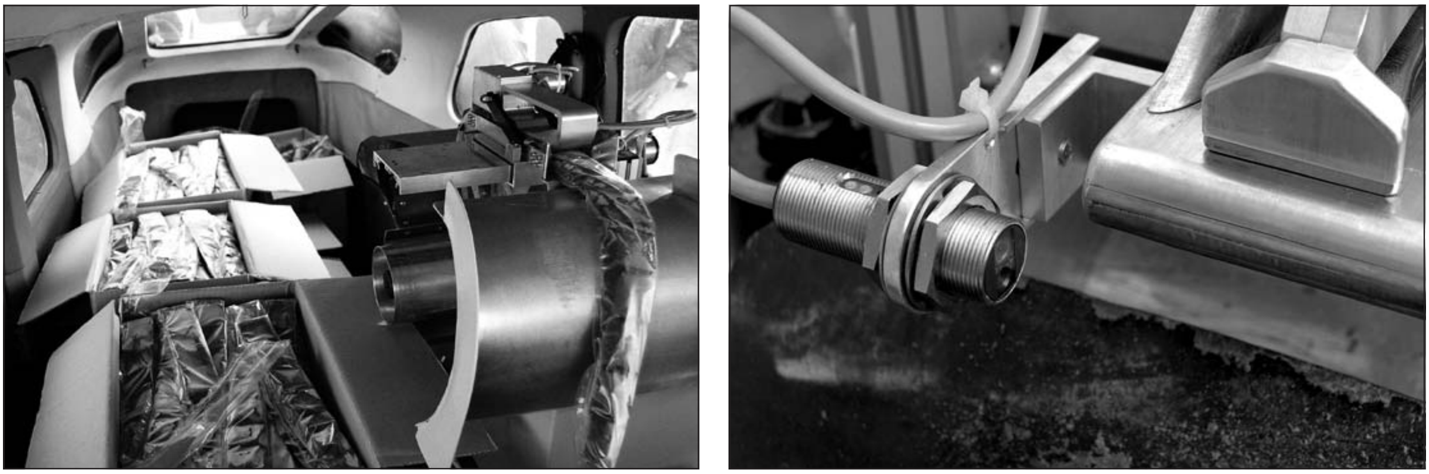

FIGURE 2: *The dropping device of the SURVIS-system together with baits wrapped in flexible foil tube (A) and the sensor for recording of individual bait release (B).*

the flight, the GPS and the control unit are loaded with the coordinates of the vaccination area and the bait density, respectively. In areas with high population density of foxes and/or other bait competitors it is very simple to set a higher bait density. In areas where no baits are to be distributed – such as lakes and inhabited areas – bait dropping can be interrupted at any time by using the remote control.

On the actual days baits are to be dropped, the plane is loaded with the baits wrapped in flexible foil tubes. SURVIS has a handling-capacity of 20 000 baits per flight. Each tube holds 800 baits and tubes can be taped together. Subsequently, one end is pulled into the dropping device (Fig. 2A). The tubes can be connected and fitted into the dropping device by the pilot him/herself. After the plane's engine is started the GPS receiver and the computer are switched on. Upon reaching the vaccination area the system is activated using the remote control that can be mounted on the joystick in the cockpit or somewhere else within easy reach of the pilot. The computer-system now runs automatically, so that the pilot can fully concentrate on flying the aircraft. The data received by the GPS receiver (ground speed, flight path and current position) allows precise and continuous determination of the plane's position at any time point in relation with the pre-programmed flight plan. The SURVIS-system works with a common GPS receiver with a serial interface, so that its data can be transmitted directly to the control unit. Together with the previously loaded information the software programme controls the release frequency of the baits depending on flight speed of the aircraft. For example, the dropping frequency increases with increasing flight speed, and conversely, when the flight speed is reduced (e. g. due to headwind), the dropping frequency also falls.

The control unit has a Flight Documentation System that collects all data on the flight path and co-ordinates of the dropping points for the bait. The intrinsic variance of GPS means that the exact location of bait droppings varies within a range of few meters.

If the GPS receiver does not receive any signals as a result of the position of the satellites (which may occasionally happen for a few seconds), the control unit calculates the current dropping frequency on the basis of the latest data received. In the event of a breakdown of the control unit, the flight does not necessarily have to be terminated. The control unit can be bypassed and the release of the baits manually controlled by the pilot using a special switch on the remote control.

Data recording and evaluation

Each bait released is recorded by the control unit through a sensor, with the exact location, time and date of release (Fig. 2B). The control unit encrypts the collected data to protect it from possible manipulation. Without the code, the data cannot be deciphered or only in a process taking at least several weeks. This offers a unique and non-corruptible possibility for the authorities to verify if the achieved bait density and bait distribution pattern corresponds with the previously determined baiting strategy. After the flight and subsequent data processing it is possible to produce a map with the exact location of each bait released. Furthermore, each of these locations can be marked with different symbols so that several vaccination flights in the same area can easily be shown on one map. Also, areas that were not "covered" during the campaigns can be identified in this way (Fig. 3A). Furthermore the data can be transformed in nearly all formats (e. g. ASCII, Excel, Access, HTML). It is also possible to transfer the data to a central database (e. g. WHO Collaborating Centre) that also receives data from other vaccination areas, where a more precise assessment of the vaccination campaigns over large areas can be conducted. Usually, maps showing the exact location of each bait dropping can only indicate whether an area was covered with vaccine baits or not (Fig. 3A). However, by using additional Geographic Information System (GIS) tools, e. g. superimposing a 1 km^2 cell grid, for example, the bait density on the ground can be determined by calculating the number of bait droppings in individual cells (baits per km^2) essentially as described by Mulatti et al. (2011). The identified numbers of baits per grid cell in a vaccination area can then be classified into any category of bait densities needed. For visualisation those categories can then be allotted to different colour scales and subsequently displayed in maps. This allows a data alignment of the assumed and real bait density on the ground, and hence, any deviation from optimal bait density can be illustrated and provided to veterinary authorities for corrective action (Fig. 3B). Examples of calculated

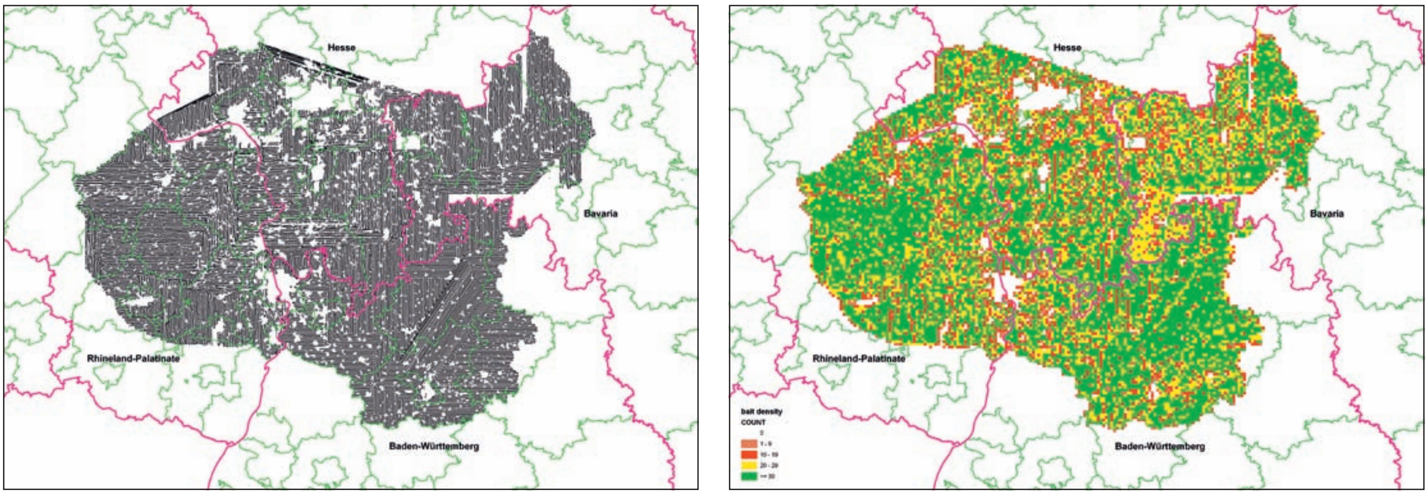

FIGURE 3: *Map of the 2006 autumn ORV campaign in a high density settlement border area between the federal states of Hesse, Rhineland Palatinate, Bavaria and Baden-Wuerttemberg, Germany, showing flight routes with individual bait drop positions (A) and the calculated bait density using GIS (B). The bait density to be applied was 30 baits/km². The none treated areas and areas with a suboptimal bait density (red and brown colored grid cells) are clearly identifiable.*

bait densities for individual vaccination campaigns from European countries are shown in Figure 4.

Discussion

Besides pioneering developments such as efficacious and safe oral rabies virus vaccines, machine-made baits, and efficient vaccination strategies, the development of an automated computer-supported aerial dropping system was a technical milestone on the way to large-scale vaccination campaigns in Europe (Rupprecht et al., 2008). The SURVIS-system was tested the first time successfully under field conditions in vaccination campaigns in the federal state of Saxony-Anhalt, Germany in 1995. Since 1999, the SURVIS-system has been used exclusively for aerial distribution of vaccine baits in Germany. The automatic bait-dropping device was also used in oral rabies vaccination campaigns in many other European countries including Austria (since 2000), Poland (since 2007), Turkey (2008–2010), Latvia (since 2008), and Italy (since 2009) as well as during field trials in the Ukraine (2009). Most recently, the SURVIS system has been used in ORV campaigns in Macedonia and Lithuania. Although in other countries, e. g. USA and Canada, computerized navigational systems have been used too for the distribution of oral rabies vaccine baits, including automated release systems (Sidwa et al., 2005; Rosatte et al., 2009), the dropping devices have not been fully automated as with SURVIS-system.

Therefore other systems need additional personnel for bait release increasing overall distribution costs. Furthermore, the SURVIS-system can be installed into almost any fixed-wing aircraft and helicopters and due to its special technology is open to almost all currently available types of vaccine baits (Gschwendner et al., 1996, Mulatti et al., 2011) and guarantees a controlled release of baits in contrast to manual release. Another advantage of the SURVIS-system is the packaging of individual baits in the sealed foil tubes thus avoiding attachments and blockages. In the near future, the SURVIS-system will be subject to further technical improvements. One idea is to supply the system with additional tools so that the control unit "recognizes" the

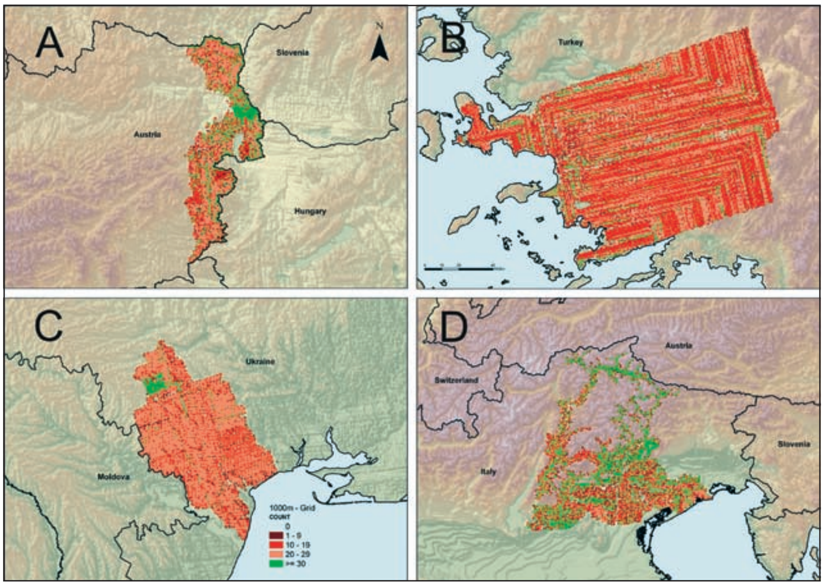

FIGURE 4: *Examples for GIS assessment of aerial distribution using a superimposed 1 km² cell grid. Figure A shows a vaccination belt established in Austria along common borders with the Czech Republic, Slovakia, Hungary and Slovenia in summer 2007. The bait density was supposed to be 25 baits/km²; Figure B is an example of an ORV campaign in the Aegean region of Turkey conducted in February 2010 using an overall bait density of 20 baits/km². In autumn 2007, an ORV field trial was conducted in south-western Ukraine (Fig. C) using a bait density of 20 baits/km². Figure D shows a GIS of an emergency vaccination in Alpine regions of north-eastern Italy in winter 2009 (30 baits/km²). Whilst in Figures B and C the calculated bait density matches the requirements, in Figures A and D dark-red coloured spots represent areas with a suboptimal bait density in mountainous terrain.*

present position of the aircraft and "remembers" in subsequent vaccination campaigns in advance if baits have to be released or not (such as lakes and inhabited areas) and at which density. In this case the system no longer has to be manually activated or deactivated.

One major advantage of the system is that it enables veterinary authorities to check the quality of aerial distribution conducted by flight services as sub-contractors on the basis of independent GIS assessment of encrypted, non-manipulated data via maps displaying individual flight routes and bait droppings as well as the calculated bait density in the vaccination area (Fig. 3, 4). In addition, the SURVIS-system facilitates the identification of gaps in vaccination coverage (non-flying zones) and regions with suboptimal bait density that would require immediate corrective actions such as additional flights or complementary hand distribution in those areas. An example where the implementation of SURVIS helped improving the success of ORV campaigns is Italy. Unsuccessful manual bait distribution to combat re-emergence of rabies in north-eastern Italy forced veterinary authorities to implement aerial bait distribution by helicopters using SURVIS since winter 2009. The system effectively supported flight management in high mountainous areas, e. g. Alp Mountains and allowed near real-time monitoring of ORV campaigns. As a result rabies cases drastically decreased within a short period of time (Mulatti et al., 2011).

This strategy had also been successfully used, for example, in ORV campaigns in peri-urban, highly dense settlement areas in Hesse, Germany, where aerial distribution was hampered by fragmented landscape (Müller et al., 2004, 2005). The resulting low level persistence of rabies in that area caused re-infection in adjacent areas in Baden-Wuerttemberg and Rhineland-Palatinate at the end of 2004 and the beginning of 2005, respectively (Müller et al., 2012). Setback analysis revealed that although the SURVIS-system had been used for years data was not thoroughly assessed. As part of corrective actions in each campaign encrypted data was sent electronically on a daily basis to the national reference laboratory for rabies where the following day maps were created and non-flying zones as well as regions with suboptimal bait density identified, which in turn were directly sent back to district veterinary authorities. Within one week those areas were covered by hand distribution, guaranteeing a complete coverage of the area. Only after these actions, rabies was brought under control (Müller et al., 2012).

In 2010, rabies re-emerged in the province Malopolskie, Poland. More than 100 cases were reported in this area meanwhile neighbouring regions remained almost unaffected. Heavy rains and floods days after aerial bait distribution in spring 2010 were suggested as the cause for the assumed low vaccination coverage in juvenile foxes resulting in the spread of fox rabies in that area (Smreczak et al., 2010). However, in neighbouring provinces that were also affected by the heavy rains no such fox rabies cases were reported. Unfortunately, in Malopolskie no bait distribution system like SURVIS had been used. Therefore, no proper quality assessment of aerial bait distribution was possible, preventing the identification of possible causes linked to the distribution of baits for this unusual setback.

Since a few years, the SURVIS-system has served as a template and blueprint for the construction of similar bait release systems for use in ORV programmes in other European countries as well. Furthermore, the SURVIS-system has not only been used in ORV campaigns in foxes but also for distribution of oral baits containing attenuated vaccine and anthelmintic drug (praziquantel) targeted at wild boars (*Sus scrofa*) and red foxes for control of Classical Swine Fever and echinococcosis, respectively (Kaden et al. 2002, 2003; Tackmann et al., 2001). Automatic bait-dropping devices should become integral part of quality assessment of ORV programs in wildlife and an essential tool for optimisation and assessment of the vaccination strategy if deemed necessary.

Conflict of interest

Peter Gschwendner, Ernst Holzhofer, and Heinz Mürke were involved in the development of SURVIS. Heiko Rüdiger, Peter Schuster, and Adriaan Vos are full time employees of IDT Biologika GmbH – a manufacturer of oral rabies vaccine baits.

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