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Summary

Mobile pastoralists in the Sahel, i.e. people who depend on a livestock production system and follow their herds as they move, remain almost completely excluded from health services. A plausible reason why they are underrepresented in national censuses and/or alternative sequential sample survey systems is that mobile people are hard to reach and stay in contact with. Due to the lack of monitoring and inadequate information systems, demographic and health related data of mobile pastoralists of sub-Saharan Africa are scarce. Accurate population statistics and cost-effective registration systems are the basis for evidence-based policies and effective new strategies to provide adapted, integrated, and sustainable social services for mobile pastoralist people in remote zones. Mobile livestock production systems need to be fostered to strengthen their role as conservators of semi-arid ecosystems and main producers of pastoral products that are contributing significantly to the gross domestic product and food provision of their countries.

Currently, the range of demographic and health surveillance methods, tools and approaches is limited to settled households and hardly applicable in mobile populations. New evaluation and monitoring methods, approaches, and tools to survey mobile households are needed.

Preventive measures (the joint human and animal vaccination program, in the Lake Chad area, provided by the Swiss Tropical Institute and the Centre de Support en Santé Internationale in Chad from 2000 to 2007) have been implemented on small scale and need to be evaluated and scaled up towards an equity effective health intervention. Therefore, estimates on population sizes and other demographic core indices like mortality and fertility in these highly mobile pastoralists' settings have to be assessed, making demographic and health information surveillance indispensable.

The study presented here, was carried out at the southern shores of Lake Chad in Chari-Baguirmi, Chad. In five random household survey rounds demographic and health related data was collected among the target population of the joint human and animal vaccination program, that comprised the main ethnic groups of Arab, Fulani, and Gorane mobile livestock keepers.

An electronic biometric fingerprint application was used to register and identify pastoralist women. We present in this study a proof-of-concept of monitoring highly mobile livestock keepers with the help of biometric technology that is further linked to a geographical information system.

The unique biometric identification number serves as mark to establish population estimates, dilution rates (in and out migration) and survival probabilities applying "Jolly-Seber multiple mark-recapture" (re-encountering) and "Bailey triple catch" methodology.

Only 5% of the total registered women were re-encountered. Since frequencies of re-encountered people are fundamental for mark-recapture estimates, the conceptualized evaluation designs and survey approaches could not be demonstrated coherently due to the low numbers of randomly re-encountered individuals. Thus population size estimates of these highly mobile pastoralist communities that concentrate in the dry season in the study area are still lacking.

Further simulation models based on random numbers helped to establish and analyze sample size numbers for the application of the multiple mark-recapture methodology and to improve future study designs.

Mortality and fertility data are based on retrospectively reported survival histories of children by 1081 mothers or female care-givers for a specific period prior to the survey. Brass indirect method has been applied to calculate rates of 61 (CI 95% 43.1 and 99.7) and Kaplan-Meier survival analysis of 79 (CI 95% 68 and 91.9) children dying before reaching the age of 5 years per 1000 births.

The total fertility rate (TFR) for the reference period from 2001 to 2006 for women indicated 7.3 children (CI 95% 6.2 and 8.9 children) per woman at the end of her theoretical reproductive life span.

It would theoretically be possible to establish retrospective reconstructed cohorts for mortality estimates using information reported by re-encountered persons on individuals that died in between survey rounds. But the retrospective reconstruction of such cohorts is highly dependent on the number of reencountered persons and the reliability of their information.

The conducted mobile demographic and health survey rounds that implemented a biometric information system linked to a geographical information system could facilitate the creation of the first health and demographic surveillance system (HDSS) in a mobile, pastoralist setting. Such a HDSS could provide an extended platform for the monitoring of mobile livestock production system parameters such as livestock population,

productivity, and pasture and water resource management related indicators. Since health of mobile pastoralists is the result of complex interactions between health systems, the economy of livestock production systems, socio-cultural background, sustainable resource management, environmental health, and political powers, broader approaches such as a "one health" approach are needed to monitor both sustainable natural resource management and progress in sustainable development in mobile livestock production systems.

Zusammenfassung

Die mobilen Viehhalter des Sahels, d.h. Menschen die von Viehproduktionssystemen abhängig sind und mit ihren Herden wandern, sind fast komplett vom Zugang zu Gesundheitsdiensten ausgeschlossen, während sie signifikant zum Bruttoinlandsprodukt ihrer Aufenthaltsländer beitragen. Die Tatsache, dass es schwierig ist, diese mobilen Menschen zu erreichen und mit ihnen in Kontakt zu bleiben ist eine eingängige Erklärung dafür, dass sie in nationalen Volkserhebungen oder alternativen Erhebungssystemen untervertreten sind. Aufgrund des Fehlens von Überwachungs- und Informationssystemen sind demographische und gesundheitsrelevante Daten in Afrika südlich der Sahara rar. Genaue Bevölkerungsstatistiken und kosteneffiziente Registrierungssysteme sind jedoch die Voraussetzung dafür, faktenbezogene politische Entscheidungen treffen zu können. Dies gilt auch für effizientes Handeln hinsichtlich neuer Strategien zur Bereitstellung von angepassten, integrierten und nachhaltigen sozialen Dienstleistungen für mobile Viehhalter in abgelegenen, ländlichen Gebieten. Soziale Dienstleistungen sollen die mobilen Viehproduktionssysteme in ihrer Rolle als Konservatoren des semi-ariden Ökosystems und Hauptproduzenten von für die Wirtschaft und Nahrungsmittelversorgung des Landes wichtigen Haustierprodukten unterstützen. Zurzeit sind Methoden, Instrumente und Ansätze zur demographischen und gesundheitsbezogenen Überwachung auf Personen mit festem Wohnsitz beschränkt, und daher für wandernde Bevölkerungsteile kaum anwendbar. Um der problematischen Erfassung dieser mobilen Menschen gerecht zu werden, sind neue Evaluations- und Überwachungsmethoden, -ansätze und -instrumente notwendig.

Medizinische Präventionsmassnahmen wie das vom Schweizerischen Tropeninstitut und dem "Centre de Support en Santé Internationale" von 2000 bis 2007 durchgeführte Impfprogramm für Menschen und Haustiere in der Region des Tschadsees wurden im kleinen Massstab bereits umgesetzt. Diese müssen jetzt auch auf nationaler Ebene durchgeführt werden, und hinsichtlich ihrer Verteilungs- und Zugangsgerechtigkeit für alle evaluiert werden.

Dazu müssen Populationsgrössen geschätzt und demographische Daten wie zum Beispiel Sterblichkeit erhoben werden. Dies macht die demographische und gesundheitsbezogene Überwachung dieser hochmobilen Viehhalter unabdingbar.

Die Studie wurde in der südlich des Tschadsees gelegenen tschadischen Region Chari-Baguirmi durchgeführt. In fünf Erhebungsrunden wurden demographische und gesundheitsrelevante Daten bei zufällig ausgewählten Haushalten in der vom

Impfprogramm betroffenen viehhaltenden Bevölkerung gesammelt. Alle Haushalte gehörten zu den massgebenden ethnischen Gruppen, bestehend aus „Arab", „Fulani" und „Gorane".

Mit Hilfe eines elektronischen biometrischen Fingerabdrucks wurden Frauen registriert und identifiziert. In dieser Studie erbringen wir den konzeptuellen Nachweis, dass biometrische Technologie in Verbindung mit geographischen Informationssystemen die Erfassung und Überwachung mobiler Viehhalter ermöglicht.

Die eindeutige biometrische Identifikationsnummer dient gleichzeitig als Markierung. Diese wiederum wird benötigt, um mit Hilfe der „Jolly-Seber multiple mark-recapture"-Methode und der „Bailey triple catch"-Methode Bevölkerungszahlen, Durchmischungsraten hinsichtlich Ein- und Auswanderung und Überlebenswahrscheinlichkeiten zu schätzen. Nur 5% aller registrierten Frauen wurden zweimal in verschiedenen Erhebungsrunden angetroffen. Anhand dieser kleinen Anzahl von wieder angetroffenen Frauen konnten die geplanten Evaluationskonzepte und Überwachungsansätze nicht auf schlüssige Weise aufgezeigt werden, weil die Häufigkeiten von wieder angetroffenen Individuen für die Anwendung von "mark-recapture"-Methoden grundlegend sind. Somit fehlen weiterhin die geschätzten Populationszahlen der hochmobilen Viehhaltergemeinschaften, die sich während der Trockenzeit am Tschadsee sammeln. Die Entwicklung von Simulationsmodellen basierend auf Zufallsnummern ermöglichte es, den Stichprobenumfang der „multiple mark-recapture"-Methode zu analysieren, um zukünftige Studienprotokolle zu verbessern.

Die Sterblichkeits- und Fruchtbarkeitsdaten basieren auf die von 1081 Müttern gemeldeten Geburten und Todesfälle ihrer Kinder, die sich auf einen zurückliegenden Zeitraum vor einer Erhebungsrunde beziehen. Unter Anwendung der indirekten Brass-Methode wurden Kindersterblichkeitsraten von 61 Kindern (95% Konfidenzintervall: 43.1 und 99.7) und unter Anwendung der Kaplan-Meier Überlebensanalyse 79 Kinder (95% Konfidenzintervall: 68 und 91.9) auf 1'000 Lebendgeburten, die vor ihrem 5. Altersjahr starben, ermittelt. Die Berechnungen für den Zeitraum 2001 bis 2006 ergaben eine Gesamtfruchtbarkeitsrate von 7.3 Kindern (95% Konfidenzintervall: 6.2 und 8.9) für eine Frau am Ende der reproduktiven Phase ihres Lebens.

Die Entwicklung von im Nachhinein rekonstruierten Kohorten unter Verwendung von Daten, die von wieder angetroffenen Personen gemeldet wurden, und die Individuen betrifft, die zwischen den Erfassungsrunden gestorben sind, wäre theoretisch möglich.

Die Rekonstruktion solcher Kohorten ist aber stark abhängig von der Anzahl der wieder angetroffenen Personen und der Verlässlichkeit ihrer gemeldeten Angaben.

Die durchgeführten mobilen demographischen und gesundheitsbezogenen Erfassungsrunden unter Anwendung eines biometrischen Informationssystems mit gekoppeltem geographischem Informationssystem könnten den Aufbau eines ersten gesundheitsbezogenen und demographischen Überwachungssystems für mobile Viehhalter ermöglichen.

Ein solches Überwachungssystem könnte als Plattform für eine erweiterte Überwachung von Parametern dienen, die das mobile Viehproduktionssystem wie beispielsweise Viehbestandszahlen, Produktivität und die Nutzung von Weide- und Wasserressourcen betreffen. Da sich die Gesundheit von mobilen Viehhaltern aus komplexen Interaktionen zwischen Gesundheitssystemen, der Wirtschaftlichkeit des Produktionssystems, dem soziokulturellen Hintergrund, nachhaltiger Ressourcennutzung, einer gesunden Umwelt und politischen Machtsystemen ergibt, sind umfassendere Ansätze wie der „one health" -Ansatz nötig. Auf diese Weise könnten sowohl die nachhaltige Nutzung von natürlichen Ressourcen als auch Fortschritte in der nachhaltigen Entwicklung in mobilen Viehhaltesystemen überwacht werden.

Résumé

Les pasteurs nomades dans le Sahel, soient les personnes qui dépendent d'un système de production animale et suivent leurs troupeaux, restent presque totalement exclus des services de santé. Les personnes mobiles sont difficiles à atteindre. Il est difficile de maintenir le contact avec elles. C'est une des raisons pour laquelle les pasteurs nomades sont sous-représentés dans les recensements et/ou dans les systèmes alternatifs de l'enquête démographique. En raison de l'absence de systèmes de surveillance et d'information insuffisante, les données démographiques et de santé concernant les pasteurs mobiles d'Afrique sub-saharienne sont rares. Bien que des statistiques exactes sur la population et les systèmes d'enregistrement rentables sont le fondement des décisions politiques. Ces informations sont indispensables pour de nouvelles stratégies efficaces afin de fournir des services sociaux adaptés, intégrés et durables pour les personnes mobiles dans les zones pastorales rurales. Les systèmes de production animale mobiles ont besoin d'être consolidés pour renforcer leur rôle en tant que conservateurs des écosystèmes semi-arides et en tant que producteurs principaux de produits pastoraux, qui contribuent de manière significative au produit intérieur brut et à l'approvisionnement en nourriture de leur pays.

Actuellement, les méthodes, les outils et les approches de surveillance démographique et de la santé sont limités aux ménages sédentaires et difficilement applicables dans les populations mobiles. De nouvelles méthodes, approches et outils d'évaluation et de surveillance pour l'enquête des ménages mobiles sont nécessaires.

Des mesures de prévention (le programme de vaccination humaine et animale, dans la zone du lac Tchad, effectué de 2000 à 2007 par l'Institut tropical suisse et le Centre de support en Santé Internationale au Tchad) ont été mises en œuvre à petite échelle et doivent être évaluées et élargies vers une intervention de la santé effective et équitable. Par conséquent, des estimations sur la taille de la population et d'autres indices démographiques de base tels que la mortalité et la fécondité des pasteurs très mobiles doivent être évaluées. Pour d'obtenir cela, les informations de surveillance démographique et de santé sont indispensables.

L'étude présentée ici a été réalisée sur la rive sud du lac Tchad en Chari-Baguirmi, Tchad. Dans cinq tours randomisés des données démographiques et sanitaires ont été recueillies dans les ménages de la population cible du programme de la vaccination conjoint de l'homme et de l'animal. Tous ces ménages appartiennent aux groupes

ethniques principaux des éleveurs mobiles, c'est-à-dire les Arabes, les Peuls et les Goranes.

Un système électronique d'empreintes digitales biométrique a été utilisé pour enregistrer et identifier les femmes pastorales. Nous présentons dans cette étude une preuve de concept de surveillance des éleveurs très mobiles, avec l'aide de la technologie biométrique, qui est également liée à un système d'information géographique.

Le numéro unique d'identification biométrique sert de marque pour établir des estimations de population, les taux de dilution (dans et hors de la migration) et les probabilités de survie appliquant la méthodologie «Jolly-Seber multiple mark-recapture» (rencontre multiple) et "Bailey triple catch".

Seulement 5% des femmes enregistrées ont été retrouvées au total. Étant donné que les fréquences de rencontre des gens sont fondamentales pour des estimations basées sur le « mark-recapture », les modèles d'évaluation et les méthodes d'enquête conceptualisés n'ont pas pu être démontrés de façon cohérente en raison du faible nombre d'individus retrouvés au hasard. Ainsi les estimations de la taille des communautés d'éleveurs très mobiles qui se concentrent sur la zone d'étude dans la saison sèche manquent encore.

D'autres modèles de simulation basés sur des nombres aléatoires contribuent à établir et à analyser le nombre d'échantillons nécessaires pour l'application de la méthodologie de «multiple mark-recapture» (rencontre multiple) et à améliorer la conception des études futures.

Les données de la mortalité et de la fécondité sont basées sur les histoires de survie des enfants rapportés rétrospectivement par 1081 mères ou donneurs de soin pour une période déterminée précédant l'enquête. La méthode indirecte de Brass et l'analyse de survie de Kaplan-Meier ont été appliquées pour calculer un taux de mortalité de 61 (IC 95% 43.1 et 99.7) et de 79 (IC 95% 68 et 91.9) enfants sur 1000 qui meurent avant d'atteindre l'âge de 5 ans.

Le taux total de fécondité (TTF) a indiqué 7,3 enfants (IC 95% 6,2 et 8,9 enfants) par femme par la fin de la vie reproductive pour la période de référence de 2001 à 2006.

Il serait théoriquement possible de reconstruire des cohortes rétrospectives pour des estimations de la mortalité, en utilisant les informations sur les individus qui sont

morts entre les deux phases de l'enquête rapportées par les personnes retrouvées. Mais la reconstruction rétrospective des cohortes dépend du nombre de personnes retrouvées et de la fiabilité de leurs informations.

Les tours de l'enquête démographique et de santé menés ont mis en place un système d'informations biométriques. Joint à un système d'information géographique, cela pourrait faciliter la création du premier système de surveillance démographique et de la santé (SSDS) dans un environnement mobile. Un telle SSDS pourrait fournir une plateforme élargie pour la surveillance des paramètres du système de l'élevage mobile tels que la population du bétail, la productivité et des indicateurs de la gestion des ressources d'eau et des pâturages. Comme la santé des éleveurs mobiles est le résultat d'interactions complexes entre les systèmes de santé, la rentabilité des systèmes de production animale, des aspects socioculturels, la gestion durable des ressources naturelles, la santé environnementale et les pouvoirs politiques des approches de «santé unique» sont nécessaires. Un système de surveillance «santé unique» permettrait à la fois d'accompagner la gestion durable des ressources naturelles et le progrès dans le développement durable dans les systèmes d'élevage mobiles.

1 Introduction

1.1 Background, context, and state of research

1.1.1 Mobile livestock production systems

The main actors in mobile livestock production systems are pastoralists using the major pastoral natural resources: water and pastures. Dawn (2004) defines pastoralism as an animal husbandry system using pastures. From an anthropologist's point of view pastoralism is a "mode of perception" (self-identity) and a "mode of production" of livestock being fundamentally important to their way of life - independently of the actual success in herd productivity and diversification (Dinucci 2003). According to different criteria, livestock owners in mobile livestock production systems are called nomadic pastoralists, nomads, mobile pastoralists, transhumants, agro-pastoralists, mixed farmers or small-scale livestock owners. Pastoralists are not necessarily mobile and nomadism does not only relate per se to pastoralism. Firstly, pastoralism is a livelihood strategy and the main production system in highland, lowland arid and semi-arid climatic zones.

Pastoralism includes animal husbandry as main source of subsistence, using rangeland pastures as main forage for livestock and dividing husbandry tasks among family members (family enterprise). Using rangeland pastures implicates a certain degree of livestock mobility (Dyson-Hudson 1980; Saizman 1990; Scholz 1995). The following definition of pastoral production systems is cited most often: "Where 50% or more of household's gross revenue (i.e. the total value of marketed production plus the estimated value of subsistence production consumed within the household) comes from livestock or livestock-related activities (for example caravan trading), or where more than 15% of household's food energy consumption consists of milk and milk products produced by the household" (Swift 1988). In agro-pastoral households, more than 50% gross revenue comes from farming and only 10-50% from pastoralism (Dinucci 2003; Rass 2006). The importance of the use of rangeland pasture resources classifies livestock production systems from agro-pastoral to mixed farming: Although in mixed farming systems livestock can have a significant share for income, animals are fed importantly with crop residues, fodder, and products grown and/or brought to the farm. Herds also can be kept partly mobile. Transhumance (or semi-nomadism) indicates that herds move regularly between fixed points of seasonally available pastures (Manderscheid 2001). Seasonal, vertical movements in mountain regions (e.g. in Switzerland) is also transhumance.

The term “nomad” or “nomadic” not only describes mobile livestock production systems but rather a mobile way of live with a diversification of livelihood activities (e.g. livestock production, trading, guiding, and caravanning). In nomadic societies, livestock is of great importance and central to the lives of nomads. Being “nomadic” is a term of (self-) perception and therefore mobile pastoralists, mobile agro-pastoralists and people conducting transhumance can be called or call themselves “nomadic” or “nomads”. In this thesis, the term “mobile pastoralism” is favored to “nomadism” or “nomadic pastoralism” as suggested by Humphrey et al. (1999) and Saizman & Galaty (1990) because it entails all degrees of mobility.

Scattered pastoral resources in arid and semi-arid climatic zones are spatially and temporally available. To reach these resources, mobility of livestock and households is the most important strategy. The mobile utilization of the potential of pastoral resources in arid and semi-arid fragile and non-equilibrium rangeland environments with strategies of combining short-term seasonal movements with long migrations is seen as a way of sustainable natural resource and land management (Niamir-Fuller 1999) - which has been demonstrated by natural and social science research. The “mobility paradigm” has emerged in the 1990^{ies} (Niamir-Fuller 1999; Morton 2000). Mobility is not only related to access to resources; it has also other important implications such as avoiding or leaving risky areas (diseases, political insecurity, drought), gathering for social events, and reaching best value markets (Scoones 1994; Majok 1996; Bourgeot 1999; Blench 2001).

Mobile pastoralists maintain a certain social and production systems related flexibility, for example in keeping lactating animals nearer to urban centers or villages with better market opportunities and non-lactating animals on better pastures farer away from urban centers. Different production systems are continuously adapted to changing situations and needs. Individual or community livelihood strategies can change within short times and are very dynamic. Dividing families and leaving older people, women, and children in a settlement, whereby livestock is driven to pastures by young adults is a common practice in mobile production systems.

Diversification of livestock in species (e.g. camels and goats are becoming increasingly important since they are better adapted to dry environments), herd splitting (animals raised in separate places) and herd loans (social obligations) can be other livelihood strategies contributing to economic success (Fratkin 1994). Livestock guarantees thus survival and wealth. Strong social alliances are based on livestock (bride price). Livestock assures a sense of well-being and is the basis of wealth and respect. Since livestock is the basis of subsistence, mobile financial capital, and social prestige, there is a tendency to maximize the number of animals which, in turn, can have a

negative impact on natural resources, health of livestock, quality of livestock products, and reproduction.

Grassland is the key resource for pastoralism, but there are also grasslands without pastoralists, which reflects the history of pastoralism and the arriving of human species in vast rangelands: In the New World and Australia, pastoralism did not develop to an extent like on the African continent, the Near and Middle East or Central Asia and people remained hunters and gatherers.

Mobile pastoralism is a very traditional organized and old production system, rooting in the period about 12'000 years ago when mankind started to keep livestock and started to farm. Agriculture and mobile livestock production have a strong complementary potential. Mobile pastoralists develop longstanding exchange arrangements with settled communities along migration routes because mobile pastoralists are never self-sufficient (Blench 2001). Many pastoralists nowadays are herders of wealthy owners who commonly live in urban areas ("Absentee herd owners").

Hatfield and Davies (2006) reviewed direct economic values of pastoralism that provide income cash, nutrition to the household (livestock sales, meat, milk, hair, hides), and indirect values since livestock is used for transport, manure, and power (e.g. to lift water from deep wells) and generated employment (e.g. transport, knowledge, skills, manure for crop farming, wildlife conservation, tourism and financial services). Livestock is of value for household livelihoods as well as for national economies. Only considering direct economic values, nine Sahelian countries generate between 24% (Burkina Faso) and 80% (Sudan) of their agricultural gross domestic product (GDP) from pastoralism.

The importance of livestock for poverty alleviation becomes evident when droughts or livestock epidemics decimate livestock, although livestock cannot be converted to cash at any given moment because livestock prices may vary considerably and large sells can endanger the continuity of mobile livestock herds (Baxter 1993; Morton 2000; Heffernan 2004). Pastoralists who loose much livestock may start mixed farming, where small ruminants and poultry then become more important for the household economy.

1.1.1.1 Trends in mobile livestock production systems

Pastoral livelihoods are affected by a rapidly changing world. Pastoral societies and economies are in transition while political regimes are unstable. Insecurity is high. In addition, natural resources are affected by climate change.

Population growth and agro-technological improvements push crop, vegetable, and fruit farmers into dryer, pastoral zones, but where cultivation of crops and horticulture is ecologically not sustainable. Therefore, cultivated fields occupy more and more pastoral resources. Formerly climatically defined borders of different production systems are shifted by human activity. Indeed, pastoralism in the proximity of Lake Chad has become seriously affected by the invasion of crop farmers into pastoral land. Access to pastures and water at the shores of Lake Chad is blocked increasingly by crop fields (Wiese 2004). Many mobile pastoralists are no longer in control of access to natural resources (Kagamé Chef Pheul personal communication 2006). These conflict situations over natural resources degrade pastures and accelerate desertification processes (Galaty 1988).

Not only cultivated surface is expanding, but also pastoral production. Due to the increase in population and urbanization, the growth in demand for livestock products (meat, milk, animals) will be greater than for crop-based food. Milk consumption has grown by 3.1% per year from 1982 to 1994 in developing countries, in contrast to 0.5% per year increase in industrialized countries (Delgado 1999). Alcamo (1994) predicts that large parts of Africa will be transformed into pastoral systems during the 21st century assuming an association between increased meat consumption and growing urbanization. But internal growth rate of pastoral livestock sector in Africa is still behind population growth and hence Africa still is a net importer of animal proteins (Tambi 2004; Hatfield 2006).

To respond to the growing demand of livestock products for urban markets, pastoral production currently experiences a growing commercialization and intensification in peri-urban areas which reduces problems of access and transport of livestock to urban markets. Market pressure coupled with inexistent land resource management plans and control strategies in an environment of social insecurity pose a threat to dry-lands due to the concentration of pastoral families and subsequent risk of overgrazing. Globally, 17% of dry-lands are lightly to moderately and 3% extremely degraded (White 2003). "Man made" desertification processes are overlaid with current climate change (perceived e.g. in increasing frequency of droughts). Environmental changes affect the mobile pastoral production system in the complex semi-arid context, which is described in more detail in (Wiese 2004): Pastoralists stated that land tenure insecurity and access to pastoral resources is the main problem of mobile livestock producers in Chad.

Next to insecurity over natural resources, mobile pastoralists have rarely access to social services (e.g. health services and education) and are not represented in policy making (Swift 1990; Donnat 2000). The mobile way of life makes access to dispensaries in villages difficult, since groups with animals have to avoid areas with crops. The

movement from place to place jeopardizes treatment over a long period. Often the most vulnerable – children and women – are excluded from health services. Other barriers to access social services are the intensive labor needs for watering animals and the social barrier for women to go to health centers alone. In addition, discrimination against mobile pastoralists when drugs were in short supply at health centers has been documented (Swift 1990; Béchir 2004). To negotiate better access to social services, settled communities have a better political and institutional status than pastoral communities. They are better represented in governmental structures. Therefore, they benefit more from social services and infrastructures like schools, markets and health care. Local leaders and traditional decision making bodies of pastoral societies have been dismantled and have not been replaced with structures allowing more community participation (Fokou 2004).

In response to improving their socio-political status, mobile pastoral societies undergo social changes and transitions with more variable livelihood strategies and modified demographic structures. Settlement is either spontaneous or as a result of governmental policies due to long droughts, encroachment of other land use systems in dry-lands, lack of primary social services in remote zones, decay or comparative lack of rural infrastructure, lack of access to markets, shifting ownership (owners in urban centers), opportunities in non-agricultural employment, breakdown of customary pastoral social hierarchies, falling standards of living, insecurity, or HIV/AIDS (Morton 2000; Janes 2004; Morton 2006). There is involuntary settlement caused by dam construction, famine, droughts, civil war, privatization of rangelands, and also due to industrial exploration of natural resources, nature reserves (protected areas), and settlement policies (Alive 2003).

Settlement policies are guided by intensification and commercialization plans of livestock products to deliver urban centers demands, social control, administration, delivery of social and livestock specific services (Pratt 1997). Generally, it is argued that a decline in standards of living of mobile pastoralists leads to settlement in order to rely on alternative income sources (cropping, hired labor, out-migration towards urban centers, rely on relief interventions, food aid, and feed supplements for livestock) (Pratt 1997; Niamir-Fuller 1999; Morton 2000). In contrast, the inverse trend of settlement is seen in a re-emergence of nomadism reported by Scholz (1995) for Africa - and especially for Mongolia and the Tibetan plateau (Humphrey 1999; Manderscheid 2001).

Decentralization processes seem to give more power to rural settings and foster the power of settled communities in remote areas. Decentralization is only a benefit for mobile pastoralists if decentralization processes strengthen regional economic cycles and

mobile livestock producers are equitably integrated in these cycles. Most importantly decentralized regulations such as taxation should not hinder mobility of pastoral people. Rural development and decentralization plans must consider mobile populations to enhance their mobile livestock production system which guarantees sustainable natural resource management in the fragile ecology of dry-lands.

1.1.2 Mobile pastoral people in the Sahel and livestock production in Chad

Map 1 shows the semi-arid tropical savanna eco-region in Africa, called the Sahel, which is the belt between the Sahara desert to the north and the slightly less arid Sudanian savanna belt to the south. It runs from the Atlantic Ocean in the west to the Red Sea in the east. The Sahel is defined by an annual precipitation of 100 – 500 mm per year that is restricted to a distinct short rainy season. The region is characterized economically through livestock keeping and expanding agriculture; climatically through hot and dry conditions; and ecologically through savanna vegetation and processes of desertification (Leser 1997).

Map 1: The Sahel (orange colored belt) runs across Africa south of the Sahara desert (source: www.eduspace.esa.int, modified by the author). The yellow circle shows the study area of this thesis.

There are estimated 120 million pastoralists and agro-pastoralists worldwide, of which 50 million live in sub-Saharan Africa. Sudan and Somalia have the largest pastoral/agro-pastoral population of seven million each followed by Ethiopia (4 million) (Rass 2006). In Chad, all demographic data are projections of an assumed growth rate of 2,5% based on the most recent national census of 1993 which results in 7,8 Mio inhabitants for 2002 (Le schéma directeur de l'eau et de l'assainissement du Tchad 2003). Only 5.7% of the population in Chad were officially classified as 'nomadic' according to a national census in 1993(citation!) (Bureau central du recensement 1998). In 1993 there were approximately 83,500 nomads among an estimated rural population of 900,000 in the Chari-Baguirmi and Kanem Districts of Chad (Ministère du Plan et de la Coopération 1995). Another source indicates that 40% of the Chadian livestock production is mobile with about 44'000 people involved (Ministère de l'Elevage du Tchad 1998). Within the Sahelian prefectures of Chad, approximately 70% are mobile livestock keepers (Le schéma directeur de l'eau et de l'assainissement du Tchad 2003). Three-forth of cattle in Chad is kept in the Sahelian zone; 80% in mobile systems and pastoralists manage 75% of all livestock (5.3 million head of cattle, 1 million dromedaries and 6.6 million small ruminants in 1996), accounting for 80% of the entire pastoral production and creating between 24% (which equaled 80 million € in 2000) and 50% (after 2000 due to the collapse of the cotton-market) of the national export revenues, with a similar volume of contraband export. Fourteen percent (= 230 million € in 2000) of the entire gross domestic product (GDP) is produced by mobile breeders of livestock. Although the economic significance of mobile pastoralism is unknown, they contribute considerably to the national economy of the country. Livestock is after petrol the second most important export good. Most important is that livestock economy benefits directly the Chadian population whereas oil revenues remain under the control of the government (Onu 2000; Wiese 2004).

1.1.3 Health of mobile pastoral people and their livestock in the Sahel

1.1.3.1 Traditional informal health and veterinary care and perception of illnesses in pastoral communities

Mobile pastoralists do not accumulate knowledge on human diseases as systematically as knowledge on animal diseases, likely because the latter can crucially affect their livelihood, therefore only few members of the community acquire specific skills in treating people (Wiese 2000).

In an opportunistic way, depending on dispersion, time pressure, illness concepts, perception of illnesses, fate, and experiences with services self-medication (application of

home remedies, for example herbs or milk products, and purchased drugs from the informal private sector without advice from a health professional) or different health care systems ranging from informal – traditional (herbal medicines, cauterisations, incisions, bone setting and special diets and treatments carried out by religious or secular experts such as marabouts, wizards, witches, shaman, Islamic teachers, traditional healers and birth attendants) or formal - modern medical services for both people and livestock are utilized (Aliou 1995). Among mobile pastoralists of Chad, the perceived success rate for any kind of treatment (formal and informal, traditional and western-type) was low (Hampshire 2002).

Fulani pastoralists' system of norms and values - *Pulaaku* – which includes the fulfilment of duties and expectations encompasses a high degree of self-control to not express discomfort in public (Krönke 2001). The fulfilment of obligations and daily tasks is considered as 'health' in many pastoral societies, but may result in attendance to any health services only at an advanced stage of disease (Münch 2007).

1.1.3.2 Nutrition and seasonality

Traditionally, the diet of pastoralists consisted of livestock products — milk, meat, and blood that were supplemented by grains and other foods that were grown or purchased. Milk was the main pastoral diet providing 60% to 75% of the daily calories (Galvin 1994). Meat was rather reserved for special occasions or times of need and consumed opportunistically, for example, when an animal died (Galvin 1992).

Diet and energy intake of pastoralist groups can vary between dry and rainy seasons - mainly caused by the availability of milk which is abundant during and after the rainy season, but which can become critical at the end of the dry season (Loutan 1984; Galvin 1992). Comparative nutritional studies show that pastoral children are better nourished than sedentary children in normal times; however, this can dramatically change during droughts (Swift 1990; Little 1993; Shell-Duncan 1995; Nathan 1996; Fratkin 1999; Shell-Duncan 2000; Fujita 2004; Glew 2004).

Following the drought periods in the early seventies and eighties, among the Kel Tamasheq of Mali energy intake from milk fell from over 50% to less than 25% (Jacks 1995). Nutritional insecurity in pastoral systems can be caused by the rapid die off of livestock after epidemics, droughts (fuelled by climate change), flooding, and breakdown of markets and monetary systems in conflict situations. Nowadays, pastoralists obtain between half and three quarters of their total calorie intake from purchased foods (Lister 2003). This makes them more vulnerable to changes in relative prices of goods they sell

and buy. Food security depends more on operations of the market in drought years than on the failure of their own production systems.

Pastoral systems are currently experiencing a transition in subsistence; shifting from mobile pastoralism to a variety of settled lifestyles (Shell-Duncan 2000). Borona pastoralists are keeping more small stock for marketing opportunities (Galvin 1994) and pastoralists are increasingly entering the market because they need to sell more animals to buy enough food (Fratkin 1999). Many families diversify their activities and also start crop-farming. Hence, diets once rich in animal protein from milk and meat, though often deficient in calories, are changing to diets more and more based on grains. Sugar has become a new important source of energy for pastoralists. A rapid change of diets together with reduced mobility patterns is promoting the epidemiologic transition from high risk of infectious diseases to more chronic ones (e.g. cardiovascular disease such as hypertension and cancers) that also become health problems of pastoralist groups.

1.1.3.3 Livestock diseases

Disease-related economic losses have been estimated at US$ 4 billion annually for Africa as a whole (Huhn 1996) and this may still be an underestimation because countries' reporting of outbreaks is also shaped by political and economic considerations and countries rarely have surveillance systems for priority livestock diseases. Highly contagious diseases of livestock such as peste des petits ruminants and Rift Valley fever can cause significant nutritional insecurity (von Ostertag 1941).

1.1.3.4 Causes of mortality among pastoralists

Livestock production among smallholders requires a great deal of manual labour that is frequently performed by the entire family (men, women and children). The loss of family members as part of the workforce and the additional costs of care for family members are heavy burdens for others in the family and may force families to sell the few animals they own (Morton 2006). An increased vulnerability to HIV/AIDS let pastoral communities struggle with unprecedented problems (ITDG 2005).

Maternal mortality rates of mobile pastoralist communities are amongst the highest world-wide. In comparison to settled communities of rural areas mortality differences have been reported between Malian zones and between nomadic groups within one zone, although these were less distinct (Hill 1984). Chabasse et al. (1985) and Brainard (1986) found higher infant mortalities among nomadic than settled populations in Mali and Kenya, respectively. Causes of increased mortality among mobile pastoral groups can be

summarized as maternal and neonatal mortality due to delayed medical attendance due to poor access to health services that lead to non- or delayed treatment of infections. Even if Brainard (1986) attributed the lower mortality rates of crop farmers to variables associated with maternal diet and nutritional status, food supplements to breast milk, and child care practices rather than to better access to primary health care. Mortality due to infections such as measles and tuberculosis are also foremost signs of insufficient access to health services and appropriate information. In Chad and Mali, the proportion of fully immunized nomadic children was almost nil (Béchir 2004; Münch 2007).

There is a higher mortality level related to malnutrition during droughts. In more extreme situations, these can translate in one of the highest infant mortality rates of the world: up to 50% of children in the Azawad-region of Northern Mali die before their fifth birthday (Münch 2007). Mortality can increase after a sudden loss in many livestock. This has been documented for the Maasai after an outbreak of Rinderpest in cattle (von Ostertag 1941). Another example occurred in Ethiopia in 2000 where an estimated 10 million persons were at risk for starvation after three consecutive years of drought that led to widespread loss of livestock, population displacement, and malnutrition (CDC 2001). The reduced productivity of livestock (in particular milk) negatively affects the nutritional status of the pastoralists, particularly of women and children in which an increasing mortality rate is observed (Münch 2007). The general and nutritional status of young children (aged 0 to 7 years) was poorer than that of young adults (15 to 30 years) (Chabasse 1985). Poor nutrition can lead to higher susceptibility to infections.

Mobile pastoralists are often involved in conflicts due to competition over natural resources. There are many demographic consequences of conflict such as forced and voluntary migration, increased mortality through destruction of health and sanitary infrastructure, and decreased fertility as a result of spousal separation or psychological stress (Randall 2005). Randall depicts also one cause of potential increased mortality that is rarely discussed: Consanguineous marriages have deleterious health and mortality consequences for the offspring and Tuareg have extremely high levels of consanguinity, which after social changes, has decreased but still are at a high level.

1.1.3.5 Predominant morbidity among mobile pastoralist communities

The main diseases and conditions among pastoralists do not differ substantially from morbidity patterns typical for poor people of (tropical) rural zones such as respiratory diseases, malaria, and diarrhoea (Swift 1990). The study of Chabasse et al. (1985) suggests few differences between sedentary and nomadic populations of Mali. Nomadic groups showed higher rates of treponemal infections than settled agricultural

groups in Mali. Ilardi et al. (1987) emphasised the rarity of intestinal parasites among Somali nomads when compared to the sedentary population. Seasonal morbidity patterns of semi-nomadic Fulani differed considerably from those of settled Rimaibe of Mali (Hilderbrand 1985). In addition to the factors common to remote rural settings of developing countries Loutan (1989) and Swift et al. (1990) identified five specific factors affecting the morbidity among mobile pastoralists:

i) Proximity to animals: The proximity of people, livestock, and wildlife provide conditions that are favourable for transmission of viral, bacterial, and parasitic zoonoses like brucellosis, tuberculosis (due to agents of the *Mycobacterium tuberculosis* complex TBC), anthrax, toxoplasmosis, cystic hydatid disease, Rift Valley Fever, trypanosomiasis and leishmaniasis in Africa, and plague in Asia. General food hygiene is of prime importance in pastoral environments due to their proximity to livestock (Loutan 1989). The overall number of illnesses considered by Fulani pastoralists to be transmissible from animal to man was very limited (Krönke 2001).

ii) A diet rich in milk: Milk is an important source of proteins, micronutrients and energy, but also a well known source of infections such as brucellosis, Q-fever, tuberculosis (*Mycobacterium bovis*), and food-borne pathogens (Smith 1979; MacPherson 1994).

iii) Mobility and dispersion with resulting difficulties in getting and maintaining treatment: Migration of people exposes them periodically to disease risks, for example at waterholes which are highly contagious places, however, migration is also a way to escape from exposure (MacPherson 1994; Foggin 1997). Nomadic mobility and dispersion, dependant on season, influence the spread of infectious diseases, such as measles (Loutan 1989). Loutan and Paillard (1992) suggested that transmission of measles was low among Tuareg nomads of Niger due to their dispersion but that they may act as a reservoir of susceptible individuals due to their low vaccination coverage. More generally, mobility of populations changes the epidemiology of diseases and physical access to health services.

iv) The hot, dry and dusty environment can lead to an increased vulnerability due to difficulties to maintain basic hygienic conditions (tuberculosis, endemic syphilis, and leprosy) and in the absence of safe drinking water mobile pastoralist groups may be more frequently affected by water-borne diseases (parasitic [such as schistomiasis] or bacteriologic [such as typhus and cholera]) (Bonfiglioli 1990).

v) Socio-economic and cultural factors including the presence or absence of traditional healers: The spread of HIV/AIDS increases due to socio-economic and structural changes (e.g. tarred roads built to connect rural areas increase transport and attract impoverished women who turn to prostitution for food) (Cohen 2005).

Schelling and colleagues showed (2005) prevalences of diagnosed diseases and conditions. The 20 most frequent diagnoses were reported in descending order: clinical malaria, pneumopathy, intestinal parasitosis, genitourinary infections (including sexually transmitted diseases), bronchitis, gastritis, joint pain, back pain, conjunctivitis, tuberculosis, headache/migraine, asthma, rheumatism, abdominal pain, upper respiratory track infection, amenorrhea, furunculosis and afebrile diarrhoea. Pulmonary disorders (e.g. bronchitis) were most often diagnosed for children less than 5 years of age. Febrile diarrhoea occurred more often during the wet season when access to safe drinking water was precarious (i.e. the large majority of nomadic camps used superficial standing water as drinking water). Malaria was only rarely clinically diagnosed among Arabs during the dry season, whereas Fulani, who stayed in the vicinity of Lake Chad, were affected during both the dry and rainy seasons. Although expected, accidents with domestic and wild animals (snake bites, scorpion sting) were not reported.

1.1.4 The Project "Santé des Nomades" in Chad

The Swiss Tropical Institute together with the CSSI (Centre de Support en Santé Internationale) in Chad and the CSRS (Centre Suisse de Recherches Scientifiques) in Côte d'Ivoire have created a platform for health topics of mobile pastoralists in Sahelian Africa and Central Asia. The research and action program should identify, test and evaluate health interventions in mobile pastoralist settings and be sensitive to the semi-arid context with its socio-economic, environmental, institutional, and political aspects. The complex socio-economic, political-institutional, and ecological situation in semi-arid areas led to interdisciplinary (a combination of natural and social sciences) and transdisciplinary (combining scientific knowledge with the know-how of lay people) approaches, while placing the beneficiaries in the center of a participatory process including all key stakeholders (governmental and administrative units, NGO's, local population, researchers, and funding agencies). The aim is to improve the health status of pastoralists and their livestock to contribute to a sustainable development of the Sahelian rural areas in fostering the mobile livestock production sector, which, in turn, will contribute to the development of Sahelian countries given mobile pastoralists' important contribution to national economies. The trans- and interdisciplinary strategies were central to the improved understanding of the health priorities and the health, economic and environmental vulnerability of neglected mobile pastoralists (Schelling 2007).

1.1.4.1 Interventions among mobile pastoralist populations in Chad; history of participatory process since 1998

The stakeholder workshop in Chad at the end of 1999 entitled "To Improve health in nomadic pastoral settings in Chad" assembled representatives of all concerned nomadic groups, researchers, actors of different governmental and non-governmental institutions. First research outcomes were presented on the vulnerability and perception toward illness and other essential needs of mobile pastoralist communities and on the situation of scientific and interventional requirements to initiate social services. The outcome of the workshop led to further iterative stakeholder assessments and an interdisciplinary research cycle. In addition, an intervention project was designed within a network of public health care workers, veterinarians, and mobile pastoralists. An intersectoral team was set up to provide human and animal vaccination campaigns, one of the most cost effective health interventions in developing countries (Schelling 2005). Between 2000 and 2007, 18 vaccination campaigns (consisting of 3 vaccination rounds per campaign) for nomadic children and women were conducted among three ethnic groups (Fulani, Arabs, and Dazagada) in the areas where the communities concentrate during the dry season (Schelling 2007). Meanwhile, the interdisciplinary research team evaluated the feasibility and limitations of such campaigns and estimated the costs of joining different sectors for joint interventions. These pilot joint campaigns not only showed the technical and organizational feasibility of simultaneous vaccination, but also the reduced costs by 15% of the public health sector when compared to separate campaigns by sharing of equipment and transport logistics between veterinary and public health personnel (Béchir 2004).

In parallel, capacity was built up: Public health workers and midwives were trained. Locally produced livestock anthrax vaccine production was continuously quality controlled and technicians of the Laboratoire de Recherches Vétérinaires et Zootechniques (LRVZ) have been trained. Training in applied field research and epidemiologic methods of public health and veterinary technicians to the level of program managers will strengthen institutions and advance individual careers.

In April 2005 the STI and CSSI have organized a subsequent workshop "Atelier de réflexion: La santé des mères et des enfants chez les communautés nomades au Tchad" in Drémié (Gredaya). Participants were from the ministries of health, livestock production, education, and finances, census office, NGOs and funding agencies, concerned communities, researchers, and economists. The outcome of this workshop was the agenda to improve the performance of the human and veterinary health systems in mobile pastoralist communities and to install a platform of exchange between actors within Chad and between Sahelian countries. Up to date, the demand driven services to

improve health with efficacious tools such as vaccination, integrated management of childhood illnesses and training of traditional midwives by pastoral communities and by public health and veterinary services who gain efficient access to mobile and sedentary populations in rural Chad are well known and highly appreciated by all stakeholders.

1.1.5 Joint Human and animal health ("one medicine") and the concept of "One Health"

Professionals from the World Health Organization and UN Food and Agriculture Organization have suggested that public health and veterinary services should share resources. Calvin Schwabe showed the outcomes and potential benefits of the "one medicine" as added value to public health that could not be achieved by the disciplinary approaches alone. He discussed the added values to public health of "one medicine" for food and nutritional security, zoonoses, comparative medical research, epidemiology and population medicine, environmental quality, mental health, and ethics (Schwabe 1984).

The 'one medicine' approach - combining human and animal health - is expanded towards a 'one health' approach by addressing pressing environmental issues. By using the "one health" approach for people and their livestock in a given environment, interventions for example are not only evaluated with regard to their performance with direct socio-health impact indicators - e.g. reduction in mortality - but also including the impact on production and ecosystems using a combined impact assessment. The assessment of pastoralists' needs in health service provision and their specific health hazards cannot be identified by biomedical means alone or by taking a socio-cultural or ecological approach because health determinants in remote rural zones depend on many factors such as mobility, the economy of livestock production systems, socio-cultural background, and political power. The "one health" approach tries to embrace all factors that are determinants of human and animal health. Thus interdisciplinary and transdisciplinary research approaches bringing together clinical, epidemiological, ecological, social and cultural disciplines are needed to launch a process of mutual learning among stakeholders to satisfy the requirements of the concept of "one health" (Bonfoh 2008).

1.1.6 Health and demographic surveillance systems and birth cohorts

The INDEPTH Network estimates that there are about 1 billion people living in the world's poorest countries who were not registered at birth and will neither be at death (INDEPTH 2002). Nearly 50 million newborns go unregistered per year worldwide (UNICEF 2005). And barely one third of countries outside North America and Europe have the capacity to obtain usable mortality statistics. Half of the countries in Africa and

Southeast Asia record no cause of death data at all (Mathers 2005) but these countries bear most of the burden of disease. Over the past 30 years, the maintenance of civil registration systems stagnated in many developing countries. Therefore, the by the UN proclaimed right to a recorded name and nationality remained unfulfilled (Szreter 2007). Indeed, because of the insufficiencies in vital statistic recording no authoritative evidence is available to show whether or not billions of dollars of aid funds are having their desired effect on mortality or poverty (Jamison 2006).

Both innovative strategies for collection of data and methods of assessment or estimation of these data are over the past four decades developed and refined interim approaches to fill the resulting information gaps. To respond to the needs for data on births, deaths, and causes of death, data collection systems such as population censuses, sample vital registration systems, demographic surveillance sites, and internationally-coordinated sample survey programs in combination with enhanced methods of assessment and analysis have been successfully implemented to complement civil registration systems. Methods of assessment and analysis of incomplete information or indirect indicators have also been improved, as have approaches to determine cause of death by verbal autopsy, disease modelling, and other strategies (Mahapatra 2007). Increasingly demographic surveillance systems are set up as an alternative to national censuses and sentinel registration systems (Guyavarch 2007). A demographic surveillance system (DSS) is a set of field and computing operations to handle the longitudinal follow-up of well-defined entities or primary subjects (individuals, households, and residential units) and all related demographic and health outcomes within a clearly circumscribed geographic area. It provides complete registration of all births and deaths with linkage to accurate denominators for determining rates and trends, along with longitudinal contextual data on determinants of health and well-being. This system offers the opportunity, at marginal extra cost, to add additional measures of risk factors, morbidity, and access to health services, as well as equity dimensions at the individual level. Unlike other data collection systems such as census, cross-sectional demographic and health surveys and sample registration, a DSS provides longitudinal and individually linked data from birth, including pregnancy outcomes, to death of a large number of individuals. Unlike a cohort study, a DSS follows up the entire population of a predefined geographic area. DSSs provide health and demographic information that reflects the prevailing disease burden of populations and assists in monitoring and tracking health threats and serve as a platform for action-oriented research to test and evaluate health interventions (INDEPTH 2002; INDEPTH 2008). Approximately 60 Demographic Surveillance Systems have been established in developing countries worldwide over the past 50 years and have proved to be increasingly useful for both

researchers and policy makers (Armstrong Schellenberg 1999; De Savigny 1999; Sankoh 2006).

DSSs facilitate birth cohort studies that are a way to identify the factors, both genetic and environmental, which predispose to potentially fatal disease in childhood and hence to develop effective strategies to address the major problem of childhood mortality in the developing world (Speert 2008). The majority of studies of child health and development are cross-sectional in nature. While cross-sectional designs are useful for testing hypothesized relationships between variables at one point in time, longitudinal studies are required to determine causality, to understand change as well as to identify the factors and processes that determine changes in health and development. Prospective longitudinal designs have no recall biases as is a limitation of retrospective studies. However, following cohorts over time is costly and difficult, requiring careful attention to cohort maintenance and attrition, together with ongoing analyses of the characteristics of cases that remain in the cohort and those who leave (Bijleveld 1998). Given the growing recognition of the importance of the life course approach for the determination of chronic diseases, birth cohort studies are becoming increasingly important.

Sahelian countries face considerable challenges to sample and register mobile pastoralists and there is no DSS covering mobile livestock keepers. Therefore, reliable census data for mobile pastoralists is inexistent. Moussavi-Nejad (2003) reports that also in Iran a great uncertainty exists about the accuracy of population statistics, particularly those concerning nomadic tribes who are difficult to reach by census-takers. There are only some approaches reported to account for mobile communities, e.g. cross-sectional sampling methods for nomadic groups were discussed by Kalsbeek (1982; 1986). He described the 'water point approach' as the likely most feasible, but, when applied in two rural zones of Somalia, logistical difficulties occurred with the approach. Another approach used to account for mobile families in low-density zones was aerial censuring. Two independent observers in an airplane both record tents, people and livestock herds in randomly selected geographical sectors. Considering that not all individuals are equally visible, this sampling approach requires a correction factor for lack of visibility, which must be assessed in field studies (Ministère de l'élevage et des ressources animales Tchad 1993). Mobile registration systems have been successfully applied in Botswana, Ecuador, and Thailand (United Nations 1998). But such methods cannot be applied directly to highly mobile populations. Capture (mark)-recapture methodology for population size estimation of Sudanese nomads was suggested by Elgoul in the 1970^{ies}, but to our knowledge has not been implemented (Elgoul 1978). Watkins and Fleisher (2002) draw from experiences in the Somali National Regional State of Ethiopia for the

establishment of a migrant tracking system and trace out the main components of such a system.

1.1.7 Biometrics of mobile people and vital data registration in developing countries

Biometrics is the science of identifying people using physiological features. Traditionally, identification strategies of individuals are based either on a password and a personal identification number (PIN) known to the individual, or on ownership such as a card, a token, and a key. Indeed, traditional identification systems are inherently insecure. Passwords can be forgotten or decrypted by an intruder and cards can be stolen or lost. Biometric identification systems (BISs) can operate in two different ways: verification (or authentication) and identification. Verification compares a PIN to the biometric feature stored in a database. For identification, the user accesses the BIS to compare biometric features in the database that will identify him or her among all enrolled users (de Luis-Garcia 2003). For convenience and speed, most BISs seek identification rather than verification (Mesec 2007).

Studies on fingerprint identification (so called dactylography) are more than hundred years old and its involvement in medical and legal inquiries are well known. A contribution by Mr. Faulds, which was published in Nature in 1880, was the first information given to the public on the subject. While hundred years ago one considered that "the readings of fingerprint evidence should be submitted to the scientific expert" (Faulds 1905), new technologies make fingerprint identification accessible for everyone today. Technology is getting ever more accurate, prices have come down, and efforts on standardization are moving forward rapidly. Public awareness of biometrics increases as a number of large-scale projects went online such as the US-VISIT program.

At present, the three most prominent technologies in use globally on first fingerprint, on second facial and on third place iris recognition. Iris and fingerprint recognition have extremely high accuracy rates and are able to perform (to varying levels of success) one-to many matching of a person's biometric template against large databases. Facial recognition is extremely user-friendly and many existing databases already use facial images as a means of identification (Lockie 2005). In many fields, research on fingerprint technology and biometrics progress towards more accuracy and efficiency (Yun 2006). In a comparison study of the characteristics of biometric technologies currently in use (fingerprint, hand geometry, voice, retina, iris, signature and face) based on different qualitative parameters, fingerprint technology results as the most adequate due to its high accuracy, its fair ease of use and high ease of

implementation and medium costs. However, the user acceptance was marked as “low” in this study (de Luis-Garcia 2003).

In the health system, biometric technology is mainly introduced in hospitals to identify patients and to link health information (diagnosis, drug distribution and disease history) as described in an example from Malawi (Yu 2005). There are few reports where fingerprint technology was used in the field of epidemiology. In a phase 2 cholera vaccine trial in Viet Nam, the authors used fingerprint technology for the identification of trial participants (The SonLa Research 2007).

1.2 Rationale

1.2.1 Problem statement and research gaps to be addressed

Data on the predominant causes of death could redirect resources to most important diseases and health status – but these are not recorded or not reliable for most pastoral settings. Accurate and timely data for mortality by age, sex, and cause both nationally and sub-nationally are essential for the design, implementation, monitoring, and assessment of health programs and policies (Shibuya 2005). In countries with well developed statistical systems, the necessary information for such descriptive epidemiology is derived from civil registration, medically certified cause of death, and population counts from regular censuses or population registers. However, Hill and colleagues (Hill 2007) have convincingly shown that such statistical data is not available for many countries with poorly developed statistical systems. The need to establish a reliable information base to support health development has never been greater (INDEPTH 2002). Demographic surveillance methodology grew out of the need for accurate information describing the at risk population (denominator) living in rural areas in the developing world where vital registration systems either do not exist, or when they exist, do not function well enough to provide information on vital statistics (Clark 2004).

A large proportion of the world’s population continues to live in areas where administrative and health infrastructures preclude continuous monitoring of health at the community level. Health data, if they are available, primarily reflect health facility utilisation. However, a high proportion of poor people have lesser access to health-care facilities than those who are better off. Poor people often treat themselves or use traditional health care. Women may suffer gender disparities (time limitations and cultural constraints to use health care facilities) particularly in rural settings. Thus, health-facility-based data are not representative of the health problems of all rural and urban communities and do therefore not reflect their health status. Health administrators

and planners thus face major difficulties in making well informed decisions because health-facility-based data provides only fragmentary and biased information (Unger 1992). Ideally, reliable health information should be population and community based, inclusive of all groups, and collected prospectively and continuously.

Mobile pastoralists in the Sahel, while contributing significantly to the gross domestic product of their countries, remain almost completely excluded from social services. Their health status and in particular their demographic composition is almost unknown (Zinsstag 2006). Census data for mobile nomadic populations of sub-Saharan Africa are inexistent but play an important role for the development of adapted health services. Baseline health status of nomadic pastoralists and their livestock were assessed in Chad (Schelling 2003; Diguimbaye-Djaibe 2006; Diguimbaye-Djaibe 2006) and were used for the development of new forms of social services, combining human and animal health services (Schelling 2007).

Assessing cost-effectiveness of interventions with population data is often difficult to conduct. Feasible methodologies for assessing health at the community level are therefore needed. These should provide necessary data in an appropriate and cost-effective way. Whilst cross-sectional approaches (and derived rapid assessment and indirect methods) can elucidate specific issues, they cannot provide comprehensive longitudinal perspectives on communities' health. A long-term approach covering a representative sample of communities is needed to obtain a more comprehensive picture. In the absence of civil registration, such systems have to start by identifying individuals in the target communities and include basic demographic surveillance (births, deaths, migration and other vital events), before they can address specific health parameters. Further methodological developments are needed in this area, together with closer integration of demographic surveillance systems outputs into health policy and planning activities. Thus there are good reasons, not just for the sake of research, to have well-managed DSSs placed in key locations for the ultimate benefit of the wider population, all the more so if associated methodologies can be further refined (Byass 2002).

Currently, the range of demographic and health surveillance methods, tools and approaches is limited to settled households and hardly applicable in mobile populations. New evaluation and monitoring methods, approaches and tools trying to approach the survey problem of mobile households are needed. Accurate population statistics and cost-effective registration systems are the basis for evidence-based policies and effective action for new strategies to provide adapted, integrated, and sustainable social services for nomadic people in remote zones that protect and foster livestock production systems as well as strengthen their role as conservators of semi-arid ecosystems and main

producers of pastoral products that are important for the national economy and food provision.

1.2.2 Entry point of the study: evaluation of joint human and animal vaccination campaigns

The main entry point of this study is to further evaluate the joint human and animal vaccination campaigns on coverage, health impacts, equity effectiveness and sustainability. Therefore, estimates on population sizes and other demographic core indices like mortality in these highly mobile pastoralists' settings are to be assessed, making demographic and health information surveillance indispensable.

1.2.3 Research network, collaborations and partners

The study is associated to the Swiss National Centre of Competence in Research (NCCR) on Partnerships for Mitigating Syndromes of Global Change (North-South). It is one of twenty National Centres of Competence in Research established by the Swiss National Science Foundation (SNSF). The NCCR North-South is implemented by the SNSF and co-funded by the Swiss Agency for Development and Cooperation (SDC), and the participating institutions in Switzerland. The NCCR North-South carries out disciplinary, interdisciplinary and transdisciplinary research on issues relating to sustainable development in developing and transition countries as well as in Switzerland (http://www.north-south.unibe.ch). This thesis is embedded within the NCCR North-South in the transversal package project 6 (TPP6) "Extensive Production Systems in Semi-Arid Regions – Options for Sustainable Future Livelihoods". The interdisciplinary TPP6 links social, institutional, economical, and environmental sciences. The objective of the TPP6 is to progress the understanding of complex semi-arid systems in their socio-economic, institutional, political, and ecological context mainly through the exchange of knowledge that contributes in quantifying factors of the semi-arid ecosystem related to the mobile pastoral production system with a strong emphasis on livestock and human health. The NCCR North-South work package 3 (WP3) focuses on the following research topics "Vulnerability and resilience", "Improved environmental sanitation" and "Equity-effectiveness to reduce health burden". The thesis is also conducting collaboration between TPP6 and WP3.

Furthermore, the thesis is embedded within a research partnership between the Swiss Tropical Institute and the Centre de Support en Santé Internationale in Chad with involvements of the Ministry of economical promotion and development, the Ministry of livestock production, the Ministry of public health, the Ministry of environment and

hydrology, the Ministry of education, and the Ministry of interior and regional planning of Chad.

1.2.4 Innovation

The main innovation of this work is the contribution to new evaluation methods and tools for health interventions in highly mobile populations. Underlying, this study conceptualizes the evaluation design of health interventions among mobile pastoralists combining assessments on the impact on health and the impact on pastoral resources towards a synthetic approach that is sensitive to the complexity of the mobile livestock production systems in the fragile semi-arid ecosystem. Last but not least is discussing good practices for community-effective interventions in mobile pastoral settings.

1.2.5 Significance for development

Novel health care provision for pastoral populations and their livestock has the potential to be applied in comparable areas of Africa and Central Asia and could significantly contribute to improved health of hardest-to-reach populations. The innovative method for the assessment of demography and morbidity of humans and livestock in mobile populations, which can be applied to any mobile population, could contribute to the systematic and sustainable monitoring of other regions and other hard-to-reach or mobile populations and therefore significantly improve the health status of mobile pastoralists and their livestock. Any participatory improvement in health will further contribute to the empowerment of marginalized people and institutions.

1.2.6 Ethical considerations

The Chadian Ministry of Health (MoH) and the Ethical Committee of the Cantons of Basel and Baselland (Ethikkommission beider Basel) in Switzerland have approved this study, including the collection, storage and analysis of biometric data. For privacy reasons, all fingerprint-related information, demographic and health data and geographical coordinates were stored in three separate databases and were only linked for final analysis via unique identification numbers. All private information was treated confidentially. Vaccination services are demand-driven by pastoral communities and by public health and veterinary services. Each field team is accompanied by a public health nurse who treats and records all clinically ill person according to the possibilities of remote field conditions. Severely ill persons are referred to the next hospital or health station for further treatment. The project is well known and highly appreciated by these services and the rural population.

2 Goal and Objectives

The goal of this study is to contribute to foster mobile livestock production systems through improving human (children and maternal) and livestock health. Preventive measures (e.g. the joint human and animal vaccination program at the Lake Chad area) have been implemented on small scale and need to be evaluated and scaled up towards an equity effective health intervention. The mobile livestock production system implies a "one health" perspective taking into account human, livestock and ecosystem (pastoral resources) health.

The first objective of this study is to provide sequent sampling survey methods and registration/identification tools for mobile people. These innovative methods and tools enable to establish, as second objective, population models to assess baseline demographic data (e.g. stratified population numbers, fertility and under five child mortality rates). The fourth objective is to elaborate an evaluation design for health interventions that is considering health and demographic indicators of people and livestock combined with a sustainable pastoral resource management monitoring.

2.1 Research questions

The central research questions of this study are:

- What are adapted ways to sequently survey health and demographic indices among mobile pastoralists?
- What population models are needed to assess and monitor population numbers, fertility and mortality rates in the study population?
- What are the conceptualized features of a combined human, animal, and ecosystem (pastoral resources) health evaluation design?

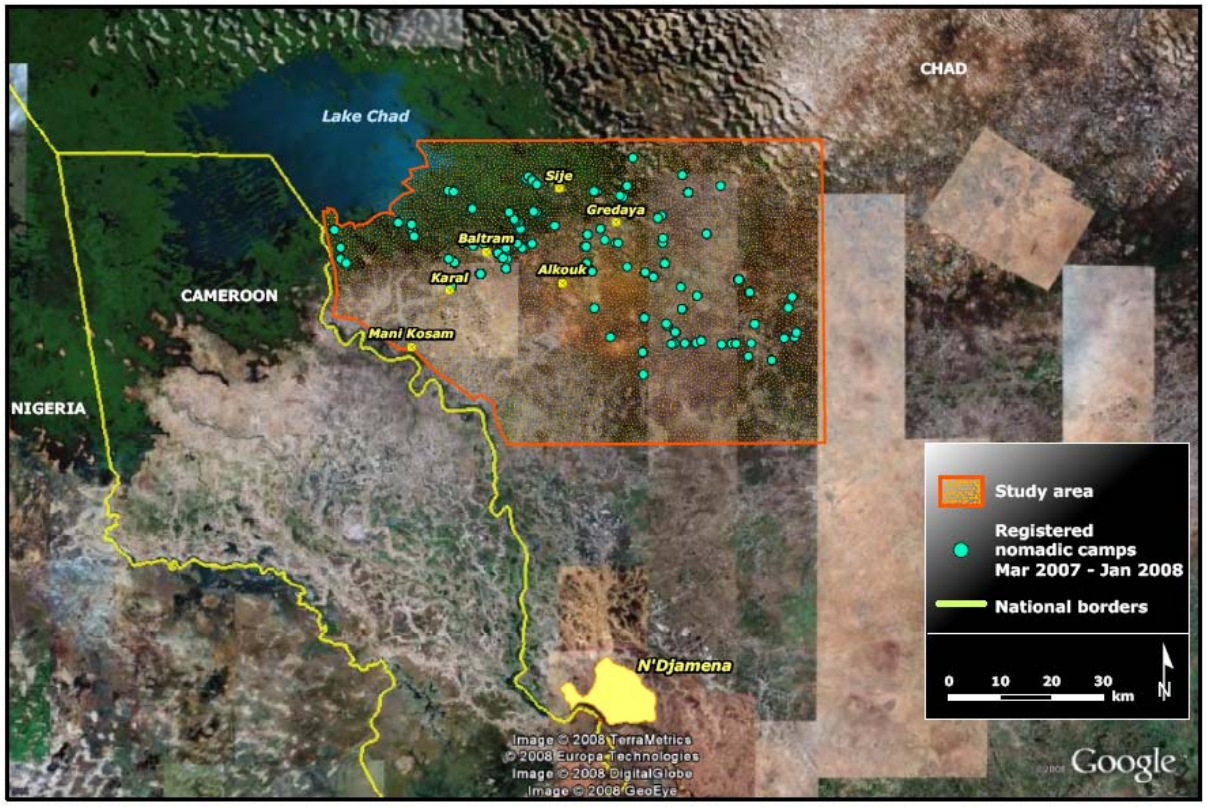
2.2 Hypothesis

In mobile livestock production systems a health intervention has a higher sustainability and equity efficacy potential if its impacts on the mobile livelihood strategies of the target population and on pastoral resources are marginal and sustainable.

3 Methods

3.1 Study area

Our study was carried out at the southern shores of Lake Chad in Chari-Baguirmi, Chad. The study area was located in the semi-arid Sahelian belt bordering South at the Sahara desert. Overall, a surface area of 4,275 km^2 was covered, with a North-South extension of 45 km and a West-East extension of 95 km. Chapter 4 describes in details the study area shown in Map 2.



Map 2: Study area of conducted surveys from March 2007 to Jan 2008

3.2 Study population

Our study population, the target population of the joint human and animal vaccination programme (Schelling 2007) in the intervention zone of "Gredaya", comprised the main ethnic groups of Arab, Fulani and Gorane mobile livestock keepers. The study population is described in chapter 4 and further details on migration patterns, household socio-economics and socio-cultural relationships are provided elsewhere (Krönke 2001; Schelling 2002).

3.3 Study design

The study is designed as a random multiple household survey. The selection of households is described in chapter 4. In contrast to settled households, there is a high variability in the camp composition between survey rounds therefore the definition of a "household" is difficult. Mothers with their children are considered as a unit.

In 5 survey rounds health related, demographic, geographic, and mark-recapture information has been collected. Mortality and fertility estimates are based on retrospective reporting of deceased and born children by their mothers. The study is outlined in the methodological sections of chapter 4, 5 and 6.

3.4 Sampling

The sampling has been organized in 5 independent surveys. A survey is consisting of several random transects or randomly chosen areas that have been visited directly depending on the ecological zone of the study area. On these surveys women and children have been registered with a biometric fingerprint tool. Demographic and health related information is recorded using the fingerprint of the women to generate a unique identification number and link the information to this number. From children we didn't take any fingerprints but all information about the children has been linked to the identification number of their mother. Further details on the organization of the surveys and the biometric registration and identification procedure are outlined in chapter 4.

Demographic data has been collected to calculate under 5 child mortality (U5MR) and fertility rates of mobile pastoralists women. The details of the data collected and the surveys are described in chapter 5.

The biometric registration number serves also as marks for the multiple mark-recapture study to establish population estimates. The mark-recapture method is organized in a „marking" and in a „recapture" procedure. A woman who is encountered for the first time has been registered in the biometric data base this registration procedure is considered as "marking". A "recapture" event on the other hand is the positive biometric recognition of a fingerprint registered in a previous survey. Mark-recapture methodology is described in chapter 6.

3.5 Analysis

Brass indirect method has been applied to calculate U5MR and total fertility rates methodology for fertility estimates according to Preston (2001). These methods and the statistical analytical information are provided in (chapter 5).

The try to establish population estimates have been undertaken with a Jolly-Seber multiple mark recapture method and a triple catch method according to Bailey. Both methods are based on the frequency of a re-encountering of an individual. In the multiple mark-recapture method survey rounds are unlimited while the triple catch foresees only three survey rounds. In both approaches newly encountered individuals get marked to be re-encountered in following survey rounds. Analytical mark-recapture issues are outlined in chapter 6.

A simulation model based on random numbers helped to establish and analyze sample size numbers and minimum requirements of numbers of people to be re-encountered for population estimates. Details are described in chapter 6.

3.6 Instruments and tools, equipment, hard and software

We used an IBM notebook (International Business Machines Corp.; New York, USA) and a fingerprint scanner W32 (Microsoft Corp.; Redmond, USA) as hardware. We used version 1.0.2 of the Desktop Identity software (Griaule Biometrics Corp.; San Jose, USA) for fingerprint registration and identification. For database management, we used Microsoft Access 2002 (Microsoft Corp.; Redmond, USA). For the field sampling electricity was assured by two Sunbag L (Off-Grid Systems Ltd.; Zillis, Switzerland) solar panels with storage batteries and a portable fuel generator (Yamaha Corp.; Hamamatsu, Japan). Geographical coordinates were collected with a hand-held global positioning system (GPS) Geko 201 (Garmin Ltd., Olathe, USA). Demographic, health and GPS data were transferred as attributes to a GIS using ArcGIS 9 – ArcMap 9.1 (ESRI, Redlands, USA) software for spatial data management and mapping. Statistical analysis was performed with Stata IC 10.1 (StataCorp LP, College Station, USA) and calculations in Microsoft Excel 2002 (Microsoft Corp.; Redmond, USA). Bayesian mark recapture models are conducted in WinBugs 1.4 (MRC Biostatistics Unit, University of Cambridge, UK). The multiple mark recapture simulation has been run and analyzed with "R" software (University of Auckland, New Zealand). Finally, text was written with Microsoft Word 2002 (Microsoft Corp.; Redmond, USA).

4 Demographic and health surveillance of mobile pastoralists in Chad: Integration of biometric fingerprint identification into a geographical information system

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4.1 Abstract

There is a pressing need for baseline demographic and health-related data to plan, implement and evaluate health interventions in developing countries, and to monitor progress towards international development goals. However, mobile pastoralists, i.e. people who depend on a livestock production system and follow their herds as they move, remain marginalized from rural development plans and interventions. The fact that mobile people are hard to reach and stay in contact with is a plausible reason why they are underrepresented in national censuses and/or alternative sequential sample survey systems. We present a proof-of-concept of monitoring highly mobile, pastoral people by recording demographic and health-related data from 933 women and 2020 children and establishing a biometric identification system (BIS) based on the registration and identification of digital fingerprints. Although only 22 women, representing 2.4% of the total registered women, were encountered twice in the four survey rounds, the approach implemented is shown to be feasible. The BIS described here is linked to a geographical information system to facilitate the creation of the first health and demographic surveillance system in a mobile, pastoralist setting. Our ultimate goal is to implement and monitor interventions with the "one health" concept, thus integrating and improving human, animal and ecosystem health.

Keywords: biometric fingerprint, biometric identification system, demographic surveillance, geographical information system, nomadic pastoralists, mobile livestock production system, Chad.

4.2 Introduction

The United Nation's (UN) Universal Declaration of Human Rights, put forth in 1948, stipulates an identity to every individual. However, the political rhetoric of human rights, and the academic discourse of entitlements, functioning and capabilities remain elusive for the global poor. Indeed, most legal and civil rights declared in constitutions and the social service provisions granted by states to their citizens are largely inaccessible to unregistered or otherwise legally non-existent individuals. Additionally, the maintenance of civil registration systems stagnated in many developing countries over the past 30 years, and hence the rights proclaimed by the UN remain in-executable. Recently, Setel and colleagues (2007) described the connection between development and the human right of registration and conjectured that several of the millennium development goals (MDGs) rely on accurate data for fertility, mortality and causes of deaths.

Sequential sample survey systems are increasingly established as an alternative to national censuses. For example the demographic surveillance systems (DSS) within the INDEPTH network generate mortality and fertility rate estimates within to monitor population dynamics over time. But there remains the concern about equity and representativeness of sample survey systems. For example, the non-representation of certain population strata in these systems and national censuses is the case for mobile pastoralists resulting in a lack of neither reliable census data nor demographic-, health- and socio-economic related data out of rural surveillance systems. To remedy this issue, cross-sectional sampling methods have been proposed for nomadic groups. Although the "water-point approach" seems to be feasible when applied in two rural zones of Somalia, there were a number of logistical difficulties (Kalsbeek 1986). Another approach that has been used to obtain population data on mobile communities in areas with a low population density was aerial censuring with two independent observers on board of an airplane both recording tents, people and livestock herds in randomly selected geographical sectors. Considering that not all individuals are equally sightable, this sampling approach requires a correction factor that takes into account the lack of visibility, which must be cross-validated with field-based studies. A capture-mark-recapture methodology is applied by population ecologists to obtain estimates on the demography of open and migratory populations. Epidemiologists have primarily used capture-recapture to estimate the degree of undercount in surveillance systems. Although this latter approach has been proposed for population size estimation of Sudanese nomads by Elgoul (1978) some 30 years ago; it has not been applied to date.

The generation of a unique identity through biometric registration is central for longitudinal surveys and censuses and could assist overcoming under-representation of mobile populations in national surveys which has the potential of contributing to the establishment of a DSS for mobile pastoralists. Fingerprint identification dates back more than 100 years and its implications in medical and legal inquiries are well acknowledged. Public awareness of biometrics has increased, which is partially explained by a number of large-scale projects, such as, for example, the US-VISIT programme. The three most prominent technologies in biometrics at present are fingerprint, facial and iris recognition. Iris and fingerprint recognition have high accuracy rates and are able to perform matching of a person's biometric template in large databases. Facial recognition, meanwhile, is particularly user friendly and a number of existing databases already use facial images for identification of individuals (BTT 2005). In many fields, research in fingerprint technology and biometrics is advancing and the accuracy and efficiency has been enhanced, as reviewed recently by Yun (2006). De Luis-Garcia and colleagues (2003) provided an overview of the key features of biometric identification, together with a description of the main biometric technologies currently in use. By assessment of characteristics of types of biometric features (fingerprint, hand geometry, voice, retina, iris, signature and face), based on different quality parameters, the fingerprint technology holds particular promise with regard to accuracy and ease of implementation, whereas costs are ranked intermediate.

Since 2000, the Chadian veterinary services and the expanded programme of immunization (EPI), together with the Swiss Tropical Institute (STI) in Switzerland and the Centre de Support en Santé International (CSSI) in Chad, are conducting joint human and animal vaccination campaigns for mobile pastoralists in the Lake Chad area. Based on observations of negligible coverage rates of the EPI among children and women, preventive measures were implemented (Schelling 2002; Schelling 2005; Schelling 2007). However, the evaluation of vaccination programs for children (against BCG, measles, yellow-fever, poliomyelitis, diphtheria, whooping cough and tetanus) and for women (against tetanus), faces considerable challenges to generate reliable baseline demographic data with regard to mobile communities. The project described here was launched for surveillance of demographic and health-related information of mobile pastoralists to show whether or not campaigns are having their desired effect on mortality in the Lake Chad area. The main objective, however, was to explore the feasibility of biometric fingerprint registration and the integration of a biometric information system (BIS) into a geographical information system (GIS) for demographic and health surveillance of mobile pastoralists.

This study has been guided by a concrete BIS application within an evaluation design of a small-scale vaccination program among pastoralist communities. Pastoral women and their children were registered by biometric fingerprint technology and monitored with BIS. Biometric registration does not register a child at birth, but children can be tracked as their information is attached to the biometric identification of their mothers.

4.3 Materials and methods

4.3.1 Study area

The study was carried out at the southern shores of Lake Chad in Chari-Baguirmi, Chad. The study area is located in the semi-arid Sahelian belt bordering south at the Sahara desert. It is bordered in the west by the Chari River and its interior delta into Lake Chad and in the north by the shores of Lake Chad. Overall, a surface area of 4,275 km^2 was covered, with a north-south extension of 45 km and a west-east extension of 95 km (Map 2). The study zone covers the area of the vaccination campaigns jointly conducted by STI and CSSI from 2000 to 2007 in the intervention zone of "Gredaya".

Rainfalls are delimited to a short rainy season from July to September with the occurrence of years of drought resulting in an internally patchy, scattered and variable availability of pastoral resources (water and pastures).

The coastal floodplains of Lake Chad are constituted of islands, swampy areas, pools and arms of the lake covering a zone of approximately 10 km from the water body to the South followed by a sandy and shrubby area for another 35 km.

4.3.2 Study population

In the dry season nomadic communities of Arab, Fulani and Gorane ethnic groups concentrate in the Lake Chad region. Communities of all three ethnic groups in the Lake Chad region are mainly cattle breeders but also keep small ruminants. Arab and Fulani groups stay close to the shores or some Fulani families occupy islands at the end of the rainy season before cultivated fields block access to the water-body. Most Fulani also have agricultural fields (Schelling 2002; Wiese 2004). Goranes are well acquainted with constructing deep wells that allow them to stay further away from the shores and using dryer pastures. When the first rains occur all groups leave the southern Lake Chad area to move east and north to feed their animals on fresh pastures. Year after year the pastoralists undertake movements over several hundred kilometres between rainy and

dry season pastures. Our study was done during the dry season when mainly short movements occur. Such movements are due to grazed pasture or dried out ponds, expired access rights and nuisance insects. Individuals encountered at the beginning (July) and the end of the rainy season (November) were likely leaving or entering the zone for their macro-movements. Further details on migration patterns, household socio-economics and socio-cultural relationships are provided elsewhere (Wiese 2004).

The most recent Chadian census dates back to 1993. At that time, there were approximately 83,500 nomads among an estimated rural population of 900,000 in the Chari-Baguirmi and Kanem districts of Chad (Ministère du Plan et de la Coopération 1995). It is conceivable that the number of nomads had been underestimated considerably because during the census period in April, several nomadic groups were located across the border in the neighbouring countries of Cameroon, Nigeria and Niger.

Our study population, the target population of the joint human and animal vaccination program (Schelling 2007) in the intervention zone of "Gredaya" comprised the main ethnic groups of Arab, Fulani and Gorane mobile livestock keepers. In randomly selected camps (selection of camps is described below) we sampled all women at reproductive age who were present during our survey, including their children younger than 12 years. The joint human and animal vaccination campaigns commenced in 2000 among mobile pastoralist communities at Lake Chad and children under the age of 5 years were targeted. Hence, the youngest were born in 2000 and the oldest in 1995. As the vaccination campaigns were implemented until 2007, we sampled in 2007 all children born between 1995 and 2007, so the eldest children sampled were 12-year-old (Abdoulaye 2006; Schelling 2007).

4.3.3 Ethical considerations

The Chadian Ministry of Health (MoH) and the Ethics Committee of the State and University of Basel (EKBB), in Switzerland approved this study, including the collection, storage and analysis of biometric data. For privacy reasons, all fingerprint-related information, demographic and health data and geographical coordinates were stored in three separate databases and were only linked for final analysis via unique identification numbers. All private information was treated confidentially.

4.3.4 Applied biometric tools

Biometrics is the science of identifying people using physiological features. BIS can operate in two different ways: verification (or authentication) and identification. Verification compares a personal identification number (PIN) to the biometric feature stored in a database. For identification, a BIS compares biometric features in the database that will identify an individual among all enrolled (de Luis-Garcia 2003). For convenience and rapidity, most BIS seek identification rather than verification (Mesec 2007). In the present study, the focus is on identification.

In the field we used an IBM notebook (International Business Machines Corp.; New York, USA) and a fingerprint scanner W32 (Microsoft Corp.; Redmond, Washington, USA) as hardware. We used version 1.0.2 of the Desktop Identity software (Griaule Biometrics Corp.; San Jose, USA) for fingerprint registration and identification. For database management, we used Microsoft Access 2002 (Microsoft Corp.; Redmond, USA). Electricity was assured by two Sunbag L (Off-Grid Systems Ltd.; Zillis, Switzerland) solar panels with storage batteries and a portable fuel generator (Yamaha Corp.; Hamamatsu, Japan). Geographical coordinates were collected with a hand-held global positioning system (GPS) Geko 201 (Garmin Ltd., Olathe, USA). Demographic, health and GPS data were transferred as attributes to a GIS using ArcGIS 9 – ArcMap 9.1 (ESRI, Redlands, USA) software for spatial data management and mapping.

4.3.5 Sampling and analysis

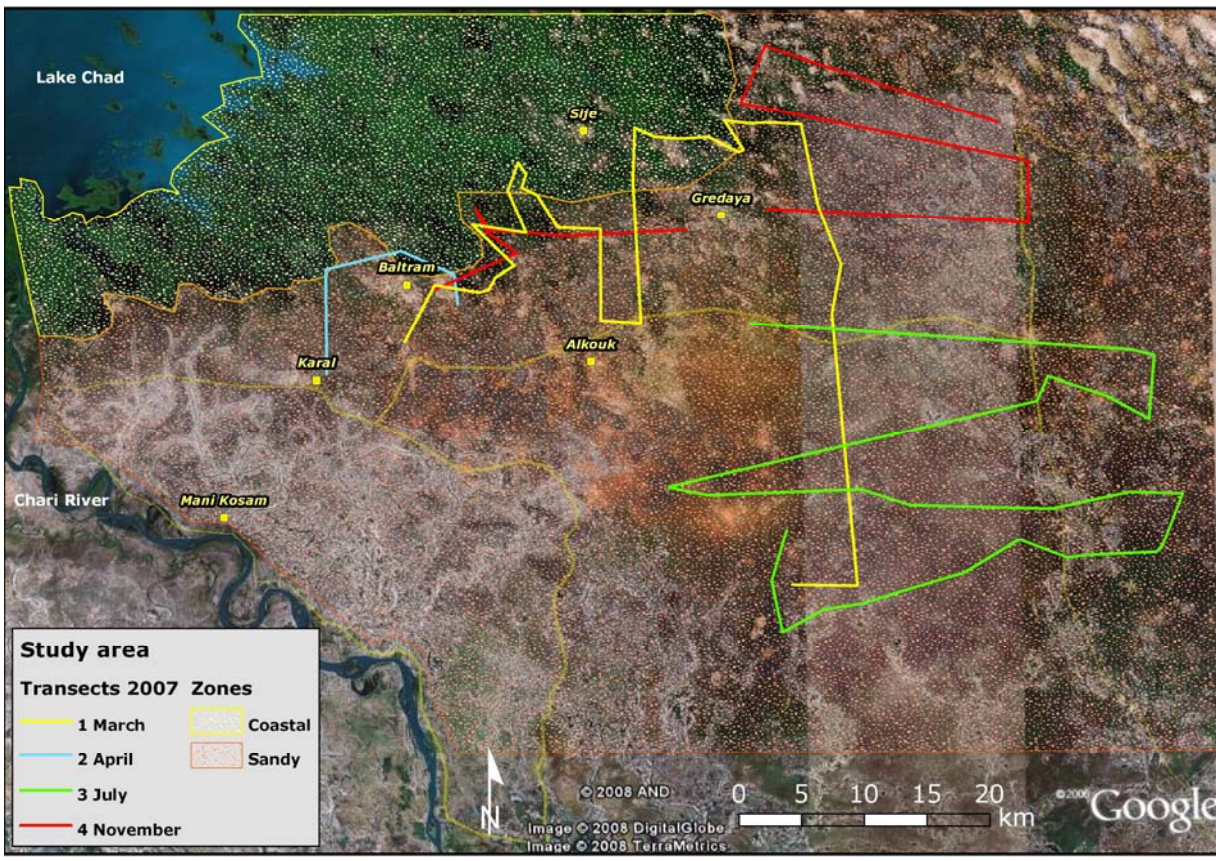
During four survey rounds of approximately two weeks each, carried out in March, April, July and November 2007, a fingerprint scanner was used under field conditions. One survey round consisted of several transects and randomly selected areas where transects could not be performed. Random transects could only be performed in the sandy and shrubby study zones whereas the coastal zone has been covered by a random selection of areas based on a list of accessible areas by car. Starting points and directions for transects were chosen by drawing of lots. There were lots with all the directions (N, NE, E, SE, S, SW, NW) and numbered lots (10, 20, 30, … , 100). The reference point was the village Gredaya (geographical coordinates: 12°57'28.40" longitude, 15°3'51.55" latitude). The number indicated the distance from Gredaya in a drawn direction where the transect should start. In these random transects visible nomadic camps (feriks) were approached. Average visibility was ~1 km depending on weather conditions (e.g. dust and sand in the air) and vegetation.

At arrival of our team in a ferik we were always received by an adult or adolescent male to whom we presented the objective and the content of the study. To obtain informed consent, according to the prevailing tradition, most often older men were consulted but not women. All available women older than 12 years were asked to present their vaccination cards if they had been vaccinated and their fingerprints were scanned using the thump of the right hand and the little finger of the left hand for registration and identification (Figure 1). Demographic and health data from the women and their children aged below 12 years were recorded. The data collection was organized in a two-step procedure; registration, followed by identification. Once an individual is registered, this individual can be readily identified again if encountered at a later survey round. This identification procedure allows that health and demographic data are constantly up-dated, using the unique fingerprint identification number as the key identifier. Relevant data obtained at registration and reencountering (e.g. geographical coordinates and date of the encounter) of individuals were recorded. Information was collected by interviewing the mothers with a pre-tested questionnaire asking for the following data: name, year of birth, ethnic group, vaccination status (doses, provider, date of last vaccination), name of husband, number of children lost in a lifetime (retrospective child mortality), age when child died and self-reported cause of death, and number of children alive at time of the interview, including name, sex, age, date of death if deceased between survey rounds and vaccination status. Health and demographic data from children were linked to the fingerprint key identifier of their mother or the woman caring for a child to avoid scanning and recognition problems of fingerprints from children which might become distorted to some degree due to growth.

Figure 1: Biometric registration of a Fulani woman south of Lake Chad (Foto M. Béchir 2007)

4.4 Results

Map 3 shows the study area in the south-coastal zone of Lake Chad and the transects of the four survey rounds along which nomadic pastoralists were identified and interviewed in 2007. Overall, in the four survey rounds 104 camps were visited and fingerprints were registered from 933 women who could be linked to 2,020 children aged between 1 day and 12 years (Table 1). Only 22 women, representing 2.4 % of the total registered women, were encountered twice. The mean number of children younger than 12 years of age per woman varied from 1.5 in the first to 2.5 in the third survey round.



Map 3: Study area south of Lake Chad and the transects of the 4 survey rounds where nomadic pastoralists were identified and interviewed in 2007 (Background Google Earth 2008).

		N of individuals registered			No of individuals re-encountered		
Round	Dates in 2007	Women	Children	Mean[1]	Women	Children	Mean[1]
1	15. – 27.3.	196	295	1.5	0	0	-
2	23.4.-15.5.	342	761	2.2	0	0	-
3	25.7.-2.8.	225	567	2.5	20	36	1.8
4	18.11.-30.11.	170	397	2.3	2	2	1
TOTAL		933	2,020	2.2	22	38	1.7

[1] Children per Woman

Table 1: Registered and re-encountered mobile pastoralist mothers and their children in four survey rounds in 2007 in the study area south of Lake Chad.

Map 4 shows all surveyed feriks in the year 2007 (depicted by points). Gorane people were encountered in each of the survey rounds in the southern part of our study area. The costal zone of the floodplains of Lake Chad is seasonally populated by Fulani and Arabs, whereas no Gorane people were encountered there. Fulani and Arab families

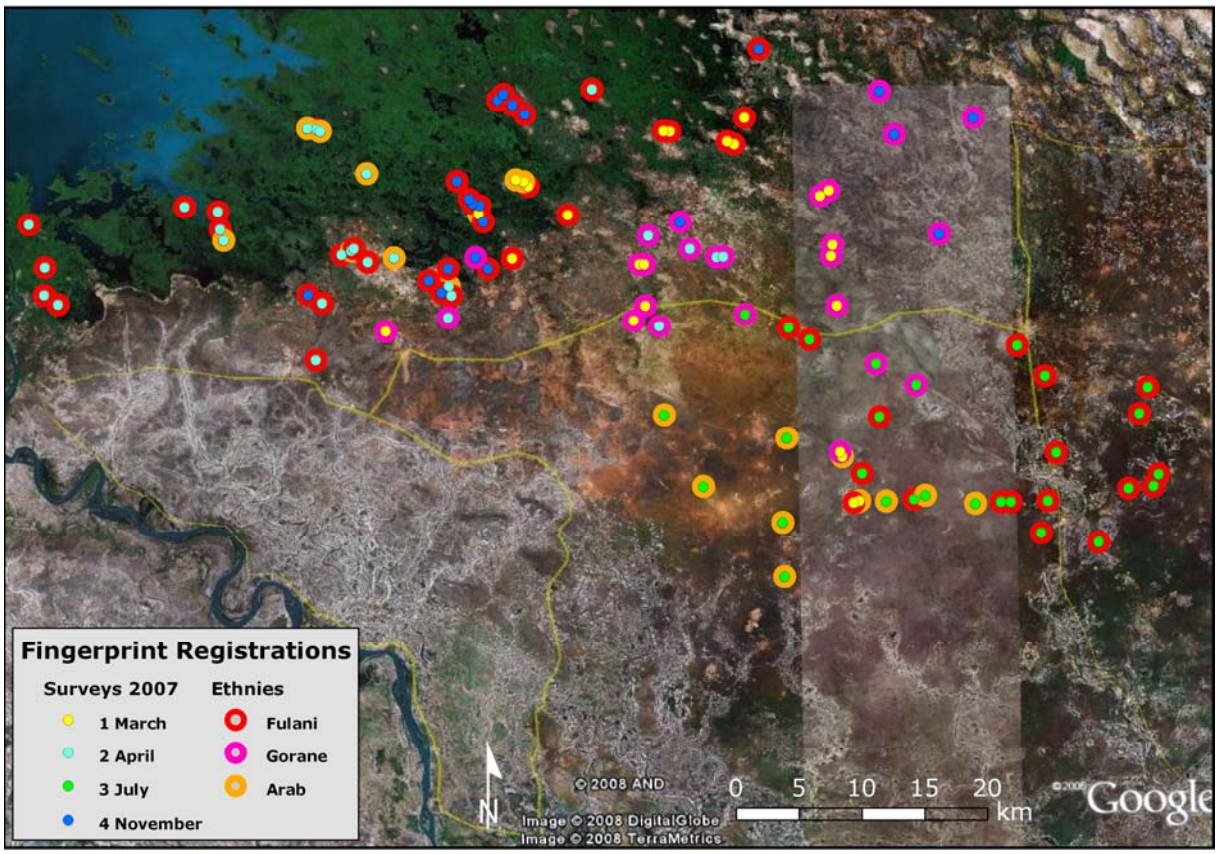
move away from the lake into dryer areas south-east. During the fourth survey round in November 2007 we observed that Fulani communities were using the coastal zone, whereas Arabs were not found in that location at that time.

Fulani and Arab women encountered twice left the shores of Lake Chad after the survey round in April and were re-encountered 20-30 km (aerial line) south-east three months later (Map 5). The two Gorane women registered twice first seen in March 2007 moved 30 km to the east where we met them again in July 2007.

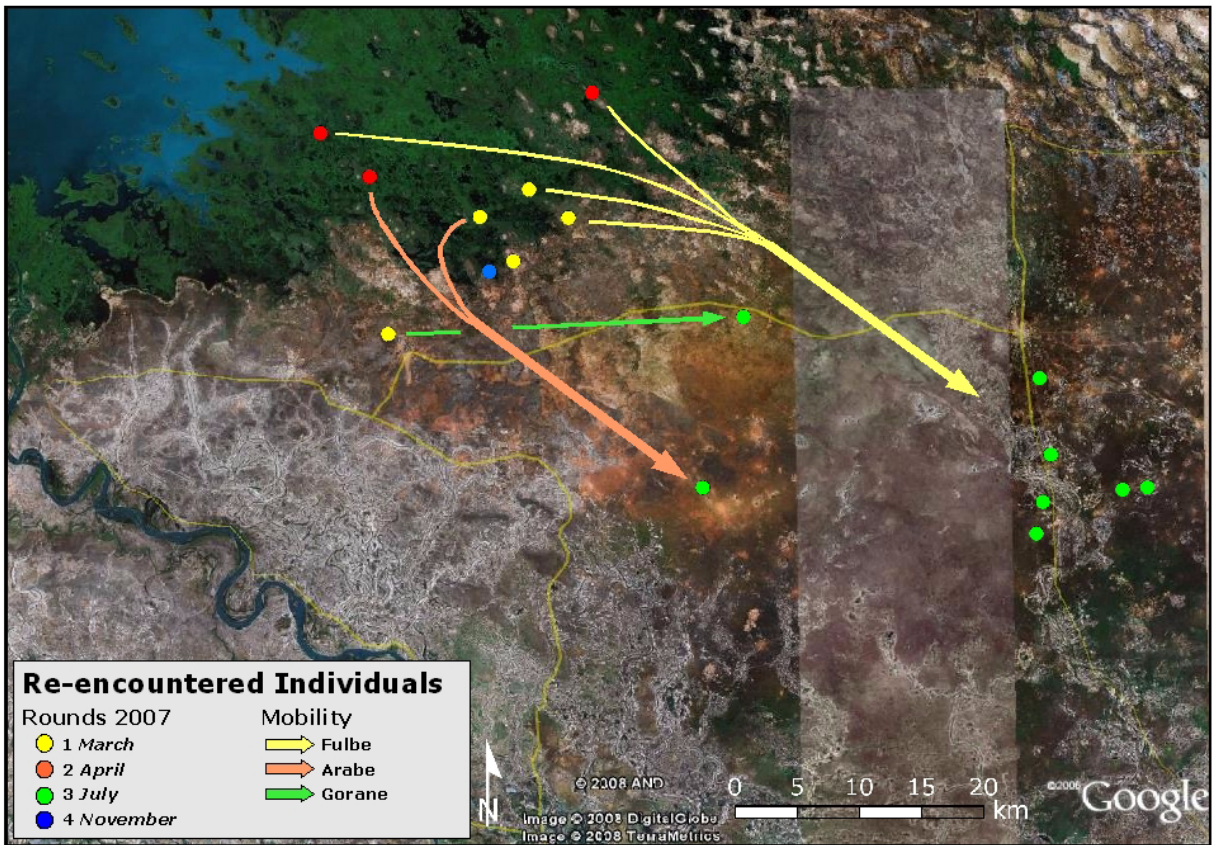
The biometric fingerprint registration and identification among nomadic people was feasible although we encountered problems in scanning the fingerprints of 94 women which corresponds to 10.1 % of all encountered women. The workload of women older than 25 years was visible in their hands: they had scratches and callus and thus their fingerprint images were of low quality. In other cases, the fingerprint light scanner had problems to scan fingers covered with "henna", the widely used make-up of all three ethnic groups. The yellow-orange-brown henna Fulani used interfered less with the scanner than the dark brown-black henna of Arab and Gorane women. Cleaning of the scanner surface and the participants fingertips with ethanol aided in the reading of fingerprints. In 94 cases we failed to obtain a satisfying image, even from the little finger of the left hand, and hence we registered these individuals according to their name, the name of the husband and the chiefs' name.

In addition to the solar panels, we used a portable fuel generator to supply the notebook and the scanner, because cloudiness (e.g. in March during the season of Harmattan winds) and heat (in April, when temperatures went up to 53°C in the shadow) inhibited the optimal functioning of the panels and batteries.

Figure 2 shows how the BIS has been integrated into a GIS, which can be used for subsequent epidemiological and population modelling approaches that should facilitate the integration into a health and demographic surveillance system (HDSS) for a mobile population.



Map 4: Study area south of Lake Chad and sampled mobile pastoralist feriks in the year 2007 (depicted by points) and main ethnicity of the people encountered (outer ring around the points). The colours of the points represent the four transects when women of childbearing age and their children were registered or re-encountered. The outer ring around the points show the main ethnicity of the people encountered. (Background Google Earth 2008)



Map 5: Study area south of Lake Chad and 22 mobile pastoralist women who were encountered twice in different survey rounds including arrows indicating their likely movement over time. Information is shown for the different ethnic groups. (Background Google Earth 2008)

4.5 Discussion

In the Sahelian semi-arid belt at the southern border of the Sahara desert, mobile livestock production systems are prevailing. Over the past 10,000 years, mobile livestock production and the nomadic way of life have evolved under these semi-arid climatic conditions with seasonal rainfalls and periodical draughts. Due to adaptation of the production system, mobile livestock production is seen as perhaps the most sustainable natural resource management strategy to use scarce and remote semi-arid rangelands (Niamir-Fuller 1999). However, sustainable development taking into account the rapid economical, environmental and socio-political changes may be difficult to achieve because mobile populations live in remote areas where they are hard to reach for surveys and interventions. The provision of social interventions and services such as health and education for pastoralists and the other 40% of the Chadian rural population living far (>15km) from the nearest health facility (Ouagadjio 1998) remains a challenge. New strategies are needed to provide adapted, integrated and sustainable social services for mobile pastoralists that protect and foster their sustainable livestock production systems (Bonfoh 2007). Changes in the demographic composition and social organization (also due to settlement to access social services) play a crucial role in sustainable use of

resources, thus demographic parameters are key indicators for the monitoring of MDGs and for appraisal of whether social, environmental and economic development is truly sustainable (Goodland 1995).

We have shown that the registration of vital data is feasible in highly mobile pastoral settings with the proof-of-concept and the methods of biometric fingerprint registration and identification. We see an opportunity in the combination of biometric identification and GIS to be an integrated tool for a HDSS among mobile people. Such a HDSS could provide an extended platform for the monitoring of livestock production system parameters such as livestock population, productivity and pasture and water resource management related indicators. It may therefore contribute to monitor both sustainable natural resource management and progress in sustainable development. Since health of mobile pastoralists is the result of complex interactions between health systems, the economy of livestock production systems, socio-cultural background, sustainable resource management, environmental health and political powers, broader approaches such as a "one health" approach are needed.

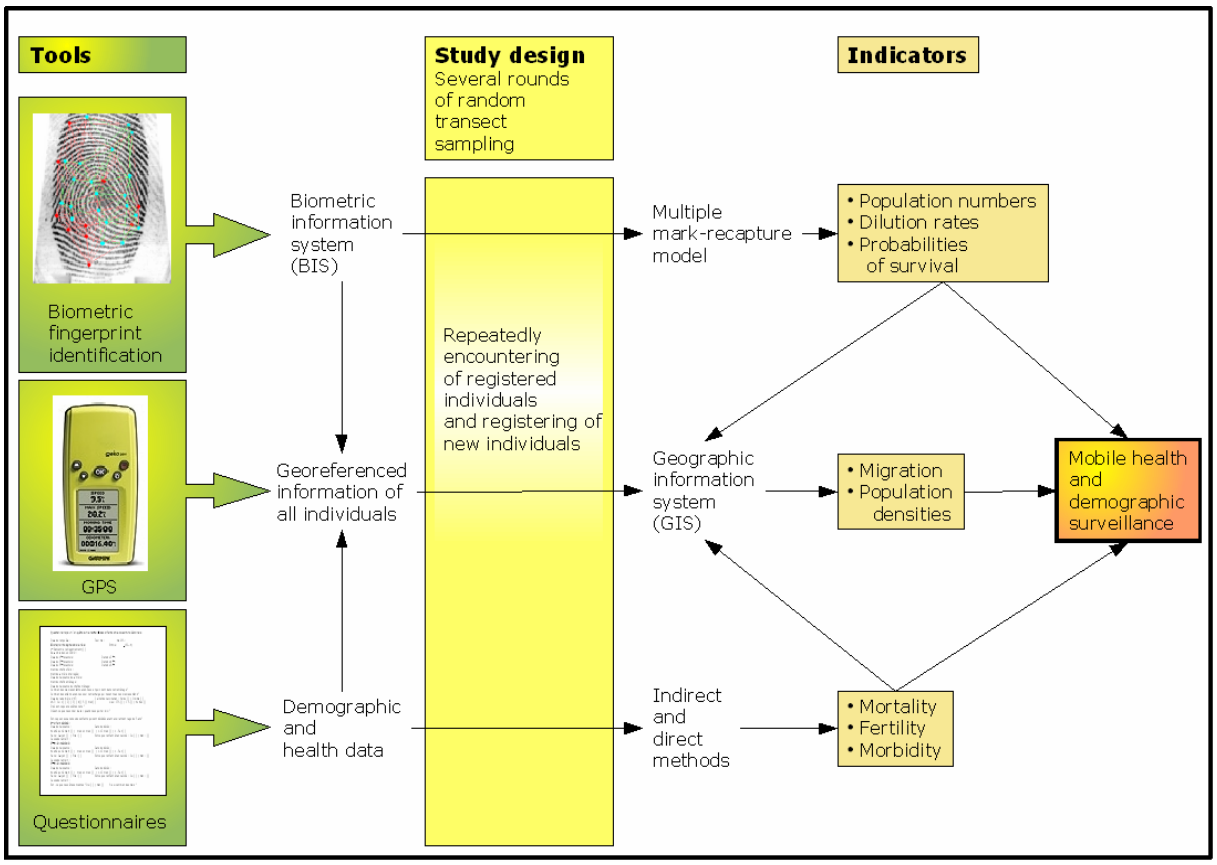


Figure 2: Suggested conceptual framework for the combination of BIS and GIS together with epidemiological and population modelling approaches towards the integration into a HDSS for mobile pastoralists.

4.5.1 Feasibility of a HDSS for mobile people

Due to heavy rains in August 2007, the third survey round was shortened from 13 to 9 days. In the second round, we achieved higher registration numbers probably because we stayed somewhat longer in the field. On average we sampled 14-15 women per day. The number of sampled women was directly linked to their availability during day time. It was exceedingly difficult to sample women when they were busy to fulfil their daily tasks. Their workload depended on available help from children (preparing meals, milking animals, care giving for other children, going to markets to sell milk and buy crop, get water for the family, collecting firewood). We found that the morning time after breakfast from 8 to 12 hours was most suitable. Another important factor influencing the number of sampled women per ferik was how soon husbands were found and how long it took to explain the purpose of the study and to obtain informed consent. Given the cultural norm with male chaperones, we could hardly establish informed "face to face" consent with the women. We assume that only women with mutual consent presented themselves. We observed women staying away. Number of sampled women per day was further affected if random transects led into unpopulated zones due to degraded pasture (e.g. thorn bush vegetation and burnt surface areas).

The illustrated assumed direction of migration as a line between the GPS coordinates of registration and re-encountering in (Map 5) has to be seen in a wider pattern of seasonal migration of mobile pastoralists, where Gorane and Fulani would move more east-westwards and Arab ethnic groups northeast-south-westwards depending on their livestock composition. It is important to note that we only encountered 2.4% of the 933 registered women twice in different survey rounds. This issue raises some concern about some aspects of the feasibility which is discussed in the next section.

4.5.2 Methodological and equipment challenges

The intermixing of the population due to micro- and macro-movements and the conducted random transects visualized a scattered population over time and space. Random transects represent a mobile survey method compared to a fixed household-based demographic survey. Obstacles in the field such as dense vegetation, crop fields, and water arms of the lake as well as burned areas often prevented to follow the selected transect up to the border of the study area. Uncompleted transects bounced then back into the study area.

Visibility was highly influenced by factors such as weather conditions and vegetation. At the end of the rainy season (November) gramineous species grew up to

2.5 m high and in March there was much sand and dust in the air due to the Harmattan winds from the north.

Since growth of fingers could influence the recognition of the fingerprint, we have assigned children's data to the identification of their mother. When children were not together with their mother but in the care of another household (for example their grandparents), we assigned the data of the child to the woman of the household of care.

We saw that among 472 vaccinated women 59% lost their vaccination card. Therefore, a centralized health care provider database combined with patient records and vaccination cards at the household-level could help to reduce loss of health information.

High losses of patient records of the nomadic people together with the difficulty to identify a nomadic individual by name, date and place of birth and social relationship led us to evaluate the usefulness of fingerprint technology. This biometric tool provides an individual identification number in the health database, where all patient records are managed. This health database contains relevant demographic information on births and deaths, together with spatial georeferenced information that can be managed in a GIS. But these quantitative data have to be interpreted with the contribution of qualitative observations. Randall (2004) promotes greater variety of data collection methods and increased triangulation in demography combining quantitative and qualitative approaches. Watkins and colleagues (2002) draw on experiences in the Somali National Regional State of Ethiopia in the establishment of a migrant tracking system and trace out the main components of such a system. They argue that any method for collecting and interpreting information on migratory patterns must be combined with an analysis of ethnic identity, group structure, and indigenous knowledge systems and, therefore, requires interdisciplinary approaches. Based on findings from five populations in Sahelian central Mali surveyed in 1981/1982, Hill (1985) concluded that broad generalization on the demography and the extrapolation of data from one to other mobile populations is inappropriate. Biometric fingerprint recognition could be an interesting identification tool for ethnological and social research to generate health and demographic evidence among mobile people. In the health system, biometric technology was mainly introduced in hospitals to identify patients and to link health information (diagnosis, drug distribution and disease history) as recently described in a study carried out in Malawi (Yu 2005). There are few reports where fingerprint technology was used in the field of epidemiology and clinical trials. In a phase II cholera vaccine trial in Vietnam the authors used fingerprint technology for the identification of trial participants (The SonLa Research 2007). To work towards the integration of fingerprint technology in a HDSS, more significance for biometric registration and identification of mobile pastoralists will be

generated by the authors using fingerprints as individual markers in a multiple mark-recapture study to estimate population sizes, in and out migration and survival rates of the same population at the Lake Chad area.

Observed good acceptance in our study (we hardly had any refusal for participation) was based on the trust mobile pastoral communities have established during the joint human and animal vaccination program to the service providers (Schelling 2007). It might be more difficult to obtain consent for fingerprinting from a pastoralist population that has not been reached by (health-) service provision.

4.6 Conclusion

Lack of monitoring and inadequate information systems are important hindering factors to plan, implement and sustain social services in remote rural zones. The biometric registration provides an unique identification number to an individual where the name, place and date of birth alone cannot identify people. In a survey of static households, identification is easier when compared to mobile households because interviewers can rely to a certain degree on re-finding the same persons in the same 123 households combined with the use of geographical information on the location of the household. Biometric registration is a methodological improvement towards permanent individual "marking" for mark-recapture for estimation of population sizes, migratory dilution rates and survival and other demographic parameters such as mortality and fertility rates. The combination of biometrics and GIS could be an adequate instrument to foster new "notfixed- household-based-methods" for studies where individuals have to be recognized and re-found individually. The use of biometric registration and identification among mobile pastoralists could contribute to the creation of a HDSS in highly mobile pastoralist settings and thus address some of the outstanding issues in surveying nomadic communities for census and health issues. This would provide vital and health-related data of marginalized populations. New interventions and services could be planned and implemented and ongoing actions could be evaluated and improved towards equity-effectiveness. For example, longer vaccination rounds in shifting vaccination zones due to changing pastures situations could better be planned to reduce drop-out rates and improve vaccination coverage. In a system's perspective, a HDSS could be extended towards the monitoring of mobile livestock production systems taking into account sustainable pastoral resource management and livestock health using the "one health" approach. The implication of biometric tools and their combination with GIS in demography and epidemiology among mobile people are being developed and need to be validated at a larger scale. Next to analyses of cost-effectiveness, legal and ethical issues of biometric data acquisition and management have to be part of a complete validation

process before biometric tools become potentially applicable towards a HDSS in highly mobile populations. This study tested the use of biometric fingerprint recognition tools and found the approach to be a good way to minimize problematic issues of registration and proper identification in subsequent samplings and surveys among mobile people.

4.7 Acknowledgments

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5 Under five mortality and total fertility rate estimates in mobile pastoral communities of Chad

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5.1 Abstract

Objective: The availability of reliable demographic data represents a central requirement for health planning and management and for the implementation of adequate interventions. This study addresses the lack of demographic data of mobile pastoral communities in the Sahel and provides under five mortality rates (U5MR) and total fertility rates (TFR) estimates together with a methodological discussion on how to generate demographic and health-related data in highly mobile populations.

Methods: In five survey rounds conducted at the Lake Chad region in Chad a total of 1081 Arab, Fulani and Gorane women with 2541 children (1336 boys and 1205 girls) were interviewed and registered by a biometric fingerprint scanner.

Findings: Based on reported information about children born and died we calculated a TFR of 7.3 children (95% CI 6.2, 8.9), a U5MR of 61 (95% CI 43.13, 99.75) with the Brass indirect method and of 79.1 (95% CI 68, 91.9) with the Kaplan-Meier survival analysis method. Due to the high mobility, the numbers of re-encountered individuals (5%) was low. Therefore, it was not possible to establish a retrospective cohort based on reported data. Environmental factors, availability of women for interviews, the need for informed consent of husbands in typically patriarchal societies like the pastoralist communities in Chad, the importance of information-education-communication campaigns, difficulties in defining "own" children in mobile pastoral societies are important determinants for the planning and implementation of household surveys among mobile pastoral communities. Prospective cohorts are the most accurate method to assess basic demographic indices. However feasibility in a highly mobile setting remains to be established

Conclusion: Prospective birth cohorts are the most accurate method to assess child mortality and other demographic indices. But feasibility in a highly mobile pastoral setting remains to be established. Future interdisciplinary scientific efforts need to target new methods, tools and approaches to include marginalized communities in operational health and demographic surveillance systems.

5.2 Introduction

There are estimated 50 million pastoralists and agro-pastoralists living in sub-Saharan Africa (Rass 2006). Extensive mobile livestock production systems (EMLPS) in sub-Saharan arid and semi-arid zones are important drivers in national economies, fundamental national food providers and ecologically sustainable (Niamir-Fuller 1999; Wiese 2004). More and more EMPLS are politically and economically marginalized. EMLPS need to be fostered, but sustainable development relies on accurate data for fertility, mortality and causes of deaths (Setel 2007). However, Sahelian countries face considerable challenges to sample and register mobile pastoralists and there is no demographic surveillance system (DSS) including mobile livestock keepers. There are only some approaches reported to account for mobile communities. Water point sampling methods for nomadic groups were discussed by Kalsbeek (Kalsbeek 1986). Watkins and Fleisher draw from experiences in the Somali National Regional State of Ethiopia for the establishment of a migrant tracking system (Watkins 2002). Overall, only few studies on demographic indices among mobile pastoralists are available (Hill 1984; Randall 1985; Brainard 1986; Coast 2001; Schelling 2005; Münch 2007).

This study addresses the lack of demographic data of mobile pastoral communities and provides U5MR and total fertility rates (TFR) estimates for further planning and evaluating health interventions among mobile pastoral people. It also contributes to the methodological discussion on how to generate demographic and health-related data in highly mobile populations.

5.3 Methods

5.3.1 Study area

The study area in Chad was located in the semi-arid Sahelian belt bordering South at the Sahara desert. Overall, a surface area of 4,275 km^2 was covered, with a North-South extension of 45 km and a West-East extension of 95 km at the southern shores of

Lake Chad in the Region of Hadier-Lamis, Chad (Map 2). It covered the intervention zone "Gredaya" of the human and livestock vaccination campaigns jointly conducted from 2000 to 2007 by the Swiss Tropical Institute (STI) and the Chadian "Centre de Support en Santé Internationale" (CSSI).

5.3.2 Sample population

Our survey population was all pastoralists targeted by the human and livestock vaccination program (Schelling 2007). It comprised the main ethnic groups of Arab, Fulani and Gorane. These groups were mainly mobile cattle breeders but also kept small ruminants. Participants were women in reproductive age and, if they had children, their children younger than 12 years.

5.3.3 Repeated demographic survey

Our study took place from March 2007 to January 2008 in the dry season (October – April) and during the transition periods between dry and rainy season (July/August) when mobile pastoral communities of all three ethnic groups gathered in the study area to use dry season pastures at the shores of Lake Chad or in proximity where ground water was accessible after transhumant movements of several hundred kilometres between rainy and dry season pastures. Details on migration patterns, household socio-economics and socio-cultural relationships of the three ethnic groups are described by Wiese (Wiese 2004).

A total of five survey rounds of approximately two weeks each have been carried out. One survey round consisted of several transects and, where transects could not be performed, of randomly selected areas. Transects could only be established in the sandy and shrubby study zone, whereas the coastal zone has been covered by a random selection of areas based on a list of areas accessible by car. Sequential random compass directions (cardinal and intermediate points) and distances (10 to 100km in 10km steps) were generated to select starting points and to establish series of transects formed by a random walk method. The reference point was the village Gredaya (geographical coordinates: 12° 57' 28.40" N, 15° 3' 51.55" E). On these random transects, all visible mobile pastoralists' camps (feriks) were visited. Average visibility was about 1 km depending on weather conditions (e.g. dust and sand in the air) and vegetation (Weibel 2008).

At arrival of our team in a ferik we were always received by a group of men to whom we presented the objective and the content of the study. To obtain informed consent, all married women older than 12 years were invited to participate with the agreement of their husbands. In typically patriarchal societies like the pastoralist communities in Chad informed consent of husbands is inevitable. Participants were interviewed and registered by a biometric fingerprint scanner for potential re-identification in a subsequent survey round (Weibel 2008). Demographic data reported by mothers or female care-givers (name, year of birth, ethnic group, name of husband, number of children lost in a lifetime, age when child died and self-reported cause of death, and number of children alive at time of the interview, including, name, sex, age, date of death if deceased between survey rounds) have been collected with a questionnaire. Questions have been asked in Arabic language and translated by Chadian colleagues from the interview team into French.

5.3.4 Data analysis

Preston et al. defined the TFR as the standard age-standardized measure of fertility rates per women. The TFR is the average number of children a woman would bear if she survived throughout the reproductive age span (10 to 50 years of age) (Preston 2001). Women have reported their age at the time of giving birth to a child. Children born were tabulated in the according age group of their mothers. Age group specific fertility rates were calculated from the number of reported children born in the reference period from 2001 to 2006. Age groups were categorised in 5 years intervals (10-14 years up to age group 45-49 years). Confidence intervals (CI) of the outcome variables of age specific and total fertility rates were compared with the explanatory variable (i.e. ethnical group).

The U5MR is the number of children died before reaching 5 years of age per 1000 children born alive (Preston 2001). The U5MR was calculated with the Brass indirect method based on self reported numbers of children ever born, whereby we used the Coale and Demeny "West family" regional model life tables (Preston 2001). The U5MR was also estimated with the Kaplan-Meier survival analysis method, which generated a survival curve plot to show the time until a child died based on reported data. This has been done to compare the two methods. Age groups for the women were done for 5 years intervals (15-19 years up to age 35-99 years). Confidence Intervals of the outcome variables of age specific U5MR and total U5MR were compared with the explanatory variable (i.e. ethnical group).

5.3.5 Hard- and software

We used an IBM notebook (International Business Machines Corp.; New York, USA) and a fingerprint scanner W32 (Microsoft Corp.; Redmond, Washington, USA) as hardware in addition to the version 1.0.2 of the Desktop Identity software (Griaule Biometrics Corp.; San Jose, USA) for fingerprint registration and identification. For database management, we used Microsoft Access 2002 (Microsoft Corp.; Redmond, USA). Electricity was assured by two Sunbag L (Off-Grid Systems Ltd.; Zillis, Switzerland) solar panels with storage batteries and a portable fuel generator (Yamaha Corp.; Hamamatsu, Japan). Geographical coordinates were collected with a hand-held global positioning system (GPS) Geko 201 (Garmin Ltd., Olathe, USA). Demographic, health and GPS data were transferred as attributes to a GIS using ArcGIS 9 – ArcMap 9.1 (ESRI, Redlands, USA) software for spatial data management and mapping.

5.3.6 Ethical considerations

The Chadian Ministry of Health (MoH) and the Ethical Committee of the Cantons of Basel and Baselland (EKBB) in Switzerland approved this study, including the collection, storage and analysis of biometric data. The participation in the interview was voluntary. For anonymity of participants, all fingerprint-related information, demographic and health data and geographical coordinates were stored in three separate databases and were only linked for final analysis via unique identification numbers. All data was treated confidentially. Vaccination services were demand-driven, well known and appreciated by pastoral and rural communities as well as by public health and veterinary services who gained effective access to mobile and sedentary populations in rural Chad. Each field team was accompanied by a public health nurse who treated or referred any clinically ill person according to the possibilities of remote field conditions. Severely ill persons were referred to the next hospital or health station for further treatment.

5.4 Results

In total, we registered and interviewed 1081 women with 2541 children (1336 boys and 1205 girls). Data of same individuals (identified by biometric fingerprint) who have been sampled a second time (n = 56) in a subsequent sample have been withdrawn from analyses (Table 2). One hundred and forty three children were younger than 1 year (6% of all children), 1055 (42%) older than 1 year but younger than 5 years; 1009 woman (93%) were older than 15 years and younger than 50 years and 27 (3%) older than 50 years. The youngest mother was 13 years old and the oldest woman registered was 66

years old. Among all women, 94 (9%) have reported being childless, where of 74.5% were younger than 20 years.

Table 3 shows the distribution of the interviewed women's ethnic group. Depending on their presence in the transect zone during a survey, the composition of ethnic groups varied between 39 – 79% for Fulani women 4 – 33% for Gorane and 0 – 86% for Arab women.

Survey	Dates of survey	Women	Boys	Girls	Total
1	15.03.-27.03.2007	240	188	179	607
2	23.04.-15.05.2007	365	476	440	1281
3	25.07.-2.08.2007	230	306	295	831
4	18.11.-30.11.2007	199	274	223	696
5	22.01.-28.01.2008	103	164	146	413
Encountered twice		-56	-72	-78	-206
Total		**1081**	**1336**	**1205**	**3622**

Table 2: Distribution of age and sex of women and children per survey round and in the total sample

Survey	Fulani	% total	Gorane	% total	Arab	% total	Total
1	94	39.1	71	29.6	75	31.3	240
2	207	56.7	72	19.7	86	23.6	365
3	182	79.1	8	3.5	40	17.4	230
4	155	77.9	44	22.1	0	-	199
5	66	64.1	34	33.0	3	2.9	103
Encountered twice	-45	80.4	-7	12.5	-4	7.1	-56
Total	**659**	**61**	**222**	**20.5**	**200**	**18.5**	**1081**

Table 3: Distribution of ethnic groups per survey round

5.4.1 Total fertility rate

The TFR for the reference period from 2001 to 2006 for women potentially reaching 50 years indicated 7.3 children (95% confidence interval (CI) 6.2 – 8.9 children) per woman. Figure 3 shows age specific fertility rates.

In total, Fulani had a TFR of 7.6 (CI 95% 6.1 and 9.5), Gorane 5.4 (CI 95% 4 and 8.6) and Arab 9.3 (CI 95% 6.4 and 13.1). As indicated by the overlapping CIs, we detected no significant differences of fertility in the ethnic groups. Figure 4 shows fertility rates per age group and ethnic group.

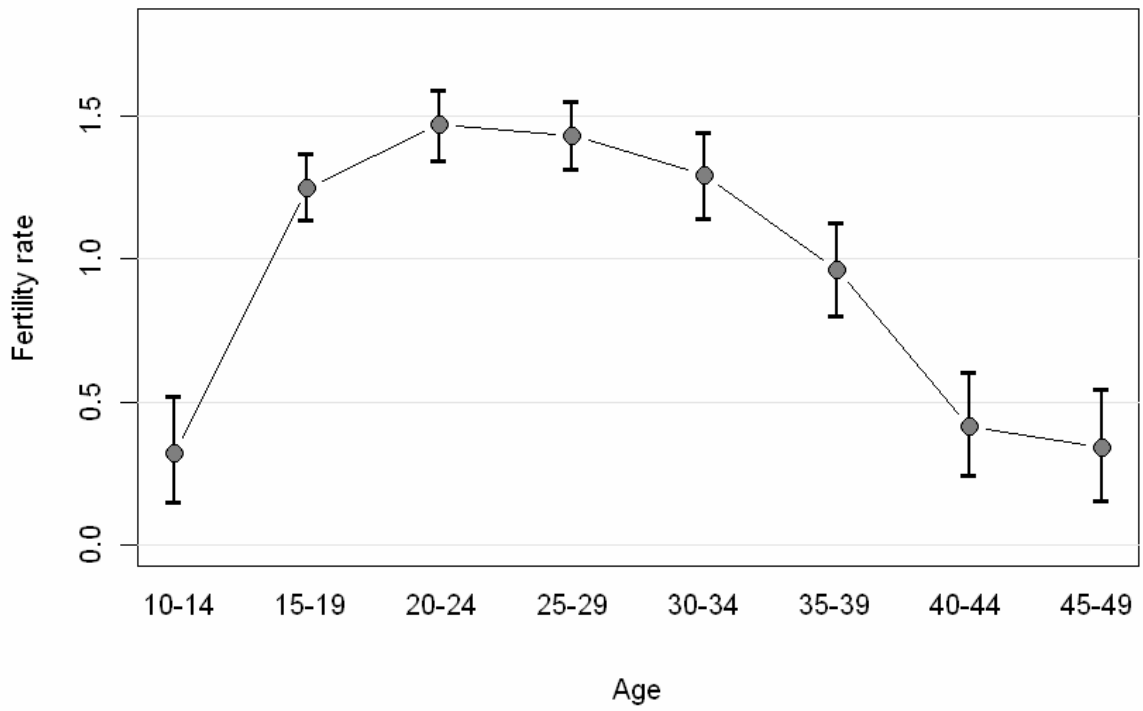

Figure 3: Fertility rates per woman in age groups with 95% CIs

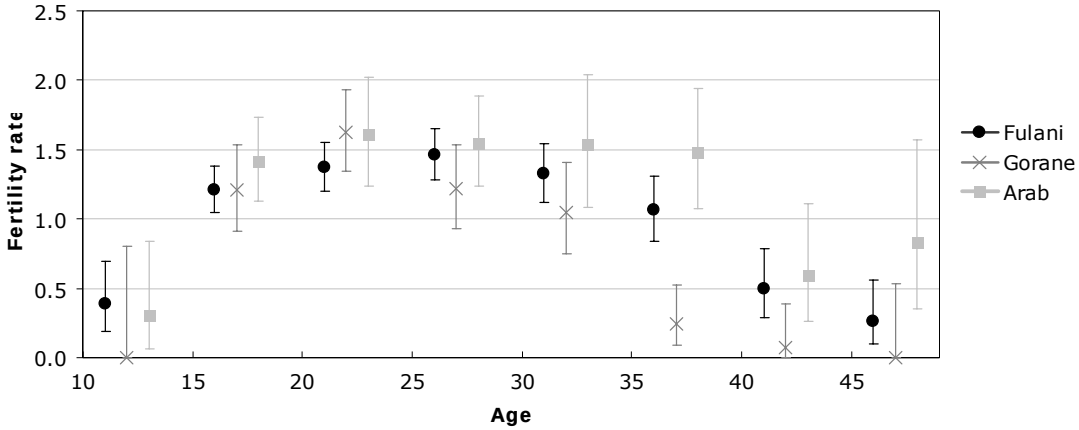

Figure 4: Fertility rates per age group stratified by ethnic group for the period 2001 – 2006 with 95% CIs.

5.4.2 Under 5 child mortality

Applying the Brass indirect method for under 5 child mortality, we have estimated an average of 61 (CI 95% 43.13 and 99.75) children dying before the age of 5 years per 1000 children born. Figure 5 shows no significant differences in U5MR levels in different age groups.

Applying the Kaplan-Meier survival analysis we have calculated 79.1 (CI 95% 68 and 91.9) children dying before reaching the age of 5 years (Figure 6) out of 1000 live births.

Fulani had a U5MR of 71.4 (CI 95% 58.6 and 86.8) for Fulani Goranes of 82.6 (CI 95% 56.9 and 119.1) and Arabs an U5MR of 103.3 (CI 95% 76.3 and 139.2 -) out of 1000 live births. However, the differences among ethnic groups were not statistically significant. The Brass method resulted with 61 U5MR in a lower mortality estimate compared to the Kaplan Meier survival analysis (79 U5MR).

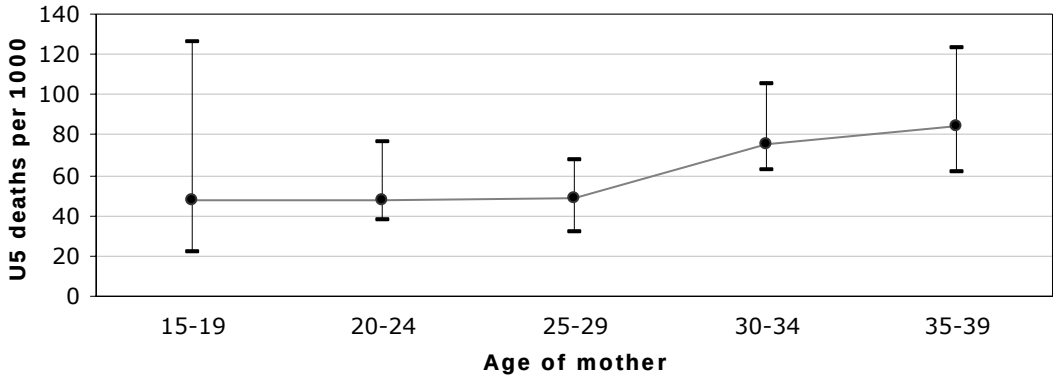

Figure 5: Under five child mortality estimates per mother's age group with 95% CIs.

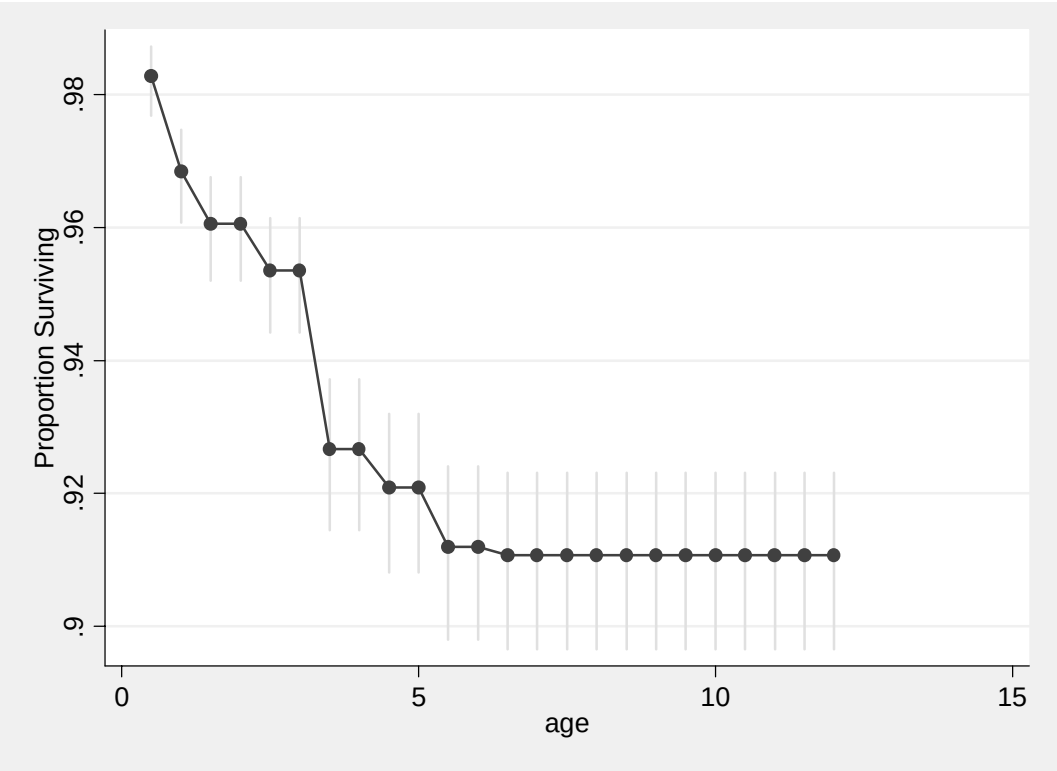

Figure 6: Kaplan-Meier survival analysis of pastoralist children of all three ethnic groups with 95% CIs

5.5 Discussion

The goal of the random transect household surveys was to establish retrospective birth cohorts with the use of biometric fingerprint registration and re-encountering (identification of a fingerprint image) of the same person randomly in a later round. A precondition is that the re-encountering of individuals is relatively frequent and the reporting of deceased individuals is accurate. Due to the low numbers of re-encountered individuals (5%) among highly mobile pastoralist communities near Lake Chad it was not possible to establish a retrospective cohort based on reported data.

Reported data could introduce a sampling bias with regard to the under-representation of women without children owing to shame and embarrassment of infertility problems. We did not know the proportion of these women in the feriks, nor how many women in general did not participate in the survey. Further we assume that some women in the old age groups presented their grandchildren or affiliated children from other family members as their truly own children. This reflects the difficulty of the definition of an "own" child in pastoralist cultural settings, although the interviewers emphasized that only own children should be reported. Accompanying health service provision including information, education and communication (IEC) campaigns of these

health services involving pastoralists' chiefs and spiritual leaders were crucial for initial acceptance to participate. However, given the perspective of health service provision, the interviewed women may also have over-reported deaths of children in the hope to mobilize further health services for their community. Potentially, there may be cases where children were reported double by different individuals between different rounds. But as we encountered only 5% of all registered women twice between survey rounds, the double-reporting would be low.

The most accurate method to obtain robust and consistent mortality information are household surveys with a prospective birth cohort rather than estimates based on retrospective and reported data (Child Mortality Coordination 2006). Visiting cohort households in regular intervals for a prospective birth cohort in mobile communities need the assistance and knowledge from local resource persons (e.g. community health workers, chiefs and other authorities) on the whereabouts of the households and its members (the composition of a household varies according to the season). If feasible, the visits would require huge logistic efforts to reach a meaningful number of randomised households that would allow for a representative stratification into ethnical groups. Depending on the degree of mobility of the households and the intervals defined for follow up it is more likely to include every encountered household and it would be challenging to establish and follow randomisation routines.

Keeping the exact time intervals of follow up visits in a prospective house hold survey constant might be problematic in a highly mobile setting. To estimate the time to reach a meaningful sample of follow up households is very challenging depending on unpredictable mobility and availability of the households, trafficability in the study area according to weather and climate, the availability of guides, and political situations. Our fieldwork showed that the number of randomly sampled women per survey round varied from 103 to 365 and the number of children varied from 310 to 916 due to different numbers of days for one survey (7 – 23 days). The deviation from planned 20 days for each survey was due to heavy rainfall (reducing numbers of the 3rd survey) and fighting between the national Chadian army and rebels' armed forces at the outskirt of the study area in January/February 2008 (5th survey). On average, we have interviewed 14-15 women per day. This number could not be increased because women had a high workload and were thus not available all day. In addition, the team often needed first the consent of the husbands, who usually were absent from the feriks during the day which delayed the sampling.

Our survey showed that the high proportion of Fulani (61%) in the sample was mainly due to the selection of the study area at the shores of Lake Chad which is predominately populated by Fulani pastoralists in the dry season. The presence of Goranes and Arabs was much more variable between surveys and their movement into the study zone was not as consistent as for Fulani. Because there is no data available on population sizes for different ethnic groups of mobile pastoralists in dry season at Lake Chad, it is hard to make any statement on the representativeness of the sample according to the study population.

The applied biometric fingerprint tool for the registration and identification of individuals was extremely helpful to identify individuals and to avoid double sampling of same individuals (Weibel 2008). Vapattanawong reported on problematic duplication of individuals exceeding 10% in three provinces in Thailand in the 2000 census (Vapattanawong 2007).

A single round retrospective demographic survey among Maasai in Kenya indicated a TFR of 7.3 children comparable to our findings (Coast 2001). The human development report 2007/2008 from the United Nations Development Program states a TFR of 6.5 children and the demographic and health survey from 2004 6.3 children per woman for Chad {UNDP, 2009 #287; Ministère de l'Economie, 2005 #486}. However, these estimates most likely do not include mobile pastoralists but only reflect TFRs of settled populations. It is possible that this study had a sampling bias with regard to under representation of women without children owing to shame and embarrassment of infertility problems (Hampshire 2002). We did not know the proportion of these women in the feriks, nor how many women in general did not participate in the study.

The only thorough demographic surveys among mobile pastoralists date back to the 1980ies among Tamasheq pastoralist in Mali. TFRs between 5 and 6 have been calculated and big differences between ethnic groups (particularly also between pastoralists and settled agricultural communities) have been observed (Hill 1984). In our study, no significant differences in TFR between different ethnic groups were observed. Randall & Winter stated that fertility of pastoral women (in their study Malian Tamasheq) was highly influenced by social organization and environmental factors that regulated mainly the availability of pastures and water (1985).

For Chad, the human development report 2007/2008 from the United Nations Development Program reported a U5MR of 208 children per 1000 children born and the demographic and health survey from 2004 191 (Ministère de l'Economie 2005; UNDP

2009). In the Chadian national estimates only the sedentary populations were included. We have found lower U5MR among pastoralists but would have expected higher than the national average (Brainard 1986). There could be a methodological reason for this discrepancy: The Brass method uses model life tables that originate not from African data (Coale and Demeny "West family" regional model life tables) (Preston 2001). According to the Child Mortality Coordination Group, these life tables need to be updated (Child Mortality Coordination 2006). In addition, to report on deceased children and infertility were sensitive topics in the study population. Female interviewers, more privacy during interviews, and more cross-checking questions in the structured questionnaire would have allowed to obtain more accurate data on U5MR and fertility; however, this could not be organized due to time limitations of interviews.

Large mortality differences between Malian zones and between mobile pastoral groups within one zone, although less distinct, have been reported (Hill 1984). In this study no significant mortality differences between ethnic groups have been found.

5.6 Conclusion

In conclusion, the implemented random transect surveys are a justifiable approach for a random sampling. However, the performance and the maintenance of several transect survey rounds were costly and time consuming and the approach was uncertain to yield sufficient data.

Future interdisciplinary scientific efforts need to target new methods, tools and approaches to include marginalized communities in operational health and demographic surveillance systems (HDSS). A mobile demographic surveillance system could facilitate birth cohort studies among highly mobile livestock keepers.

Follow up of households could be based on new technologies to locate migrated households (GPS, mobile phones). Households could also be followed up with integrative approaches, embedded in multi-sectoral intervention packets while providing simultaneously access to basic infrastructures such as domestic markets and water, finances and conflict resolving institutions. Surveillance systems could be combined with market/ water infrastructures and social services.

5.7 Acknowledgements

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6 Mark-recapture methods for population estimates of mobile pastoralist communities in Chad

6.1 Abstract

Population size estimates and other demographic indices are crucial to plan, provide, evaluate and improve health services. Seasonality dependent population size estimates for the Lake Chad area are lacking. In this chapter we try to establish population estimates applying the Jolly-Seber multiple mark-recapture and the Bailey triple catch method. Further we simulate the Jolly-Seber multiple mark-recapture experiment to establish required sample sizes. Possibilities to establish confidence intervals of estimates are tested with a Bayesian model. The sample sizes should contribute to the development of a study protocol to estimate population sizes for open and mobile populations.

Of 1081 registered women in total 56 (5.2%) were re-encountered twice. Therefore population estimates varied for the Jolly-Seber method between 15'688 and 204874 and for the Bailey triple catch method between 14257 and 24200. The analysis of our data and the simulation lead to the conclusion, that for an estimate of a population size of about 20'000 that is within the 5% confidence intervals, at least 20 survey rounds are needed with 400 individuals sampled per survey round.

6.2 Introduction

The inclusion of marginalized mobile pastoral people into national health planning and the provision of health services to these hard to reach communities are facing considerable challenges (Swift 1990; Donnat 2000; Béchir 2004; Wiese 2004). One underlying problem is the lack of accurate population data of these populations. Population size estimates and other demographic indices are crucial to plan, provide, evaluate and improve health services (Schelling 2007). There are different approaches of gaining population data from mobile pastoralists and ways population sizes for national statistics have been estimated and are documented (Elgoul 1978; Kalsbeek 1982; Kalsbeek 1986; Ministère de l'élevage et des ressources animales Tchad 1993; Ministère du Plan et de la Coopération 1995; Ministère de l'Elevage du Tchad 1998; United Nations 1998; Watkins 2002; Le schéma directeur de l'eau et de l'assainissement du Tchad 2003; Moussavi-Nejad 2003; Rass 2006).

Capture-mark-recapture methodology is applied by zoologists and population ecologists to obtain estimates on the demography of animal populations. Epidemiologists

have primarily used capture-recapture to estimate the degree of undercount in surveillance systems. A sample of individuals from a target population is randomly encountered (captured), registered (marked) and released. A second sample is re-encountered (captured) at a later point in time. Using the frequencies of marked individuals encountered in both samples (the 'recaptures') and the numbers encountered (caught) in just one sample, it is possible to estimate the number not caught in either sample, thus providing an estimate of the total population size. In this basic approach, estimates can only be derived for closed populations. Approaches with more than two rounds (the initial marking and a subsequent recapture round) using multiple marking and recapturing procedures over three rounds (Baileys triple catch method) or indefinite survey rounds (Jolly-Seber multiple mark-recapture method) allow to assess population sizes of open population. Since these approaches include parameters concerning in- and out migration and vital events like birth and death.

Elgoul (1978) advocates for mark-recapture methodology for population size estimates among mobile pastoralists. (Schelling 2007) calculated vaccination coverage of the joint human and animal vaccination campaign provided in mobile livestock keeping communities in Chad using a triple-catch mark-recapture based Bayesian model.

Although there are first estimates gained through the integration of the triple-catch approach into a Bayesian model, further research on evaluation approaches and methods to assess and estimate population data among highly mobile pastoralists has been undertaken in the need for demographic and health information surveillance for mobile pastoralist people. Especially adequate methods are lacking since common household methods are not applicable on mobile populations.

The objective of this study was to estimate total numbers of women in pastoral communities concentrating during the dry season in the study area south of Lake Chad. Due to civil unrest in Chad the sampling in the field had to be stopped several times so that the number of re-encountered individuals remained low. As all mark-recapture approaches are based on frequencies of re-encountered (recaptured) individuals a more theoretical objective has thereupon been phrased: how many survey rounds need to be conducted and how many individuals have to be sampled per survey round to ensure accuracy of population estimates using the Jolly-Seber multiple mark-recapture methodology in the highly mobile pastoralist communities of the southern shore of Lake Chad.

6.3 Methods

6.3.1 Sampling, data, parameters and assumptions of the model

Our study was carried out at the southern shores of Lake Chad in Chari-Baguirmi, Chad. The study area was located in the semi-arid Sahelian belt bordering South at the Sahara desert. Overall, a surface area of 4,275 km^2 was covered, with a North-South extension of 45 km and a West-East extension of 95 km. Chapter 4 describes in details the study area shown in Map 2.

Our study population, the target population of the joint human and animal vaccination program (Schelling 2007) in the intervention zone of "Gredaya", comprised the main ethnic groups of Arab, Fulani and Gorane mobile livestock keepers. The study population is described in chapter 4 and further details on migration patterns, household socio-economics and socio-cultural relationships are presented elsewhere (Krönke 2001; Schelling 2002; Wiese 2004).

Innovative combinations of biometric fingerprint technology and multiple mark-recapture models are promising approaches to tackle the survey problem of mobile households. But the conceptualized evaluation designs and survey approaches using mark-recapture methodology could not be demonstrated coherently within the field case study of the joint human and animal vaccination program, although 5 survey rounds have been conducted in the Lake Chad area. In these 5 survey rounds, 1081 women have been registered. The sampling is described in detail in Weibel and colleagues (2008). A registration by a biometric fingerprint tool assigns a unique identification number to an individual that can be used as mark. Unfortunately, over the 5 survey rounds only 56 women were randomly re-encountered again, which resulted in low accuracies of the population estimates.

The multiple mark recapture of Jolly-Seber and the triple catch method of Bailey is used for population size estimates of an open population (Bailey 1951; Jolly 1965; Seber 1965). This method follows the principles of the Petersen method for closed populations which states that the proportion of marks in a recapture sample is an estimate of the proportion of marks in the population (Formula 1).

M = Total marked individuals in a population
N = Population size
t = survey round (the first round is always the initial "marking-only" round)
m(t) = number of marked individuals encountered in survey round (t)

m_{01} = number of individuals marked in initial marking round (0) and re-encountered in round (1)

m_{02} = number of individuals marked in initial marking round (0) and re-encountered in round (2)

m_{12} = number of individuals marked in round (1) and re-encountered in round (2)

m_{012} = number of individuals marked in initial marking round (0) and re-encountered in round (1) and (2)

s(t) = number of individuals left newly marked in round (t).

u(t) = number unmarked individuals encountered in survey round (t)

n(t) = number of marked and unmarked individuals encountered in survey round (t); m(t) + u(t)

α(t) = proportion of marked individuals of n in survey round (t)

R(t) = number of the s(t) individuals and re-encountered again in a later round (t)

z(t) = number of the s(t) individuals before round (t), not encountered in round (t), but encountered in some round after (t).

φ(t) = Probability of survival at survey round (t)

λ(t) = Dilution rate at survey round (t) for Jolly-Seber multiple mark recapture

λ(t) = Gains to the population in the time interval t(2) between second and third survey round for the Bailey triple catch

μ(t) = Losses of the population in time interval t(1) between first (initial marking) round and second survey round

6.3.2 Peterson Method

$$\frac{M}{N} = \frac{m}{n}$$

Formula 1: Peterson Method for a closed population

6.3.3 Jolly-Seber multiple mark-recapture estimates

The Jolly-Seber and Bailey method allow multiple marking due to multiple survey rounds. The triple catch approach is based on three survey rounds whereas the multiple mark recapture method applies an undefined number of survey rounds. The two approaches are further elaborated in Seber (2002).

$$\hat{\alpha}_t = \frac{m_t + 1}{n_t + 1}$$

Formula 2: Proportion of marked

$$\hat{M}_t = \frac{(s_t + 1)z_t}{R_t + 1} + m_t$$

Formula 3: Number of marked individuals in the population M(t)

$$\hat{N}_t = \frac{\hat{M}_t}{\hat{\alpha}_t}$$

Formula 4: Population size before time t (Number of marked / Proportion of marked)

$$\hat{\phi}_t = \frac{\hat{M}_{t+1}}{\hat{M}_t + (s_t - m_t)}$$

Formula 5: Probability of survival at time t (Ratio of marked at the start of sample (t+1) to the marked at the end of sample (t))

$$\hat{\lambda}_t = \frac{\hat{N}_{t+1}}{\hat{\phi}_t[\hat{N}_t - (n_t - s_t)]}$$

Formula 6: Dilution rate (individuals added to the population through birth and immigration)

6.3.4 Bailey triple catch

$$N_1 = \frac{s_1 n_1 (m_{02} + m_{012})}{m_{01} m_{12}}$$

Formula 7: Population estimates at time (t)

$$\hat{\lambda} = \exp(\hat{\beta} t_2) = \frac{m_{01} n_2}{n_1 (m_{02} + m_{012})}$$

Formula 8: Gains to the population in the time interval t(2) between second and third survey round.

$$\hat{\mu} = \exp(-\hat{\alpha} t_1) = \frac{s_1(m_{02} + m_{012})}{s_0 m_{12}}$$

Formula 9: Losses of the population in time interval t(1) between first (initial marking) round and second survey round.

$$v(N_1) = N_1^{\,2}\left(\frac{1}{m_{01}} + \frac{1}{m_{12}} + \frac{1}{m_{02} + m_{012}} - \frac{1}{n_1}\right)$$

Formula 10: Variance of the population size

$$v(\lambda) = \lambda^2\left(\frac{1}{m_{01}} + \frac{1}{m_{02} + m_{012}} - \frac{1}{n_1} - \frac{1}{n_2}\right)$$

Formula 11: Variance of the gains to the population

$$\hat{\mu} = \exp(-\hat{\alpha} t_1) = \frac{s_1(m_{02} + m_{012})}{s_0 m_{12}}$$

Formula 12: Variance of the losses of the population

To apply these formula to a population, the assumption that the rates of loss and gain are constant during the study period have to be met, because gains are assessed for t(2) (Formula 8) and losses for t(1) (Formula 9).

6.3.5 Assumptions

The following assumptions for the multiple mark-recapture and the triple catch for an open population have to be fulfilled for application:

1. Every individual, marked or unmarked is independent and has the same probability of being captured in every survey round (t)
2. All marked individuals have the same probability of surviving from the survey round (t) to (t+1)
3. Marks are not lost
4. Marks of re-encountered individuals are not overlooked
5. Sampling time is negligible in relation to intervals between samples.

6.3.6 Bayesian Model

A Bayesian model was fitted to estimate the population sizes of women. We have estimated the parameters of the model following Bayesian inference implemented by Markov chain Monte Carlo simulation.

In the model and in the results presented in Table 7, "N" is the estimated population size of pastoralist women, p is the probability for a woman in the total population to have been registered (probability of m) and pc is the probability of being re-encountered (probability of n). Mn is the mean and var is the variance of the prior distribution of the pc (probability of n). For pc, a beta distribution has been assumed. The posterior parameters are calculated for each transect.

6.3.7 Multiple mark-recapture simulation

A multiple mark-recapture simulation was programmed with the "R" software (University of Auckland, New Zealand). This simulation was based on the assumption that integer numbers from 1 – 20'000 represented 20'000 individuals in a model population of 20'000 in total. The program was randomly selecting n numbers out of these 20'000. Selecting a number twice was not possible. The first selection was considered as the first survey round and n as the number of women registered during the first survey. The second random selection again produced n random numbers out of all 20'000 numbers. Again we had n sampled individuals in the second survey round. Those numbers that have now been selected in the first and in the second round were considered as recaptures (in the 1st survey registered and in the 2nd survey re-encountered individuals). This sampling of random numbers has been continued for 20 rounds. These 20 rounds then run in the simulation t times. We simulated also the augmentation of n, the numbers of sampled individuals per round.

6.3.8 Software and equipment

For the instruments and software used for the field sampling please refer to chapter 4. Data was managed in Microsoft Access 2002 (Microsoft Corp.; Redmond, USA) and Stata IC 10.1 (StataCorp LP, College Station, USA). The mark-recapture estimates were calculated in Microsoft Excel 2002 (Microsoft Corp.; Redmond, USA). The Bayesian models were fitted in WinBugs 1.4 (MRC Biostatistics Unit, University of Cambridge, UK) and the Simulation run and analyzed by "R" software (University of Auckland, New Zealand).

6.4 Results

The number of marked individuals m and M was known after each survey round and corresponded with registered individuals. When a registered individual was re-encountered, recognized and identified by the biometric fingerprint tool it accounted for a new m. M was equal to the total number of individuals registered in all survey rounds. All unmarked individuals encountered in a survey round accounted for u. The total number of individuals sampled in a round was the sum of m and u. Out of the total registered 1081 women 56 (5.2%) were encountered twice.

6.4.1 Jolly-Seber multiple mark-recapture

Table 4 shows the numbers of registered (marked) and re-encountered individuals per survey round (t). This matrix was used to establish the variables to calculate the population size estimates presented in Table 5.

Last encountered in Survey round	**Survey round (t)**				
	1	**2**	**3**	**4**	**5**
1		0	12	2	12
2			10	0	6
3				0	2
4					12
5					
Tot marked, m(t)	**0**	**0**	**22**	**2**	**32**
Tot unmarked, u(t)	**240**	**365**	**208**	**197**	**71**
Tot encountered, n(t)	**240**	**365**	**230**	**199**	**103**

Table 4: Matrix of registered and re-encountered individuals per survey round

Survey round	**Estimated No. of women**
1	*(*)*
2	204'874
3	15'688
4	20'646
5	*(*)*
Average	**80'403**

Table 5: Population size estimates of pastoralists women in dry season at the Lake Chad.

(*) It should be noted that population size (Formula 3) and dilution rate (Formula 6) cannot be obtained for the first round. Further, none of the estimates can be made for the last round. The probability of survival (Formula 5) cannot be applied for the second to last round. Thus, using the Jolly-Seber method, it was necessary to begin one time period earlier and continue up to two time periods after the time interval of interest.

6.4.2 Bailey triple catch

Each three out of the five survey rounds were combined together to calculate population estimates using the Bailey triple catch method. The calculated standard error (SE) of the point estimate was very wide (Table 6).

Survey rounds	N	SE
1, 4 & 5	19'801	16'106
1, 3 & 5	24'200	19'692
2, 3 & 5	14'257	12'446
Average	**19'419**	**16'081**

Table 6: Population size estimates (N) of pastoralist women and standard error (SE) of the calculations.

6.4.3 Bayesian modeling

Two models were fitted (model 1 and model 2). These two differed in the setting of the uniform prior. In both models the population estimates presented in Table 7 and Table 8 were strongly dependent of the setting of the uniform prior. This indicated that data was not robust enough to satisfy the model and to produce accurate estimates in both models.

6.4.3.1 Prior and posterior estimates of model 1

```
model{
  for (i in 1:5){
      n[i]~dbin(pc[i],N)
      m[i]~dbin(p[i],n[i])
      pc[i]~dbeta(a,b)
      p[i]<-M[i]/N
}
      N~dunif(4000,100000)
 a<-mn*((mn*(1-mn)/var)-1)
 b<-a*(1-mn)/mn
  }
```

Data

```
# nn=R
list(m=c(0, 0,20,2,32),
n=c(240,366,227,196,103),
M=c(0,240,606,813,1007),mn=0.03,
var=0.0002719)
```

Inits

```
list(N=30000, pc=c( 0,0.05,0.5,0.1,0.1))
```

Node	Mean	Posterior CI 2.5%	median	Posterior CI 97.5%
N	8804.0	6978.0	8722.0	11240.0
p[2]	0.0277	0.02137	0.02753	0.03452
p[3]	0.06994	0.05395	0.06951	0.08717
p[4]	0.09384	0.07238	0.09326	0.1169
p[5]	0.1162	0.08966	0.1155	0.1449
pc[1]	0.02773	0.02081	0.02754	0.03564
pc[2]	0.04208	0.03208	0.04174	0.05367
pc[3]	0.02626	0.01979	0.02606	0.03381
pc[4]	0.02271	0.01706	0.02253	0.02934
pc[5]	0.01211	0.008759	0.01201	0.01605

Table 7: Results of the Bayesian model 1 with uniform prior N (4'000, 100'000)

6.4.3.2 *Prior and posterior estimates of model 2*

```
model{

 for (i in 1:4){
    n[i]~dbin(pc[i],N)
    m[i]~dbin(p[i],n[i])
    pc[i]~dbeta(3,100)
    p[i]<-M[i]/N
    }

a<-mn*((mn*(1-mn)/var)-1)
b<-a*(1-mn)/mn
N~dunif(10000,100000)

 }
```

Data

```
# nn=R

list(m=c(0,20,2,32),
n=c(366,227,196,103),
M=c(240,606,833,1029),mn=0.02912621,
var=0.0002719)
```

Inits

```
list(N=20000, pc=c( 0.05,0.01,0.05,0.01))
```

Node	MC error	Posterior CI 2.5%	Median	Posterior CI 97.5%
N	11.48	10020.0	10540.0	12420.0
p[1]	2.189E-5	0.01932	0.02278	0.02395
p[2]	5.526E-5	0.04878	0.05752	0.06048
p[3]	7.597E-5	0.06705	0.07906	0.08314
p[4]	9.34E-5	0.08282	0.09766	0.1027
pc[1]	3.731E-5	0.02868	0.03439	0.03888
pc[2]	2.454E-5	0.01763	0.02137	0.02479
pc[3]	2.058E-5	0.01515	0.01849	0.02164
pc[4]	1.141E-5	0.007736	0.00981	0.01201

Table 8: Results of the Bayesian model 2 with uniform prior N (10'000, 100'000)

6.4.4 R Simulation

Figure 7 shows three different scenarios of sampling 100, 200 and 400 individuals per survey round, over 50 survey rounds simulated 300 times. The solid lines indicate the sample size estimated after a certain number of surveys conducted while the dashed lines indicate accordingly the 95% confidence intervals. The confidence limits of +/- 1'000 individuals among an estimated 20'000 are not reached with a sample size of 100 individuals per survey round even after 50 rounds. The estimates only gain accuracy of +/- 5% if at least 20 survey rounds are conducted and at least 400 individuals are sampled in each round.

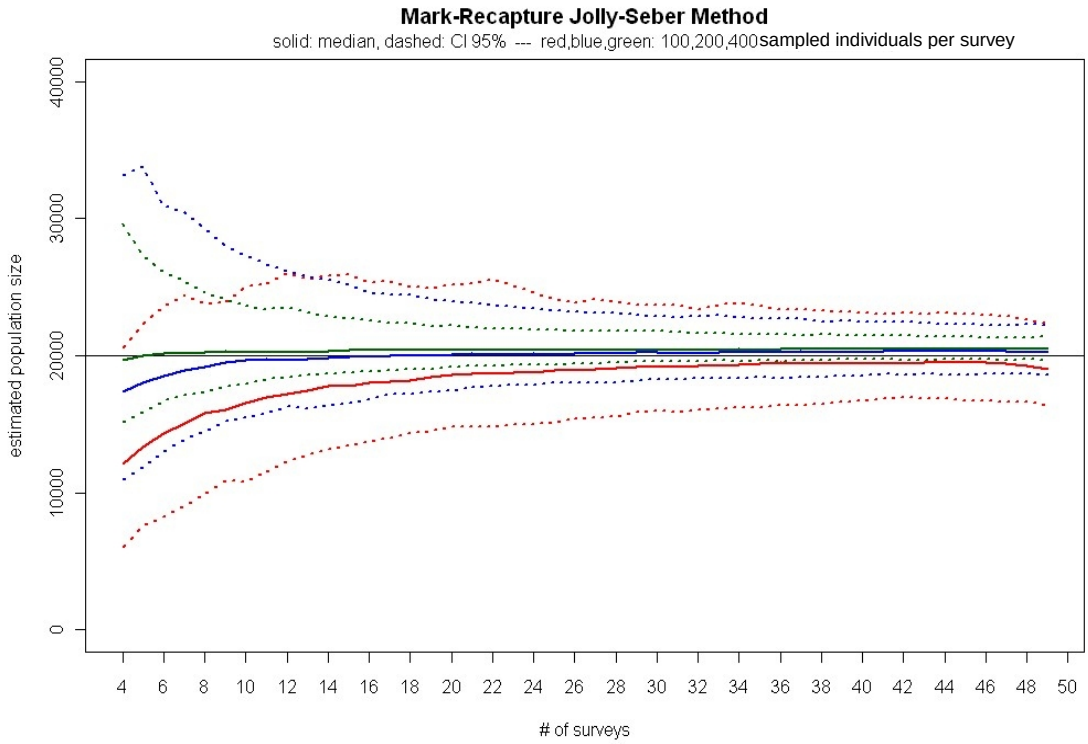

Figure 7: Simulation of the Jolly-Seber multiple mark recapture method

Figure 8 and Figure 9 show 10 survey rounds simulated 500 times based on random numbers for assumed population sizes from 10'000 to 50'000 individuals and dependent on the number of sampled individuals per survey round from 50 to 800. For an assumed population size of 20'000 and 200 individuals sampled per round, mean differences of the population sizes estimated by the simulation are at 16% and are increasing with lower numbers of individuals sampled per rounds and assumed higher population sizes. Even if 800 people are sampled per round and the survey is organized in 10 rounds, confidence intervals are still approximately 20% in the case of a population size of assumed 20'000. In the more realistic case of 200 sampled individuals per round and an assumed sample

size of 20’000, confidence intervals still are approximately 20% and the mean bias is 4%. The mean bias is a systematical bias. For example for a population of 20’000 and 200 sampled people per round, the simulation calculated +/- 4% inaccuracy of the simulated estimates with regard to the assumed population size, increasing with low sample sizes per round and higher population sizes.

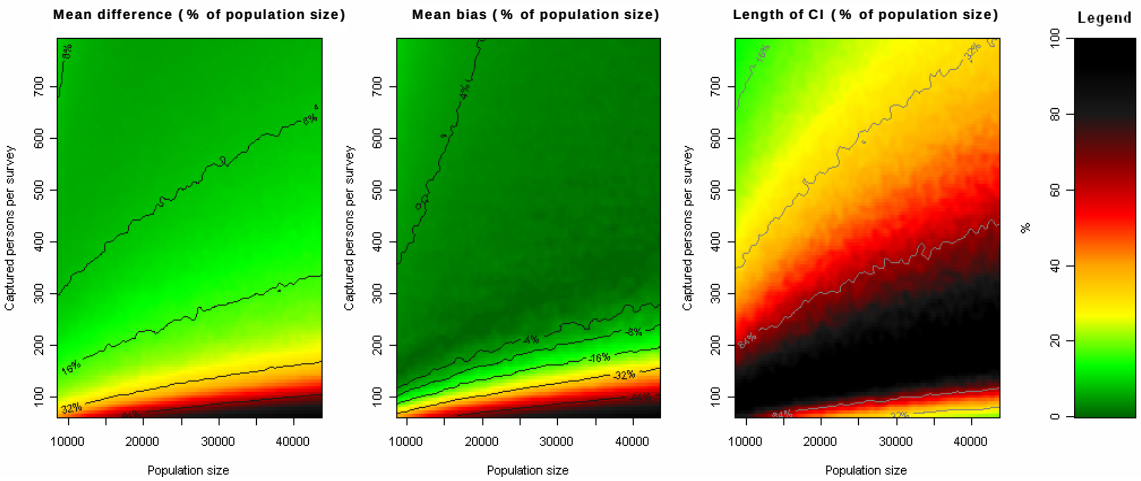

Figure 8: Results of a simulation of a Jolly-Seber multiple mark-recapture model depending on assumed population sizes of 10’000 – 40’000 people, 10 survey rounds and 50 – 800 individuals sampled per survey round.

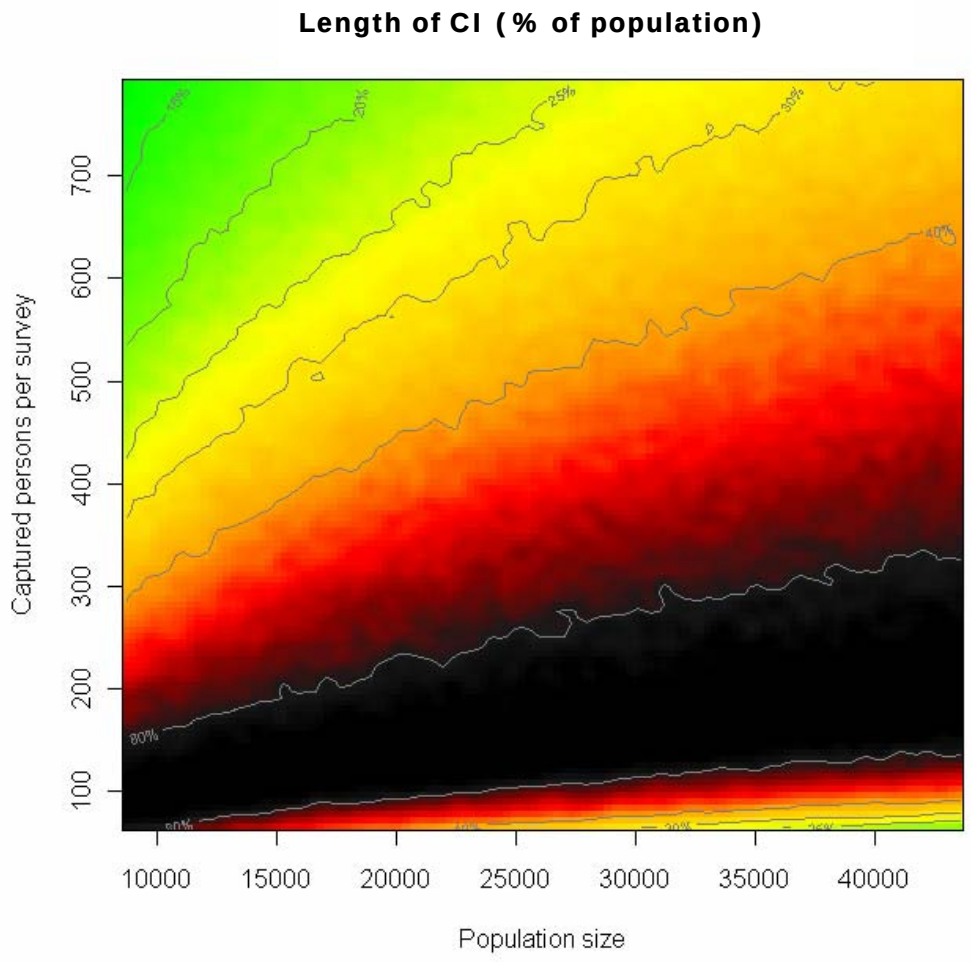

Figure 9: Results of a 500 time simulation of a multiple mark-recapture experiment depending on assumed population sizes of 10'000 – 40'000 people, 10 survey rounds and 50 – 800 individuals sampled per survey round.

We simulated a scenario of an assumed population sizes of 10'000 – 40'000 people, 10 survey rounds, 50 – 650 individuals sampled and 20 re-encountered people per survey round over 200 times (Figure 10). In this simulation we assumed a fixed number of 20 individuals to be re-encountered each round. Results of the mean differences, mean bias and CIs did not differ substantially from scenarios shown in Figure 7 to Figure 9 (all in Appendix).

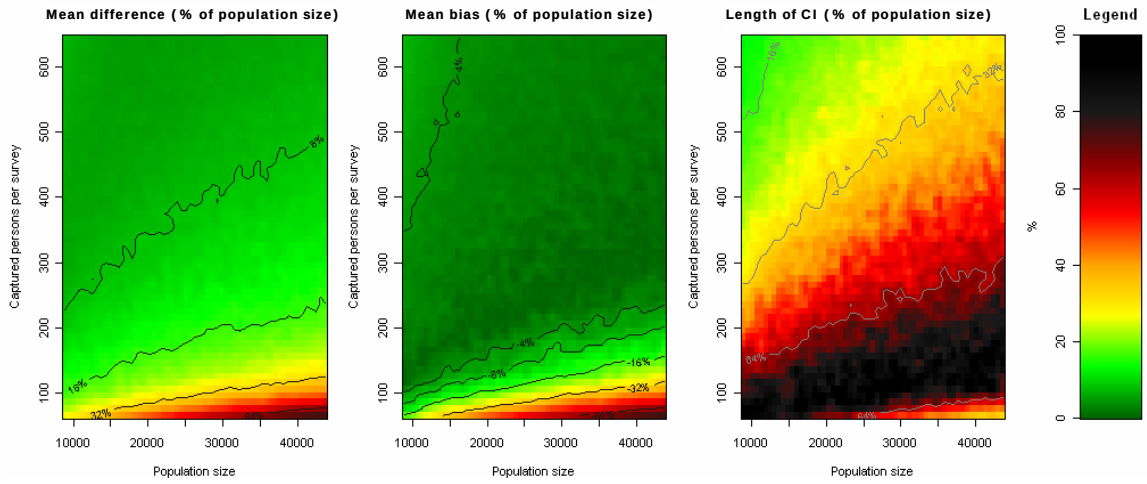

Figure 10: Results of a 200 time simulation of a multiple mark-recapture experiment depending on assumed population sizes of 10'000 – 40'000 people, 10 survey rounds, 50 – 650 individuals sampled and 20 re-encountered people per survey round.

6.5 Discussion

The underlying assumptions for the multiple mark-recapture and the triple catch methodology have been implemented as good as possible. For a strict randomization of individuals of the sampled population, every individual, marked or unmarked should be independent. The mobile people of our study population were considered as highly mobile and were intermixing between survey rounds. Even if they moved in the dry season to the borders of Lake Chad they did not stay at the same location the whole season. They undertook movements of several 10 km during the dry season within the study area. Reasons for these micro-movements were due to depleted pastures, waterholes or fire wood, blockage of access to the lake by growing crop and vegetable fields, and pressure of insects and thus risk of. The distribution patterns of the mobile pastoralists were thus not purely random, but rather dependent on factors of their micro-movements in combination with variable climatic factors. Another important consideration is that mobile pastoralist people do not move independent from each other. They move and stay in associated groups. There was a certain intermixing of these groups between sampling rounds, but its degree was not known.

The implemented random transect surveys are a justifiable approach for a random sampling. However, the following draw backs need to be considered in future studies. The performance and the maintenance of several transect survey rounds were costly and time consuming and, yet, the approach was uncertain to yield sufficient data. The random

selection of transects resulted also in selection of areas where no pastoralists have been present.

Through the implementation of biometric fingerprint technology, we could avoid the violation of the assumption that marks are lost. In previous mark-recapture surveys vaccination cards were used as marks. But the rate of lost vaccination cards was high (Schelling 2007; Weibel 2008).

The assumption that marks of re-encountered individuals should not be overlooked is depending in our case on the accuracy and the handling of the biometric tool put in place. For further details please see (Weibel 2008).

The low sample size of re-encountered people led to large standard errors of estimates, also when the data was fitted to a Bayesian model to calculate confidence intervals of the estimates from the Jolly-Seber multiple mark-recapture method. The study area was too large to be sampled as a whole within one survey round. Thus the random selection of parts within the study area could lead to overlapping or widely dispersed survey rounds. In this context the degree of micro-movements were highly influential on the probability of re-encountering a woman.

Our results showed that the probability of survival (Formula 5), the dilution rate (Formula 6), gains (Formula 8) and losses (Formula 9) are not indicated because of inaccuracies of estimates due to low re-encountering size.

The value of the mark-recapture methods for epidemiology, demography and public health has been demonstrated and documented among others by the International Working Group for Disease Monitoring and Forecasting (1995). Epidemiologists have primarily used mark-recapture approaches to estimate the degree of undercount in surveillance systems. A mark-recapture population sample additional to the human registrations can be used for estimating undercount of a census. In public health, the method is increasingly used and often called 'dual-system estimation'. Here, pre-existing, overlapping but incomplete person record lists are taken to generate estimates of prevalences, incidences, or mortality rates of diseases, especially for rare ones (Hook 2000).

For example for a population of 20'000 and 200 sampled people per round, the simulation calculated +/- 4% inaccuracy of the simulated estimates with regard to the

assumed population size, increasing with low sample sizes per round and higher population sizes. This systematic bias has to be included in accuracy estimates.

6.6 Conclusion

In this study we can show minimum sample size requirements for a multiple mark-recapture study which will improve further study designs to obtain more reliable data.

The analysis of our data and the simulation lead to the assumption, that for an estimate of a population size of about 20’000 that is within the 5% confidence intervals, at least 20 survey rounds are needed with 400 individuals sampled per survey round. However, the number of re-encountered people is the random in these highly mobile pastoralist populations and, thus, it is difficult to make firm recommendations on a study design aiming at establishing demographic parameters.

In the light of the resource demanding maintenance of survey rounds based on random transects to generate mark-recapture data that were not effective in this study, alternative, more effective randomization methods are needed. As long as good and effective randomization methods can generate reliable and strong mark-recapture data, the mark-recapture methodology has a valuable potential to be integrated in evaluation and planning designs for health service provision among mobile pastoral people.

7 Discussion

7.1 From random mobile household surveys towards a mobile health and demographic surveillance system

7.1.1 Methodological considerations

This study implemented several rounds of random household surveys to collect demographic and health related data.

The randomization was established through random transects. The basic idea of a transect is to follow straight randomly predefined routes crossing the entire study area. Thus transects can only be conducted in areas accessible by car and surface characterization that allow straight routes. This can be problematic in areas where dense vegetation, crop and vegetable fields or water arms (at the border of Lake Chad) predominate. Therefore, the study area was divided into two sampling zones (Map 3) depending on the feasibility of transects. Where transects seem not to be possible, randomization was established by drawing defined locations by lot. All randomization methods and the transect approach is further explained and discussed in chapter 4.

Furthermore, there is also a randomization established by the micro movements of the study population itself. These micro movements can be considered as a form of "self" randomization of mobile pastoralists and are outlined and discussed in chapters 4 and 6.

This randomization process ("self" randomization) and the randomization methods applied (transects and select locations by lot) have different potentials depending on the targeted indicator. To estimate population sizes, dilution rates (in and out migration of an open population) and mortality applying mark recapture methods the way randomization was established in the study is not fully satisfying. The study showed that, random transects only led to a random re-encountering of approximately 5% of the sampled population. But as explained in chapter 6, these frequencies of re-encountering individuals is predominant to establish reliable population estimates

For mark-recapture approaches, random transects should be done where there is no alternative randomization of households or the areas are fulfilling the following assumptions as good as possible:

- The entire area under study can be covered with transects during one survey round
- The entire area is accessible by car.
- Visibility range has to be comparable between survey rounds.

However, semi-arid ecological systems vary over time which affects the practicability: from extreme dryness with scarce vegetation coverage and good visibility interrupted by dusty wind episodes with almost no visibility to exploding vegetation during rainy season that can be affected by bushfires that are set by settled people to banish mobile pastoralists from their zone. These bushfires crucially influence also the assumed independent movements and whereabouts of individuals for the mark recapture approaches (Chapter 6). In our study no pastoral people were encountered in these burnt areas.

Randomization performed (transects and lots) and experienced ("self randomization") has also the potential to establish cohorts retrospectively through the marking (biometric fingerprint registration) and re-encountering (identification of a fingerprint image) procedure (mark-recapture method). When a woman is encountered for the first time, she and her children are registered and become members of the cohort. Whenever an individual is re-encountered in a subsequent survey round, the individual remains a member of the cohort, if not encountered due to death the date has to be communicable and thus represents the time when an individual left the cohort. After several (survey) rounds conducted, a retrospective cohort can be reconstructed and established. For example, using the information of a mother who has been registered during round 1 survey and then only re-encountered during round 5 survey. She reported in the round 5 survey that her child died between round 2 and 3 surveys. Therefore, this particular child left the cohort between round 2 and 3. The establishment of such cohorts is highly dependent on the frequencies of re-encountered individuals (mothers) and their reporting of deceased individuals (their children and other mothers) that have been registered during previous survey rounds.

In our study, we showed that it is neither possible to reconstruct reasonable posterior confidence intervals for the Jolly-Seber multiple mark-recapture method for estimates of population sizes, dilution and survival rates nor the reconstruction of the described retrospective cohorts for mortality estimates out of the low number (5%) of re-encountered individuals as initially thought.

For mortality estimates not based on reported cases, the generation of strictly planned cohorts of reasonable size that can be followed up in more or less regular intervals is inevitable. However, this is not possible for mobile communities, although a good practice would be to visit these households directly at monthly intervals instead of randomly via the described randomization methods to obtain crucial information regarding deceased individuals in the cohort. In this case, the whereabouts of mobile households belonging to the study can be ascertained together with local resource persons (e.g. community health workers, chiefs and other authorities) at the markets, at waterholes and ponds or at health centers. A mobile pastoralist cohort should also – as is true for other cohorts - allow assessing approximate time of infection or, seasonal nutrition.

Concerning the high costs of a random transect approach (approximately 1'500 CHF for one mission of two weeks sampling approximately 200 women) visiting mobile pastoralists household not randomly by transects, but reaching selected households on a direct way, would be more effective. In addition, random transects in the semi-arid hot and dry season are demanding for the research team.

7.1.2 Development of a mobile demographic and health surveillance system and scaling up

A demographic registration and health monitoring system can be seen as a social service such as health care provision, education, and information, regulations in market opportunities or credit and insurance services. Social services, in the best case, are provided by and in stewardship of the State. There is evidence that a prominent hindering factor for the implementation of social services (e.g. health services and education) among mobile pastoralists is accessibility to these services and vice versa the services to mobile people. As for other social services for mobile pastoralist communities, demographic and health surveillance systems where mobile people cannot be reached for registration or follow up surveys or they themselves have restricted access due to their way of life (mobility, remoteness, livestock production), social disparities (ethnic groups, gender) or political and institutional weaknesses (lacking representation in decision making and laws). Therefore, within the underlying complexity of accessibility of a surveillance system, all aspects of mobile livestock production in all its ecological, economical, social, political and institutional dimensions have to be considered.

Surveillance systems could be coupled with integrative approaches combining market, infrastructures and social services. The innovation of the integrative approach is

the strategy to join resources and outcomes: for example intersectoral joint human and animal health interventions combined with market facilities and infrastructures like water points. Building on the fundamental approach that health problems cannot be effectively tackled in isolation but in a context of production activities and food security, surveillance systems could be embedded in multi-sectoral intervention packets while providing simultaneously access to basic infrastructures such as domestic markets and water, finances and conflict resolving institutions (Bonfoh 2006; Fokou 2007). As currently many pastoral areas are affected by conflicts or armed and violent disputes, conflict-resolving interventions may need to be associated. Peace consolidation is a precondition for social cohesion and development.

There are experiences from the "Tiviski dairy" in Mauritania. The dairy processing plant links pastoral product promotion with access to social and financial services (Abeiderrahmane 2005). Where large pastoral associations are involved in social services provision, monitoring and surveillance could be integrated and ownership of registration given communities. Other experiences with service provision to mobile pastoralists are with formal and informal education approaches. There is acquaintance from fieldwork of mobile primary schools that are in stewardship of mobile pastoralist communities at the Lake Chad. Integrated in these structures, health and population indices could be monitored. Further a self sustaining information system circulating market information and information on the availability of pastoral resources could be initiated or used (if existent) and a population data reporting system integrated.

A mobile demographic surveillance system should be embedded in community structures and institutions and should have a strong participatory monitoring fundament. Tools and steps of the implementation and establishment of a mobile surveillance system could follow an iterative research cum action process. This framework involves all stakeholders at all levels to negotiate strategies and to initiate and foster dialogues. Stakeholder and multilevel workshops create important platforms to validate research results and to plan further actions (Schelling 2007). In general a regular and consistent communication among all actors involved (nomadic groups, researchers, planners and administrators of social services, etc.) through repetitive meetings and workshops are crucial elements for success of innovations.

The existence of socio-cultural differences between ethnic nomadic groups makes it necessary to develop specific monitoring systems and communication strategies adapted to each group. With regard to improved accessibility and registration success, education,

communication and information approaches adapted to the context and linked to the provision of essential services were central for health interventions (Wyss 2004).

Technical and operational challenges to build up a mobile surveillance system that runs for several years include appropriate data management, synchronisation of different databases, transmission of field data to data management units, the link to the health system and others. An input of conceptual, operational and technical expertise from the international network for the demographic evaluation of populations and their health (INDEPTH), that currently consists of 37 health and demographic surveillance system (HDSS) sites in 19 countries in Africa, Asia, Central America and Oceania will be essential. Some technical aspects are further elaborated in the next chapter.

In the Sahel, concepts and strategies to reach the vulnerable population strata in terms of equitable access to social services have been developed and need scaling up and accompanying policies (Bonfoh 2007). And these concepts and strategies provided could be adapted and used to implement mobile surveillance and monitoring systems in mobile pastoral areas. Once implemented the health and demographic surveillance system could potentially be an information pillar in a comprehensive new pasture law or intersectoral planning and action. In Chad intersectoral approaches for the planning and provision of social services for mobile pastoral people have been developed from the local to the national level. The strategy "Minimum Social Action Package" (MSAP) is being adapted by the Chadian government to develop a social service policy to nomadic population. After a national workshop involving 12 ministries, a national program was drafted and is currently being analyzed for improvement and the generation of a donor's round table for funding. Also the UN Office for the Coordination of Humanitarian Affairs (OCHA) and the African Union (AU) are currently developing a continent-wide policy framework to secure and protect the lives, livelihoods and rights of pastoralists in Africa, supported by the Swiss Agency for Development (IRIN Humanitarian news and analysis 2009).

Scaling up and the initiation of a surveillance system will only be possible with the existence of appropriate institutional frameworks. The institutional approach assesses and defines institutional requirements necessary to ensure population monitoring. The main problem persists, also in the case of regulations for a surveillance system, that unlike the pre-colonial structures, today's institutions are not compatible with the livelihood strategies of mobile populations. Fokou and colleagues (2004) suggest that new institutional frameworks such as updated pastoral codes and norms have to be created in all cases to support the livelihoods of mobile pastoralists and to include them in decision

making processes. The maintained registration and surveillance systems could give these people a voice and entitlements.

7.2 Framework conditions and the role of a demographic and health surveillance system for supporting strategies in Sahelian mobile livestock production systems

As outlined in the introduction, mobile pastoral systems and pastoral livelihoods are under pressure because they are affected by economic, social, environmental-climatic and institutional changes (Morton 2006). This results in pastoral societies undergoing transformations and transition processes. Subsequently, conflicts over decreasing natural resources, social disparities, health stress and unsustainable use of natural resources are increasing and thus forcing affected communities to various coping strategies that have political, social and economic implications (Scoones 1995). These current processes often marginalize mobile pastoral people (IFAD 2004). In the following, these implications are outlined while considering the role of a demographic and health surveillance system in strengthening mobile livestock production systems.

The most prominent implication of pastoral communities in adaptation to externalities is the conflict about shrinking pastoral resources. Pastoralists are currently loosing control of access to pastures and water. This underlying conflict situation stresses their livestock production, their health, the ecology, and socio-political and institutional aspects of the mobile livestock production system. The only way to mitigate the burden of conflict situations is through regulating access to scarce resources. The main difficulties of access regulations of scarce pastoral resources are related to issues such as securing mobility, regulating transhumance and investing in livestock production infrastructure (Bonfoh 2007). Conflict mitigation strategies need adequate monitoring and surveillance systems for pastoral resource management and for the demography and health of all stakeholders to guide decision processes.

Despite the common opinion that living conditions of pastoralists are degrading, there is also a potential for capturing their economic force through improved marketing of livestock, processing of pastoral products and potentially by tourism. Delgado and colleagues (1999) have favored and supported with some evidence this hypothesis in stating that there is a growth in livestock production with great economic potential to propel sustainable livelihoods of pastoralists – this was termed the livestock revolution as an alternative view to the ‘green revolution’ (Delgado 1999). However, a livestock revolution is only possible when various social categories (mobile pastoralists and sedentary populations, women, youth, and herders) have an equitable and effective

access to resources. And, access regulations have to ensure sustainable resource management facilitated by a appropriate institutional frameworks and accompanied with an equitable and sustainable provision of basic social services in particular health, education, and information, because this can decrease tensions between communities.

In summary, sustaining livelihoods of millions of pastoralists as well as natural resource management in semi-arid regions is needed, given the new externalities. This implies better secured access to natural resources, new institutions set-ups (representation in decision making process), adapted social services (health, education, information) and economic incentives (market and microfinance). Such strategies to enhance sustainability of pastoral systems in Sahelian Africa only can be planned, implemented and monitored based on evidence of demographic and health related population data, because these are among the most sensitive indicators of development and transition processes.

7.3 Good practices of health service provision to mobile pastoralist people in the Sahel

Demographic and health surveillance systems have the objective to foster strategic, often political decisions through information. This information also is directed into health care planning, service provision and the evaluation of interventions. The goal of this study was to contribute to the development of equity effective and sustainable health services for pastoral people thus discussion chapter aims at giving an overview of implemented and tested health interventions among mobile pastoralists.

Problems of health service provision for mobile pastoralists are most often related to constraints of access to health services. These barriers to health services can be classified in geographical, economic, cultural, technical, social and political barriers, whereby mobility and lack of conflict management seem to be major barriers (Wiese 2004). Effective health interventions target the causes of these barriers. The causes of constraint access are:

- Poverty and remoteness of rural and pastoral zones. Loutan (1989) impressively describes the lack of infrastructure and long distances for pastoralists of Mali and Niger to diagnostic and drug distribution centers that are commonly located in urban centers. Other sources document the ability of health and veterinary systems to deliver services in Africa, is constrained by a declining public-sector budget, loss of confidence due to unmet (increasing) expectations and needs, and a severe shortage of human resources – especially of qualified personnel (Wyss 2003; Cheneau 2004). Gilson (1995) states that quality of care provided in rural dispensaries is generally poor. They lack adequate infrastructure, drugs, quality of care, supervision and weak monitoring and information systems. However, a broader focus shows inequality in its relation to social disadvantages not only due

to poverty, but also to specifics of gender, socio-cultural and economic factors, ethnicity (ethnic minorities) and other factors such as geographical settings that can worsen the ill-effects of poverty (Braveman 2000).

- Even with efficient and good quality fixed or mobile clinics, significant barriers to service delivery may still exist due to factors such as mistrust and non-inclusion in planning (Imperato 1969). Discrimination at health centres is not unusual. When availability of drugs and vaccines is reduced at health centres, mobile pastoralists are likely to be discriminated and excluded first from treatment or vaccination (Swift 1990; Omar 1992; Azarya 1996). Quality of care offered at health facilities can be an important pull-factor – and bad quality or mistrust a push-factor.
- Mobile pastoralists are rarely ever represented in village health (centre) committees informing their people about services offered at dispensaries and defining the tasks of a health program and taking responsibility for it. Community participation in primary health care however, would seemingly increase utilization of dispensaries. Health committees for and with nomadic communities remain to be established.
- Often traditional medicines and treatments are preferred by mobile pastoralists because of their availability. But traditional medicine – as recognized by the health service – provides both beneficial and inefficient, if not harmful, practices and therefore, communities should be empowered to make informed choices (Spicer 2005).
- Livestock keeping and the mobility prevent from stationary treatment or longer visits. However, the spatial fluidity of social networks that need to be mobilized in cases of illnesses might be a more important consideration (Hampshire 2002). Next to the remoteness of zones suitable for livestock production, these zones are also characterized by subliminal conflict situations between pastoralists and crop farmers imposing further barriers to health centers.
- Gender disparity, deeply rooted in many pastoral societies, is an important determinant of access to health services.
- Barriers and constraints of access to veterinary services and scarcity of adequate information on performance of livestock services (Catley 1999) are (roughly) the same as for public health services.

In general to improve equitable access, community-based approaches may better align health services with communities' needs, expectations, and resources. From a providers' perspective, most basic requirements cannot be met due to the limited accessibility of health care provisions to pastoralists. But there are good examples where health services for pastoralists could have been implemented.

Complementary to any health care is the provision of appropriate information. Indeed, pastoral communities with their perceived exclusion from planning often ask for sufficient information on health topics. Information, Education and Communication (IEC) approaches prove to be crucial and valuable. Health messages should be adapted to their cultural background and consider the high levels of illiteracy.

An approach with strategically well placed static or fixed health centres can work well with transhumant communities. However, provision of static health care structures

alone rarely addresses sufficiently the constraints to access. Cohen (Cohen 2005) describes that static health facilities offering voluntary counselling and testing of HIV/AIDS – with immediate reception of results - has become a popular service among Kenyan Turkana.

In pastoralist communities, the role of community health workers (CHW) as a relay between their community and outside practitioners can be significant. The following principles make CHWs more effective for mobile pastoralists: i) CHW and midwives remain mobile and are well accepted by target communities, ii) costs for long-term provision of basic drugs and supervision must be foreseen in budgets of executing agencies, iii) periodic additional courses be given to sustain a good quality in recognition and treatment of common diseases; iv) women are also trained as CHW; v) the set-up of a well established system to refer serious cases to hospitals or clinics. Duba et al. (2001) argue that strong, integrated and community-based primary health care can provide an alternative for inadequacies in the health system.

Obviously, mobile health units are best adapted to mobile populations for preventive interventions or screening activities (e.g. tuberculosis) in remote zones that are hardly possible otherwise. They may remove the need for hospitalisation of pastoralist patients. However, mobile health services had more-fold costs than static facility services (Brenzel 1994) - particularly if operating independently from static health facilities (Aliou 1992). King (1992) reports of mobile health care units of The African Medical and Research Foundation (AMREF) among Maasai pastoralists in Kenya. A more recent evaluation suggested that there is a need for more community participation and integrated approaches including access to essential drugs, mother and child health, and other programs (Wanzala 2005). In Chad, Schelling et al. (2007) demonstrated the feasibility of combining vaccination programs for mobile pastoralists and their livestock. There are also experiences made of combining mobile and static health services in the Agadez region of Niger with more favourable outcomes than single approaches where the mobile units were to expensive and performance poor and whereas the fixed health structured next to pastoral zones were utilized infrequently by mobile pastoralists (Aliou 1992). Our experience in Chad is that during the mobile vaccination services, the pastoralists perceive the quality services that are offered at the health centres and start to trust the health providers. The public health sector was thus able to use the mobile campaigns as a gateway to the pastoralists. Increasingly, nomadic parents are now visiting health centres with their children for treatment and prevention.

There are also good examples of intersectoral combined approaches and involvement of informal health services. Also professionals from the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) and other authors have proposed sharing resources for public health and veterinary services to deliver health interventions at lower costs, thereby allowing for economies of scale (Ward 1993; Majok 1996). Joint vaccination campaigns for pastoralists and their livestock and successful phasing-in of human health after implementation of animal health programs (after community trust and household incomes have been build up) are described for Chad and the Greater Horn of Africa (Catley 1999) respectively. McCorkle (1996) argues that, especially for remote or rural peoples of the developing countries, an intersectoral approach partly modelled along the lines of traditional, non-western patterns for the joint delivery of basic healthcare services to both humans and animals would be more appropriate and feasible than attempting to impose a dualistic western-style structure on services. Formal and informal, traditional and modern medical sectors could be joined by including traditional/local practitioners and effective ethnomedical practices as integral parts of such a delivery system (Last 1990; McCorkle 1994). For example an adaptation of the mobile DOTS should consider the presence and influence of traditional healers together with specific contacts with modern health services (Zinsstag 2006).

There are experiences to establish tuberculosis case detection and directly observed treatment, short-course (DOTS) in a mobile context in Mauritania (Ould Taleb 2005), community-based DOTS approaches in East Africa (Lwilla 2003; Wandwalo 2005). In Ethiopia (Afar region), Sudan, and Kenya, Médecins Sans Frontières (MSF) established the 'TB manyatta approach'' (Keus 2003).

In the absence of public social services the private sector can play a role in service delivery as reported from remote zones of Mauritania, where wealthier members of the community may either contribute with remittances or with hired private services to offer health care and education facilities (Ould Taleb 2007). Conventional public health and veterinary strategies often need to be complemented, and in some cases, replaced by alternative strategies to more effectively reach remote zones. For example, by public contracting of private agents and competent non-governmental organisations (NGOs), self-help groups and civil society organisations could deliver more selected services (Ahuja 2004).

The reported consumption of meat from animals that died from anthrax by pastoralists (Lamarque 1989) illustrates the importance of food safety. Schelling and

colleagues (2008) further suggest a zoonoses prevention and control package for mobile primary health care units. Such a package would aim to control zoonoses and to prevent transmission to humans and must be in agreement with national control policies and would consist of rapid field tests, vaccinations, de-worming treatments.

In summary, following recommendations on the provision of health services in mobile pastoralist communities have been made (Schelling 2008).

Mobile communities have to be included in decision making processes and maintained registration and surveillance systems could give these people a voice and entitlements.

- Building up trust between programs and pastoralists is usually a prerequisite for successful interventions, and hereby mutual respect between all actors involved is crucial. In some instances, a basis of trust is only achieved by a longer-term commitment of organisations.
- Pastoral leaders must be identified carefully and early. Leaders can decisively influence the opinion of community members, enabling community participation to voice their needs and improve access to services they want.
- Identifying health services that are priority demands of communities with interdisciplinary and intersectoral assessment frameworks in participatory ways.
- The health of pastoralists' animals is of great importance and animal health can provide a gateway for communities to access the human health sector.
- Mobile health services may need to be implemented at the beginning of a health programme to reach the communities (settled and mobile rural families of a remote zone) as well as to establish an initial contact between pastoralist families and health personnel; ideally local health personnel.
- Information, Education and Communication (IEC) campaigns are essential for all health interventions given the backload of health information in the communities. Information material has to be adapted to pastoral cultures.
- The quality of care in static health centres can be improved if health personnel are informed on common misunderstandings surrounding mobile pastoralists and on their specific needs.
- Community-based health and animal health workers and midwives are an important part of health service provision to mobile pastoral communities because their services are available nearby – of particular importance to women - and they can play the role of intermediaries between their community and health staff.
- Coordination and cooperation between Programs will strengthen long-term sustainable development interventions without undermining them. Duplications should be avoided and expertise and experiences of each program can be tapped if sufficient exchanges between programs exist.

7.4 Combined "one Health" evaluation concept of health services in Sahelian mobile livestock production systems

Zinsstag (2005) stipulates that a reinvigorated formulation of the "one medicine" concept towards "one integrated health system" is needed to strengthen public-health actions towards an equity effective achievement of the MDGs. This formulation needs sensitivity regarding specific contexts of societies, cultures, and health systems by integrating contributions from new institutional economics, cultural epidemiology in a broader ecosystemic concept. Since evaluation and monitoring are important elements for the implementation of public health interventions, this chapter 7.4 conceptualizes a combined monitoring approach, following the idea of "one health". The idea of "one Health" implies that interventions are not only evaluated with regard to performance and direct social-health impact indicators (e.g. reduction in mortality), but also in a systemic broader view, including natural resource management, human and animal health, economic productivity together with demographic aspects.

Further elaborations are based on the case of the joint human and animal vaccination campaign in the intervention zone of Gredaya in Chad and indicated as "Entry Point" in Figure 11. The intervention is documented in detail in (Schelling 2007).

Figure 11 illustrates two main aspects of the conceptualization. One aspect targets livestock production system indices following arrow (1). The other compartment assesses population indices using biometric tools (2). Both are primarily assessing fundamental livestock and human demographic indices. Proposed indicators in this figure for monitoring mobile livestock production systems (3) comprises of: degrees on pastoral potentials (Mobility, Flexibility and Diversification), quality and quantity of natural resources and the degree of accessibility to pastures and water, further economic indicators such as livestock productivity, access to markets, and value of pastoral products. All these indicators influences the availability and quality of pastures and have thus to be included in pasture monitoring. Integrated pasture monitoring is an important pillar for an evaluation design in a "one health" perspective (4). Biometric fingerprint technology provides fundamental accuracy in identifying an individual (5). Therefore, follow up surveys are possible without the information of household's location. Through random encountering of people multiple mark-recapture methods can be applied to estimate population numbers, survival rates, and migration dynamics. It potentially is also providing reconstructed retrospective cohorts as outlined and discussed in (chapter 7.1). The conceptualization results in a mobile health and demographic surveillance system including also livestock monitoring parameters gained through earmarking and multiple mark-recapture methodology. The "one health" monitoring concept is consisting

out of integrated pasture monitoring (containing aspects of marketing and productivity of mobile livestock production systems).

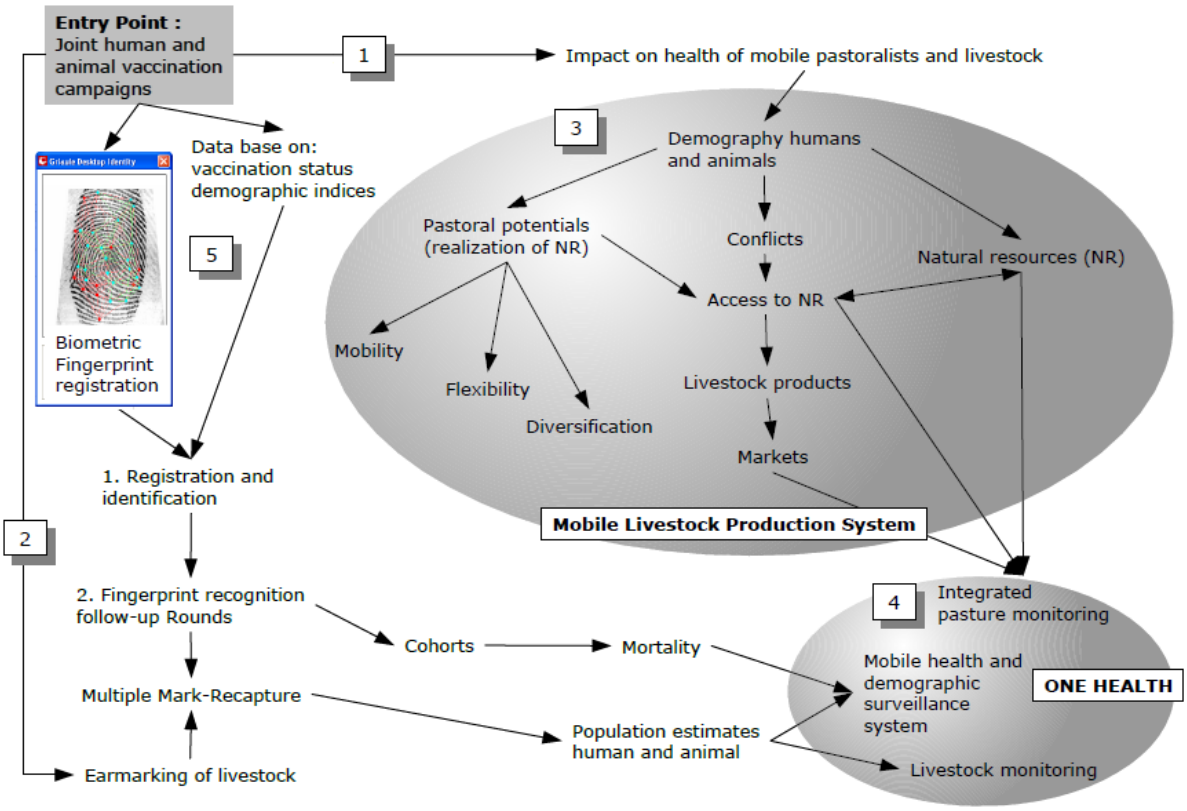

Figure 11: Concept of a "one health" monitoring of interventions in a mobile livestock production system

Access to natural resources is often governed by conflict. Therefore conflict monitoring is integrated in this concept. These conflicts are often between settled farmers and mobile people, thus implicating that equity efficient monitoring designs in mobile pastoralist communities have to cover the entire rural area integrating also the rural population in contact with mobile pastoralists. Furthermore this statement is guided by the claim that a health services delivery strategy and policy for nomadic pastoralists must be specific but also integrated into national health policies and will therefore necessarily be based on decentralized decision-making and management in order to reach equity effectiveness (Tanner 2005).

Pasture monitoring should be guided by dynamic non-equilibrium theory by Behnke and colleagues (1993). This theory states that in arid and semi-arid zones due to environmental variability, rangeland and livestock are governed by fundamentally different "non-equilibrium" processes in which plant and animal's dynamics are largely interdependent to one another. Behnke and colleagues (1993) further question the usefulness of the "carrying capacity" of rangelands, or the theoretically estimated fixed

maximum animal numbers to be allowed to sustain rangelands. As a result, the concepts of the dynamic non-equilibrium of the ecology of arid lands, and the advantages of opportune and flexible use, rather than controlling stocking rates, have now generally being accepted as the recommended scientific basis of livestock development. In this theory, combined trans- and inter disciplinary perception assessments on health and environment could be integrated.

Finally the concept described could be integrated into monitoring concepts prioritizing poverty alleviation through sustainable and strengthened livestock production. Randolph and colleagues (2007) have reviewed such approaches also adapting the Sustainable Livelihoods Framework from Carney (1998).

8 Conclusions and Outlook

- This study tested the use of biometric fingerprint recognition tools and found the approach to be a good way to minimize problematic issues of registration and proper identification in subsequent samplings and surveys among mobile people.
- The application of biometric registration is a methodological improvement of identification of mobile households and individuals and permanent individual "marking" for mark-recapture approaches for the estimation of population sizes, migratory dilution rates and survival and other demographic parameters such as mortality and fertility rates.
- The combination of biometric registration and identification among mobile pastoralists could contribute to the creation of a HDSS in highly mobile pastoralist settings and thus address some of the outstanding issues in surveying nomadic communities for census and health issues.
- In a system's perspective, a HDSS could be extended towards the monitoring of mobile livestock production systems taking into account sustainable pastoral resource management and livestock health using the "one health" approach.
- The results from the mortality and fertility surveys showed that there are no differences in under 5 mortality and fertility rates between mobile pastoralist ethnic groups.
- In this study we can show minimum sample size requirements for a multiple mark-recapture study which will improve further study designs to obtain more reliable data.
- The implication of biometric tools and their combination with GIS in demography and epidemiology among mobile people are being developed and need to be validated at a larger scale.
- Analyses of cost-effectiveness, legal and ethical issues of biometric data acquisition and management have to be part of a complete validation process before biometric tools become potentially applicable towards a HDSS in highly mobile populations.
- An estimation of the total population of these highly mobile pastoralist communities still is lacking.
- Yet, demographic indices and health outcomes are most relevant and can substantially contribute to decision processes if they have an equity dimension. To obtain this equity dimensions point estimates of mortality data have to be improved towards more frequent collection systems and these systems have to represent all

socio-economic and ethnic groups of a geographical region despite their remoteness or hardness to reach them.

- This would provide vital and health-related data of marginalized populations. New interventions and services could be planned and implemented and ongoing actions could be evaluated and improved towards equity effectiveness.

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Appendix: Curriculum Vitae

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Education:

20.2.2009	Ph.D. Defence, University of Basel, Faculty Phil. Nat., Epidemiology
2005 - 2009	Ph.D. Candidate in Epidemiology, Swiss Tropical Institute, Basel Courses with: Prof. M. Tanner, Prof. D. de Savigny, Prof. C. Lengeler, Prof. T. Smith, Prof. J. Utzinger, PD P. Vounatsou, Prof. M.G. Weiss, Prof. J. Zinsstag,
1996 - 2003	Studies in Geography, Nature-Landscape-Environmental protection (NLU), Botany at the University of Basel. Soil science at the Alberts-Ludwigs-University, Freiburg (DE) M.Sc.: Leaf litter break down and decomposition rates of different tree species in different natural and forestry habitats in the Lama forest in south Benin.
1990 - 1994	Secondary School in Basel
1986 - 1990	Secondary School in Allschwil
1981 - 1986	Primary School in Allschwil

Publications:

Masnada S., Weibel D., Wurtz M. (2003): La faune et la flore en Baie d'Audierne. Des scientifiques suisses sur le terrain: La qualité des eaux dans les étangs du littoral. Cap Caval 26. p. 3-7.

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