Introduction to the Special Issue Celebrating the Life and Work of Elke Zimmermann

Ute Radespiel1 · Marina Scheumann1

Received: 29 March 2022 / Accepted: 31 May 2022 / Published online: 15 June 2022
© The Author(s) 2022

Elke Zimmermann passed away prematurely on July 25, 2019, at the age of only 61 years (see obituary in the International Journal of Primatology by Radespiel et al., 2019). Over the 34 years of her career as a zoologist and primatologist, she became interested in and published on a large variety of research topics and study species ranging from amphibians to primates and worked with equal dedication on free-ranging animal populations and with standardized experimental approaches in captivity.

Encouraged by her father, Elke became interested in zoology very early in life. She published her first article when she was 16 years old on an inventory of reptiles, which she had observed during an excursion with her family in Southern Spain (Zimmermann, 1975). Her first article on primates followed 2 years later, in which, together with her father, she assembled recommendations for the housing of lorises (Nycticebus spp.), squirrel monkeys (Saimiri spp.), and talapoin monkeys (Miopithecus spp.; Zimmermann & Zimmermann, 1977). At that time, all these species were housed in her family’s house and garden. She continued to publish on the biology of primates (Zimmermann et al., 1979, 1980), amphibians (Zimmermann & Zimmermann, 1980, 1981), and reptiles (Zimmermann, 1976, 1978) while she studied biology at the University of Hohenheim. Although she wrote her dissertation on the neurobiological basis of acoustic communication in frogs and regularly published on amphibians until 1994 (Zimmermann, 1990a; Zimmermann & Zimmermann, 1994; Zimmermann et al., 1990), primates became her main interest after her PhD and during her career. She was interested in the evolution of primates, but in contrast to most researchers who focused on haplorrhine primates, Elke investigated the roots of the primate order and specialized on strepsirrhine primates. She always

Handling Editor: Joanna Setchell.

✉️ Ute Radespiel
ute.radespiel@tiho-hannover.de

✉️ Marina Scheumann
marina.scheumann@tiho-hannover.de

1 Institute of Zoology, University of Veterinary Medicine Hannover, Foundation, Bünteweg 17, 30559 Hannover, Germany
aimed to identify what kind of skills might be common for all primates. To get deeper insights into the evolution of primates, she also studied tree shrews (*Tupaia* spp.), which were thought to share a common ancestor with primates at that time (Binz & Zimmermann, 1989). Later she established a self-sustaining mouse lemur and tree shrew breeding colony to do comparative research on the two species.

Elke Zimmermann’s main work and scientific interests fall into seven major categories: (1) Reproduction and husbandry, (2) Behavioral ecology and health, (3) Biodiversity and phylogenetics, (4) Acoustic communication, (5) Taxonomy and communication, (6) Lateralization, and (7) Cognition and neuroethology. While this introduction cannot possibly review her entire work (>170 scientific publications) in detail, we briefly summarize her major scientific activities before introducing the contributions that are part of this special issue.

**Reproduction and Husbandry**

From the very beginning of her career, when still working on frogs, until shortly before her death, Elke studied and published on defining suitable husbandry conditions for the species that she worked with and maintained in captive breeding colonies (e.g., frogs: Zimmermann & Zimmermann, 1987; Strepsirrhini: Schulze et al., 1998; Wittkowski et al., 2022). Driven by scientific interest and a strong feeling of responsibility for her study species in captivity, she had an ongoing interest in identifying the factors that regulate and influence successful reproduction, development, health, and longevity of her study species (e.g., frogs: Zimmermann, 1990a, 1986; Zimmermann & Zimmermann, 1994; slow lorises (*Nycticebus coucang*): Zimmermann, 1989b; tree shrews (*Tupaia belangeri*): Hertenstein et al., 1987; mouse lemurs (*Microcebus* spp.): Buesching et al., 1998; Hülskötter et al., 2017; Radespiel & Zimmermann, 2001a, 2003; Wrogemann & Zimmermann, 2001; Zimmermann & Radespiel, 2013; Zimmermann et al., 2016). This interest in reproductive schedules, their intra- and interspecific variation, and their consequences for social organization, mating systems, and communication in animals also drove her research on free-living primates (Randrianambinina et al., 2007; Rasoloharijaona et al., 2000; Rina Evasoa et al., 2018; Schmelting et al., 2000).

**Behavioral Ecology and Health**

When Elke initiated a long-term field project on nocturnal lemurs in Ankarafantsika National Park, Madagascar, in 1994, she and her students started working on the social organization of the mouse lemurs (*Microcebus* spp.), Milne Edward’s sportive lemurs (*Lepilemur edwardsi*), and western woolly lemurs (*Avahi occidentalis*) inhabiting the seasonal dry deciduous forests in the park. They routinely captured the two sympatric mouse lemurs, the gray mouse lemur (*Microcebus murinus*) and the golden-brown mouse lemur (*M. ravelobensis*), in monthly trapping sessions to investigate their population dynamics and seasonal reproductive schedules (Radespiel et al., 2021; Randrianambinina et al., 2003a). They used radiotelemetry and,
later, molecular methods to study the habitat use, sleeping site ecology, ranging patterns, social organization and mating systems of mouse lemurs (Joly & Zimmermann, 2011; Kessler et al., 2016; Lutermann et al., 2006; Radespiel et al., 1998, 2001, 2003b, 2009; Rendigs et al., 2003; Schmelting et al., 2007; Weidt et al., 2004), sportive lemurs (Rasoloharjaona et al., 2003; Rasoloharjaona et al., 2008), and western woolly lemurs (Ramanankirahina et al., 2011; Ramanankirahina et al., 2012). Elke was always convinced that long-term studies are important to a deep understanding of species-specific adaptations and the evolution of lemurs in their complex abiotic and biotic environments (Kappeler et al., 2017). The behavioral and socioecological findings from her long-term work formed the foundation for several important studies of vocal communication and group coordination in solitarily foraging species. She complemented these studies with captive studies that allowed detailed behavioral observations on individuals of known life history, on topics like mouse lemur female dominance (Hohenbrink et al., 2016; Radespiel & Zimmermann, 2001b), kin recognition (Kessler et al., 2012), and female mate choice (Craul et al., 2004; Radespiel et al., 2002). During the past 10 years, Elke became interested in the impact of site-, species-, or sex-specific patterns of habitat use, sleeping site ecology, and sociality on primate parasite load and health (Hokan et al., 2017, 2018; Klaus et al., 2017, 2018; Klein et al., 2018, 2019), a very appropriate topic for a researcher working in a veterinary school that also has an Institute for Parasitology.

**Biodiversity and Phylogenetics**

From the very beginning of her career, Elke was fascinated by the extraordinary biodiversity of tropical biomes (Masters et al., 1994; Nash et al., 2013; Zimmermann, 1998). Therefore, when starting to work on Madagascar in the early 1990s, she was determined to contribute to our understanding of the evolution of the behavioral, ecological, reproductive, and morphological diversity within the endemic radiation of lemurs, on intraspecific and interspecific levels. This interest sparked her work in Ankarafantsika National Park, and also across a broader geographic scope in the rest of northwestern to northern Madagascar and in other parts of the island (Rakotoarison et al., 1997). As a result, and very early on, she and her students described a new mouse lemur species, the golden-brown mouse lemur (*Microcebus ravelobensis*), found first beside Lake Ravelobe in Ankarafantsika National Park (Zimmermann et al., 1998). The new species description was based on distinct phenotypic features such as fur coloration and tail length that distinguish this cryptic taxon from its sympatric congener, the gray mouse lemur (*M. murinus*), and from the Goodman’s mouse lemur (*M. lehilahytsara* from Andasibe (formerly called *M. rufus*), the only reddish mouse lemur species known at that time from eastern Madagascar (Zimmermann et al. 1998). This discovery was later supported by molecular and multiple other traits (Braune et al., 2008; Pastorini et al., 2001; Schmelting et al., 2000; Radespiel et al., 2003a).

In conjunction with the work of other groups in other parts of the island and based on many months of demanding fieldwork in remote and understudied regions of Madagascar (Olivieri et al., 2005; Randrianambinina et al., 2003b, 2010;
Rasoloharijaona et al., 2005), Elke’s work triggered a large scale and ongoing taxonomic revision of the genus *Microcebus*, which led to the current recognition of 24 species (Poelstra et al., 2021). It became clear that many rivers and altitude act as effective gene flow barriers for many mouse lemurs (*Microcebus* spp.) and sportive lemurs (*Lepilemur* spp., n = 26 species), and Elke contributed to seven further species descriptions in these two genera (Andriaholinirina et al., 2006; Olivieri et al., 2007; Craul et al., 2007).

The extraordinary species diversity in nocturnal lemurs was long overlooked due to their cryptic life style (Zimmermann & Radespiel, 2014) and was repeatedly criticized due to a general scarcity of divergent phenotypic features (Tattersall, 2007), which motivated Elke until her very end to illuminate species divergence in other relevant traits, such as reproduction, behavior, and communication (Evasoa et al., 2019; Hasiniaina et al., 2020; Mendez-Cardenas et al., 2008; Rina Evasoa et al., 2018). Besides her genuine scientific interest in the evolution and adaptations of cryptic nocturnal lemurs, Elke was alarmed by the ongoing destruction, degradation, and fragmentation of lemur habitats all over the island. She was convinced that research and conservation are tightly linked and benefit from each other. While the effective conservation of species requires a solid knowledge of their ecological requirements, and the effective protection of a given forest can directly benefit from the onsite presence of researchers, our ability to continue our research on free-living primates depends on their long-term survival. In this context, Elke regarded it as her responsibility to supervise and support many Malagasy students of primatology and hoped for a better future that can only be built by a well-trained and dedicated next generation.

**Acoustic Communication**

Vocal communication is the research topic that spanned Elke’s whole career, and she became a world expert on the vocal communication in strepsirrhine primates. Even in her first publications, Elke complemented her ethograms with the description of vocalizations either using onomatopoetic descriptions (Zimmermann & Zimmermann, 1977) or adding sonograms, which was technically challenging at the time (frogs: Honegger et al., 1985; Zimmermann & Zimmermann, 1985, 1988b; Zimmermann et al., 1990). In 1981, Elke wrote her diploma thesis about the vocal repertoire of Senegal galagos (*Galago senegalensis*) and Sunda slow lorises (*Nycticebus coucang*). She noticed that the animals opened their mouth, but she could not hear any sounds. She borrowed an ultrasonic detector from a colleague and her brother wrote a computer program to analyse ultrasound (Zimmermann, 1995). Using this, Elke provided the first evidence that primates are able to produce ultrasonic vocalizations, such as bats, dolphins, whales, rodents, and insectivores (Zimmermann, 1981). Later, she was the first to document ultrasonic sounds in the mouse lemurs of Madagascar (Zimmermann, 1995a).

During her career Elke published vocal repertoires for a variety of species (e.g., slow loris (*Nycticebus coucang*): Zimmermann, 1985b; Zimmermann et al., 1979, Senegal bushbaby (*Galago senegalensis senegalensis*): Zimmermann, 1985a, mouse
lemurs (Microcebus spp.): Hasiniaina et al., 2018; Zimmermann, 2010, 2018; sportive lemur (Lepilemur spp.): Mahaboubi et al., 2015; proboscis monkey (Nasalis larvatus): Röper et al., 2014; gelada (Theropithecus gelada): Aich et al., 1990; tree shrew (Tupaia belangeri): Binz & Zimmermann, 1989). She was interested in the function of vocalizations for social interactions and investigated the use of vocalizations in territorial defense (Ramanankirahina et al., 2016; Rasoloharijaona et al., 2006), antipredator behaviour (Scheumann et al., 2007a), social bonding (Mendez-Cardenas & Zimmermann, 2009), mother–infant communication (Scheumann et al., 2007b, 2017b), honest signalling of social status (Aich et al., 1987; Hasiniaina et al., 2018), and group coordination (Braune et al., 2005). She also was interested in what kind of information vocalizations encode and studied indexical cues of kinship (Kessler et al., 2012, 2016, 2018; Zimmermann & Hafen, 2001), familiarity (dialects: Hafven et al., 1998; Zimmermann, 2001), individual identity (Kessler et al., 2015; Leliveld et al., 2011; Zimmermann & Lerch, 1993), and hormonal status (Buesching et al., 1998; Zimmermann, 1996). In addition to vocal production, she focussed on the perception of sounds by studying hearing abilities (tree shrews: Zimmermann, 1993; mouse lemurs: Schopf et al., 2014, 2016), and neuronal processing (frogs: Binz et al., 1990; Zimmermann & Rahmann, 1985, 1987), and by performing playback experiments on the perception of social calls (Braune et al., 2008; Kessler et al., 2012, 2018; Konerding et al., 2011; Leliveld et al., 2010; Scheumann & Zimmermann, 2008).

During the time when nonhuman primates lived with her under the same roof, Elke also gained great insight into primate ontogeny (Zimmermann, 1987, 1989a, 1991). Hand-raising two gray mouse lemur infants (Microcebus murinus), which were abandoned by their mother, she and a student studied the vocal ontogeny of mouse lemurs. They discovered that the complex advertisement call of mouse lemurs is not present directly after birth and occurred for the first time when infants were 2-3 weeks old (Zimmermann, 1995a). On the one hand, the development of an advertisement call in hand-raised animals without acoustic contact to conspecifics pointed to an innate mechanism. On the other hand, she found that the call structure differed between normally raised and hand-raised animals suggesting that auditory feedback might influence the developmental process. Throughout her career, Elke was interested in the role of auditory feedback on the development of calls (Benson et al., 1992; Zimmermann, 1991), and she inspired her students to continue this research (Romero-Mujalli et al., 2021; Scheumann et al., 2017b).

From 2003 to 2010, Elke was the speaker of the interdisciplinary research group “Acoustic Communication of Emotions in Nonhuman Mammals and Man: Production, Perception and Neuronal Processing” granted by the German Research Foundation, which brought together psychologists, biologists, and musicians to study the principles of emotional communication (Altenmüller et al., 2013). She and her students contributed studies of the encoding of arousal in the vocalizations of tree shrews (Tupaia belangeri; Schehka et al., 2007; Schehka & Zimmermann, 2009, 2012), mouse lemurs (Microcebus spp.; Scheumann & Zimmermann, 2008; Scheumann et al., 2007b; Zimmermann, 2010, 2018), and cats (Felis silvestris catus; Konerding et al., 2016; Scheumann et al., 2012). She was particularly interested in the evolution of human laughter, demonstrating a phylogenetic relationship of laughter
across ape species (Davila Ross et al., 2009, 2010) and its emotional contagion in orang utans (*Pongo pygmaeus*; Davila Ross et al., 2008). Combining research in humans and animals, she also studied how humans perceive the emotional valence of animal sounds (Scheumann et al., 2014; Scheumann et al., 2017a).

**Taxonomy and Communication**

From her early career onwards, Elke compared the vocal repertoires of different animal species (strepsirrhines: Mendez-Cardenas et al., 2008; Zimmermann, 1995a, b, 1988, 1990b; Zimmermann et al., 1980, 1988; frogs: Zimmermann, 1990a; Zimmermann & Zimmermann, 1988a; tree shrews (*Tupaia* spp.): Esser et al., 2008). She became particularly interested in the role of advertisement calls in speciation (Zimmermann, 1992, 2017, 2018; Zimmermann et al., 2000a). By comparing advertisement calls of different closely related species, she noticed that bioacoustics is a powerful tool for discriminating cryptic species (Zimmermann, 2013, 2016) and used this tool to investigate speciation in the cryptic mouse lemurs (*Microcebus* spp.; Braune et al., 2008; Hasiniaina et al., 2020; Zimmermann, 2013, 2016; Zimmermann et al., 2000b). One of her last papers showed that similarities in agonistic calls match phylogenetic proximity (Hasiniaina et al., 2020). Playback studies supported these species-specific signatures by showing different behavioural responses in individuals listening to conspecific versus heterospecific vocalizations (Braune et al., 2008; Scheumann & Zimmermann, 2008).

**Lateralization**

Because Elke was interested in the evolution of language, she also was interested in the extent to which manual lateralisation contributed to the evolution of language. She investigated manual lateralisation in mouse lemurs (*Microcebus* spp.; Leliveld et al., 2008; Scheumann et al., 2011; Scheumann & Zimmermann, 2008), tree shrews (*Tupaia belangeri*; Joly et al., 2012; Maille et al., 2013), and cats (*Felis silvestris catus*; Konerding et al., 2012). To study the lateralized processing of conspecific vocalizations, she and her students adapted the head turn orientation paradigm as a noninvasive method to investigate the lateralization of brain processing (Konerding et al., 2017; Leliveld et al., 2010; Scheumann & Zimmermann, 2008).

**Cognition and Neuroethology**

Elke investigated the cognitive skills of mouse lemurs (*Microcebus* spp.), including multimodal predator and prey recognition (Kappel et al., 2011; Piep et al., 2008; Sündermann et al., 2008), spatial memory (Joly et al., 2008; Joly & Zimmermann, 2007, 2011), learning (Fritz et al., 2020a; Joly et al., 2014; Schmidtke et al., 2018a), and personality (Fritz et al., 2020a; Schmidtke et al., 2020). Due to a personal case in her family, in her later years Elke became interested in Alzheimer research. She
was part of the EU-funded research project DEVELAGE, which investigated the extent to which mouse lemurs qualify as an animal model for Alzheimer disease. With her postdocs, she adapted the CANTAB (Cambridge Neuropsychological Test Automated Batteries) chamber for mouse lemurs, which is a neuropsychological test chamber based on a touch screen paradigm to investigate memory function and decline in humans and animals without linguistic cues. Using this test battery, they established protocols and trained mouse lemurs to perform visual discrimination tasks to test the effect of aging on their learning performance and memory (Joly et al., 2014; Schmidtke et al., 2018a). She compared the results to neuropathologies identified using in vivo MRI (Fritz et al., 2020a, b; Schmidtke et al., 2020). She also combined her behavioural studies with veterinary studies of aging (Dubicanac et al., 2018; Dubicanac et al., 2017; Schmidtke et al., 2018b).

This Special Issue

Elke Zimmermann’s broad scientific horizon forms the umbrella for this special issue of the International Journal of Primatology. This issue brings together 10 studies conducted by her former students, friends, and colleagues whose work overlaps with her research interests and whose diverse scientific scope represents a last tribute to Elke’s own work. The contributions include research on the reproduction, feeding ecology, ranging, population ecology, conservation, and communication of lemurs and other nonhuman primate species.

The first contribution, by Radespiel et al. (2021), contains a detailed analysis of the long-term reproductive dynamics of the two mouse lemur species (*Microcebus* spp.) that co-occur in Ankarafantsika National Park. While basic species differences in reproductive schedules of these two species emerged very early on in Elke’s long-term project (Schmelting et al., 2000), a more comprehensive evaluation of various possible drivers (e.g., climate, photoperiod, body mass, age) of the observed interannual, interspecific, and interindividual variations in female reproductive activation and conception likelihoods became possible when integrating 4,321 reproductive records collected over 24 years. The authors interpret the species differences in reproductive schedules as the result of divergent evolutionary histories of the two mouse lemur species in different parts of Madagascar.

In the second contribution, Randrianarison et al. (2022) studied the feeding ecology of six habituated groups of indris (*Indri indri*) in Maromizaha Protected Area in eastern Madagascar, which Elke had visited and supported. The authors quantified the diet of indris over 9 years, during which they were mainly folivorous and had a very diverse diet without large seasonal fluctuations. Furthermore, they provide details of the vegetation structure, phenology of feeding trees, and phytochemical content of leaves and fruits in the diet of indris. Interestingly, the authors also observed regurgitation and reingestion of vomitus in four of six groups of indris and hypothesized that this rather unusual behavior may help to detoxify their diet, which contained secondary compounds, such as alkaloids and condensed as well as hydrolyzable tannins.
The third contribution, by Longondraza et al. (2022), investigated patterns of scent marking in diademed sifaka (Propithecus diadema) in the same study site, Maromizaha Protected Area. The authors observed five sifaka groups over 14 months to test whether marking and overmarking serve territorial defense and is influenced by sex, rank or season. They found that sifakas scent marked at a higher rate in peripheral and overlapping areas, supporting the territorial defense hypothesis, and scent marking was performed (a) more often by males than females, (b) more often by dominant than subordinate individuals, and (c) regularly during the migration period when males typically disperse. The authors therefore suggest that scent marking, and in particular overmarking by males, may also serve to claim mating resources, consistent with a mate-guarding strategy, whereas females may rather scent mark for self-advertisement.

In the fourth contribution, Steffens et al. (2022) investigated patterns of co-occurrence of the gray mouse lemur (Microcebus murinus) and the golden-brown mouse lemur (M. ravelobensis) in Ankarafantsika National Park by applying trapping and visual survey methods in 58 different forest sites situated in forest fragments (n = 42) or in continuous forest sites (n = 16). This large-scale dataset, to which Elke contributed in earlier years, was collected over 18 years, and was assembled by a collaboration between Canadian, German, Portuguese and Malagasy scientists. While the golden-brown mouse lemur generally preferred continuous forest habitat over forest fragments and yearly encounter rates were negatively associated with rainfall, the gray mouse lemur had higher encounter rates in the drier habitats available in forest fragments than in the continuous forest, but yearly encounter rates were positively associated with yearly rainfall. These divergent ecological preferences and responses to fragmentation and rainfall suggest different ecological adaptations and niches for the two species that may be related to the nonexclusive effects of different dietary needs, microhabitat requirements, tolerance toward varying degrees of aridity, and vagility over dry open spaces.

The fifth contribution, by Lehman and Mercado Malabet (2022), investigated whether lemur responses to forest edge effects undergo seasonal variations in four lemur species (Peyriéras woolly lemur (Avahi peyrierasi), red belliied lemur (Eulemur rubriventer), Ranomafana Bamboo lemur (Hapalemur griseus ranomafanensis), and mouse lemurs (Microcebus sp.) in Vohibola III Classified Forest in southeastern Madagascar. This topic is highly relevant to our understanding of lemur responses to habitat fragmentation. All three larger lemur species were rather edge adverse in general, and were found on average more than 520 m away from edges. Although all species were found closer to edges during the cold dry season than during the warm wet season, this difference was significant only for one species, the Peyriéras’ woolly lemur, that has a rather selective, folivorous diet. The authors related their species-specific findings to differences in feeding habits, ecological plasticity and space use, as well as human interventions in and close to these habitats.

The sixth contribution, by Davila-Ross et al. (2022), investigated the effects of approaching motorboats on stress-related behaviors in the proboscis monkey (Nasalis larvatus) in a riparian forest area in Sabah, Malaysia. The authors systematically compared the behavior of male and female members of one-male multi-female groups under varying travel speed and distance between the boat
and the groups. They showed that proboscis monkeys show stress-related behaviors when boats come close (<60 m) to the groups, which has important conservation implications, as boats are also often used for ecotourism in the region.

The seventh contribution, by Scheumann et al. (2022), investigated the role of vocalizations as a third-party vocal intervention signal in proboscis monkeys (Nasalis larvatus). The data for this contribution stem from Elke’s project on vocal communication in proboscis monkeys, which she started in 2010. Using vocal recordings from free-living proboscis monkeys, the authors showed that bray vocalizations by the male in one-male/multi-female groups occur significantly more often after agonistic shriek calls and terminate sequences of agonistic vocal displays in 65% of cases. Additional video and audio recordings in Labuk Bay Monkey center showed that brays occur more often after female-female than after offspring-offspring conflicts. The authors suggest that brays work as a vocal third-party intervention in a species living in the high canopy with limited visibility.

In the eighth contribution, Coye et al. (2022) compared the vocal repertoires of two primate species, Diana monkeys (Cercopithecus diana) and Campell’s monkey (C. campbelli), to investigate evolutionary drivers of primate vocal communication. These two species are closely related but differ in socioecological factors, such as predation and group size. The authors found similarities in the overall vocal repertoire of the two species but also unique vocal units. These nonshared vocal units were uttered in the predation context, suggesting that predation might be an evolutionary driver for the diversification of alarm calls.

In the ninth contribution, Valente et al. (2022) perform a cross-species comparison of the vocal repertoire of two sympatric strepsirrhine Malagasy primate species, diademed sifakas (Propithecus diadema), and indris (Indri indri) to explore acoustic diversity at the evolutionary origin of primates. To compare the vocal repertoires, they used modern mathematical approaches such as t-SNE reduction technique and hard clustering. A cluster analysis based on data for both species found distinct clusters differentiating the call types from the two species. Call types of both species clustered together in only 1 of 16 clusters. This indicates high vocal diversity between the two species. The authors argue that instead of a single factor, a combination of several factors such as phylogeny, environmental constrains and social complexity shaped vocal diversity in the Indriidae.

The tenth and final contribution, by Fichtel et al. (2021), investigated whether vocalizations are an honest signal of physical condition in grey mouse lemurs (Microcebus murinus). First, the authors showed that a manipulation of the dietary regime (restricted vs. nonrestricted) affects the body mass of the animal. Second, they investigated the effect of body mass on the acoustic parameters of two agonistic call types, the grunt and the tsak. For the grunt, but not for the tsak, they found a correlation between body mass and spectral parameters. Heavier animals produce grunts with more energy in the low frequency part than lighter individuals. This suggests that the acoustic structure of grunts varies according to physical condition and that grunt vocalizations therefore can be considered an honest signal of fitness in mouse lemurs.
Conclusions

The contributions assembled in this issue provide new insights into various species-specific adaptions to ecological factors or social constraints, very much alike the research approach that Elke Zimmermann often took in her work. While some of them relate seasonal variations in the habitat or human disturbance to feeding, reproduction, space use, or sympatry, others examine social and environmental influences on olfactory or vocal communication. Although most studies focus on a better understanding of the proximate mechanisms that regulate behavioral variation, all of them consider the evolutionary processes that may have generated the observed patterns.

Acknowledgments  We thank all authors of this special issue for their motivation and persistence to compose contributions that well reflect the scientific breadth that characterized the research interests of Elke Zimmermann. We are indebted to Joanna Setchell, the Editor-in-Chief of the International Journal of Primatology, for her encouragement, patience, and continuous support during the entire production process of this special issue and for her helpful comments on a previous version of this editorial.

Funding  Open Access funding enabled and organized by Projekt DEAL.

Declarations

Conflict of Interest  The authors declare that they have no conflict of interest.

Open Access  This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Aich, H., Zimmermann, E., & Rahmann, H. (1987). Social position reflected by contact call emission in gelada baboons (Theropithecus gelada). Zeitschrift Für Säugetierkunde, 52(1), 58–60.
Aich, H., Moos-Heilen, R., & Zimmermann, E. (1990). Vocalizations of adult gelada baboons (Theropithecus gelada): Acoustic structure and behavioural context. Folia Primatologica, 55(3-4), 109–132. https://doi.org/10.1159/000156508
Altenmüller, E., Schmidt, S., & Zimmermann, E. (2013). Evolution of emotional communication: From sounds in nonhuman mammals to speech and music in man. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199583560.001.0001
Andriaholinirina, N., Fausser, J. L., Roos, C., Zinner, D., Thalmann, U., Rabarivola, C., … Rumpler, Y. (2006). Molecular phylogeny and taxonomic revision of the sportive lemurs (Lepilemur, Primates). BMC Evolutionary Biology, 6, 17. https://doi.org/10.1186/1471-2148-6-17
Benson, B. N., Binz, H., & Zimmermann, E. (1992). Vocalizations of infant and developing tree shrews (Tupaia belangeri). Journal of Mammalogy, 73(1), 106–119.
Binz, H., & Zimmermann, E. (1989). The vocal repertoire of adult tree shrews (Tupaia belangeri). Behaviour, 109, 142–162. https://doi.org/10.1163/156853989x00196
Binz, H., Zurhorst, C., Zimmermann, E., & Rahmann, H. (1990). Neuronal substrates involved in processing of communicative acoustic signals in tree shrews - a 2-deoxyglucose study. *Neuroscience Letters, 112*(1), 25–30. https://doi.org/10.1016/0304-3940(90)90316-2

Braune, P., Schmidt, S., & Zimmermann, E. (2005). Spacing and group coordination in a nocturnal primate, the golden brown mouse lemur (*Microcebus ravelobensis*): The role of olfactory and acoustic signals. *Behavioral Ecology and Sociobiology, 58*(6), 587–596. https://doi.org/10.1007/s00265-005-0944-4

Braune, P., Schmidt, S., & Zimmermann, E. (2008). Acoustic divergence in the communication of cryptic species of nocturnal primates (*Microcebus* ssp.). *BMC Biology, 6*, 19. https://doi.org/10.1186/1741-7007-6-19

Buesching, C. D., Heistermann, M., Hodges, J. K., & Zimmermann, E. (1998). Multimodal oestrus advertisement in a small nocturnal prosimian, *Microcebus murinus*. *Folia Primatologica, 69*(Suppl.1), 295–308. https://doi.org/10.1159/000052718

Coye, C., Zuberbühler, K., & Lemasson, A. (2022). The evolution of vocal communication: Inertia and divergence in two closely related primates. *International Journal of Primatology*. https://doi.org/10.1007/s10764-022-00294-y

Craul, M., Zimmermann, E., & Radespiel, U. (2004). First experimental evidence for female mate choice in a nocturnal primate. *Primates, 45*, 271–274.

Craul, M., Zimmermann, E., Rasoloharijaona, S., Randrianambinina, B., & Radespiel, U. (2007). Unexpected species diversity of Malagasy primates (*Lepilemur* ssp.) in the same biogeographical zone: A morphological and molecular approach with the description of two new species. *BMC Evolutionary Biology, 7*, 83. https://doi.org/10.1186/1471-2148-7-83

Davila Ross, M., Menzler, S., & Zimmermann, E. (2008). Rapid facial mimicry in orangutan play. *Biology Letters, 4*(1), 27–30. https://doi.org/10.1098/rsbl.2007.0535

Davila Ross, M., Owren, M. J., & Zimmermann, E. (2009). Reconstructing the evolution of laughter in great apes and humans. *Current Biology, 19*(13), 1106–1111. https://doi.org/10.1016/j.cub.2009.05.028

Davila Ross, M., Owren, M. J., & Zimmermann, E. (2010). The evolution of laughter in great apes and humans. *Communicative & Integrative Biology, 3*(2), 191–194. https://doi.org/10.4161/cib.3.2.10944

Dubicanac, M., Radespiel, U., & Zimmermann, E. (2017). A review on ocular findings in mouse lemurs: Potential links to age and genetic background. *Primate Biology, 4*(2), 215–228. https://doi.org/10.5194/pb-4-215-2017

Dubicanac, M., Joly, M., Struve, J., Nolte, I., Mestre-Frances, N., Verdier, J. M., & Zimmermann, E. (2018). Intraocular pressure in the smallest primate aging model: The gray mouse lemur. *Veterinary Ophthalmology, 21*(3), 319–327. https://doi.org/10.1111/vop.12434

Esser, D., Schekha, S., & Zimmermann, E. (2008). Species-specificity in communication calls of tree shrews (*Tupaia: Scandentia*). *Journal of Mammalogy, 89*(6), 1456–1463. https://doi.org/10.1644/07-Mamm-a-360.1

Evasoa, M. R., Zimmermann, E., Hasiniaaina, A. F., Rasoloharijaona, S., Randrianambinina, B., & Radespiel, U. (2019). Sources of variation in social tolerance in mouse lemurs (*Microcebus* ssp.). *BMC Ecology, 19*, 20. https://doi.org/10.1186/s12898-019-0236-x

Fichtel, C., Kappeler, P. M., Perret, M., Huchard, E., & Henry, P. Y. (2021). Honest signaling in mouse lemur vocalizations? *International Journal of Primatology*. https://doi.org/10.1007/s10764-021-00265-9

Fritz, R. G., Zimmermann, E., Meier, M., Mestre-Frances, N., Radespiel, U., & Schmidtke, D. (2020a). Neurobiological substrates of animal personality and cognition in a nonhuman primate (*Microcebus murinus*). *Brain & Behavior, 10*(9), e01752. https://doi.org/10.1111/brb3.1752

Fritz, R. G., Zimmermann, E., Picq, J. L., Lautier, C., Meier, M., Kastner, S., & Schmidtke, D. (2020b). Sex-specific patterns of age-related cerebral atrophy in a nonhuman primate *Microcebus murinus*. *Neurobiology of Aging, 91*, 148–159. https://doi.org/10.1016/j.neurobiaging.2020.02.027

Hafen, T., Neveu, H., Rumpler, Y., Wilden, I., & Zimmermann, E. (1998). Acoustically dimorphic advertisement calls separate morphologically and genetically homogenous populations of the grey
mouse lemur (Microcebus murinus). *Folia Primatologica, 69*, 342–356. https://doi.org/10.1159/000052723

Hasiniaina, A. F., Scheumann, M., Evasoa, M. R., Braud, D., Rosaloharijaona, S., Randrianambinina, B., & Zimmermann, E. (2018). High frequency/ultrasonic communication in a critically endangered nocturnal primate, Claire’s mouse lemur (Microcebus maminatra). *American Journal of Primatology, 80*(6), e22866. https://doi.org/10.1002/ajp.22866

Hasiniaina, A. F., Radespiel, U., Kessler, S. E., Evasoa, M. R., Rosaloharijaona, S., Randrianambinina, B., … Scheumann, M. (2020). Evolutionary significance of the variation in acoustic communication of a cryptic nocturnal primate radiation (Microcebus spp.). *Ecology and Evolution, 10*(8), 3784–3797. https://doi.org/10.1002/ece3.6177

Hertenstein, B., Zimmermann, E., & Rahmann, H. (1987). Zur Reproduktion und ontogenetischen Entwicklung von Spitzhörnchen (Tupaia belangeri). *Zeitschrift des Kölner Zoos, 30*, 119–133.

Hohenbrink, S., Schaartschmidt, F., Bunemann, K., Gerberding, S., Zimmermann, E., & Radespiel, U. (2016). Female dominance in two basal primates, Microcebus murinus and Microcebus lehilahytsara: Variation and determinants. *Animal Behaviour, 122*, 145–156. https://doi.org/10.1016/j.anbehav.2016.10.008

Hokan, M., Strube, C., Radespiel, U., & Zimmermann, E. (2017). Sleeping site ecology, but not sex, affect ecto- and hemoparasite risk, in sympatric arboreal primates (Avahi occidentalis and Lepilemur edwarsi). *Frontiers in Zoology, 14*(44). https://doi.org/10.1186/s12983-017-0228-7

Hokan, M., Zimmermann, E., Radespiel, U., Andriatsitohaina, B., Rosaloharijaona, S., & Strube, C. (2018). Are sleeping site ecology and season linked to intestinal helminth prevalence and diversity in two sympatric, nocturnal and arboreal primate hosts (Lepilemur edwarsi and Avahi occidentalis)? *BMC Ecology, 18*, 22. https://doi.org/10.1186/s12893-018-0178-8

Honegger, R. E., Schneider, C., & Zimmermann, E. (1985). Notizen zur Aufzucht von Schmuckhörnchen (Tupaia belangeri). *Zeitschrift des Kölner Zoos, 30*, 119–133.

Hülskötter, K., Schmidtke, D., Dubicanac, M., Siesenop, U., Zimmermann, E., Gerhauser, I., … Herder, V. (2017). Spontaneous listeriosis in grey mouse lemurs (Microcebus murinus), but not in Goodman’s mouse lemurs (Microcebus lehilahytsara) of the same colony. *Veterinary Microbiology, 208*, 94–96. https://doi.org/10.1016/j.vetmic.2017.07.023

Joly, M., & Zimmermann, E. (2007). First evidence for relocation of stationary food resources during foraging in a strepsirhine primate (Microcebus murinus). *American Journal of Primatology, 69*(9), 1045–1052. https://doi.org/10.1002/ajp.20418

Joly, M., & Zimmermann, E. (2011). Do solitary foraging nocturnal mammals plan their routes? *Biological Letters, 7*(4), 638–640. https://doi.org/10.1098/rsbl.2011.0258

Joly, M., Scheumann, M., & Zimmermann, E. (2008). Wild mouse lemurs revisit artificial feeding platforms: Implications for field experiments on sensory and cognitive abilities in small primates. *American Journal of Primatology, 70*(9), 892–896. https://doi.org/10.1002/ajp.20560

Joly, M., Scheumann, M., & Zimmermann, E. (2012). Posture does not matter! Paw usage and grasping paw preference in a small-bodied rooting quadrupedal mammal. *PLoS One, 7*(5), e38228. https://doi.org/10.1371/journal.pone.0038228

Joly, M., Ammersdorfer, S., Schmidtke, D., & Zimmermann, E. (2014). Touchscreen-based cognitive tasks reveal age-related impairment in a primate aging model, the grey mouse lemur (Microcebus murinus). *PLoS One, 9*(10), e109393. https://doi.org/10.1371/journal.pone.0109393

Kappel, P., Hohenbrink, S., & Radespiel, U. (2011). Experimental evidence for olfactory predator recognition in wild mouse lemurs. *American Journal of Primatology, 73*(9), 928–938. https://doi.org/10.1002/ajp.20963

Kappeler, P. M., Cuozzo, F. P., Fichtel, C., Ganzhorn, J. U., Gursky-Doyen, S., Irwin, M. T., … Zimmermann, E. (2017). Long-term field studies of lemurs, lorises, and tarsiers. *Journal of Mammalogy, 98*(3), 661–669. https://doi.org/10.1093/jmammal/gyx013

Kessler, S. E., Scheumann, M., Nash, L. T., & Zimmermann, E. (2012). Paternal kin recognition in the high frequency/ultrasonic range in a solitary foraging mammal. *BMC Ecology, 12*, 26. https://doi.org/10.1186/1472-6785-12-26

Kessler, S. E., Scheumann, M., Hanbury, D. B., Nash, L. T., Zimmermann, E., & Watson, S. L. (2015). Screams in the night: Pilot study reveals moderate evidence for individual differences in lorisoid vocalizations. *International Journal of Primatology, 36*(3), 666–678. https://doi.org/10.1007/s10764-015-9847-z

Kessler, S. E., Radespiel, U., Nash, L. T., & Zimmermann, E. (2016). Modeling the origins of primate sociality: Social flexibility and kinship in mouse lemurs (Microcebus spp.). In S. M. Lehman, U.
Introduction to the Special Issue Celebrating the Life and…

Radespiel, & E. Zimmermann (Eds.), The Dwarf and Mouse Lemurs of Madagascar: Biology, Behavior and Conservation Biogeography of the Cheirogaleidae (pp. 422–445). Cambridge University Press. https://doi.org/10.1017/COBO9781139871822.023

Kessler, S. E., Radespiel, U., Hasiniaina, A. I. F., Nash, L. T., & Zimmermann, E. (2018). Does the grey mouse lemur use agonistic vocalisations to recognise kin? Contributions to Zoology, 87(4), 261–274. https://doi.org/10.1163/18759866-08704003

Klaus, A., Zimmermann, E., Röper, K. M., Radespiel, U., Nathan, S., Goossens, B., & Strube, C. (2017). Co-infection patterns of intestinal parasites in arboreal primates (probuscics monkeys, Nasalis larvatus) in Borneo. International Journal for Parasitology: Parasites and Wildlife, 6(3), 320–329. https://doi.org/10.1016/j.ijppaw.2017.09.005

Klaus, A., Strube, C., Roper, K. M., Radespiel, U., Schaarschmidt, F., Nathan, S., … Zimmermann, E. (2018). Fecal parasite risk in the endangered proboscis monkey is higher in an anthropogenically managed forest environment compared to a riparian rain forest in Sabah, Borneo. PLoS One, 13(4), e0195584. https://doi.org/10.1371/journal.pone.0195584

Klein, A., Zimmermann, E., Radespiel, U., Schaarschmidt, F., Springer, A., & Strube, C. (2018). Ectoparasite communities of small-bodied Malagasy primates: Seasonal and socioecological influences on tick, mite and lice infestation of Microcebus murinus and M. ravelobensis in northwestern Madagascar. Parasites and Vectors, 11, 18. https://doi.org/10.1186/s13071-018-3034-y

Klein, A., Strube, C., Radespiel, U., Springer, A., & Zimmermann, E. (2019). Differences in infection patterns of vector-borne blood-stage parasites of sympatric Malagasy primate species (Microcebus murinus, M. ravelobensis). International Journal for Parasitology-Parasites and Wildlife, 10, 59–70. https://doi.org/10.1016/j.ijppaw.2019.07.003

Konerdning, W. S., Brunke, J., Schekha, S., & Zimmermann, E. (2011). Is acoustic evaluation in a non-primate mammal, the tree shrew, affected by context? Animal Cognition, 14(6), 787–795. https://doi.org/10.1007/s10071-011-0411-8

Konerdning, W. S., Hedrich, H. J., Bleich, E., & Zimmermann, E. (2012). Paw preference is not affected by postural demand in a nonprimate mammal (Felis silvestris catus). Journal of Comparative Psychology, 126(1), 15–22. https://doi.org/10.1037/a0024638

Konerdning, W. S., Zimmermann, E., Bleich, E., Hedrich, H. J., & Scheumann, M. (2016). Female cats, but not males, adjust responsiveness to arousal in the voice of kittens. BMC Evolutionary Biology, 16, 157. https://doi.org/10.1186/s12862-016-0718-9

Konerdning, W. S., Zimmermann, E., Bleich, E., Hedrich, H. J., & Scheumann, M. (2017). The head turn paradigm to assess auditory laterality in cats: Influence of ear position and repeated sound presentation. PeerJ, 5, e3925. https://doi.org/10.7717/peerj.3925

Lehman, S. M., & Mercado Malabet, F. (2022). Seasonal variations in lemur edge proximity in South-Eastern Madagascar. International Journal of Primatology. https://doi.org/10.1007/s10764-021-00268-6

Leliveld, L. M. C., Scheumann, M., & Zimmermann, E. (2008). Manual lateralization in early primates: A comparison of two mouse lemur species. American Journal of Physical Anthropology, 137(2), 156–163. https://doi.org/10.1002/ajpa.20852

Leliveld, L. M., Scheumann, M., & Zimmermann, E. (2010). Effects of caller characteristics on auditory laterality in an early primate (Microcebus murinus). Plos One, 5(2), e9031. https://doi.org/10.1371/journal.pone.009031

Leliveld, L. M. C., Scheumann, M., & Zimmermann, E. (2011). Acoustic correlates of individuality in the vocal repertoire of a nocturnal primate (Microcebus murinus). Journal of the Acoustical Society of America, 129(4), 2278–2288. https://doi.org/10.1121/1.3559680

Longondraza, M., Cascella, A., Vadala, L., Valente, D., De Gregorio, C., Torti, V., … Gamba, M. (2022). Marking versus overmarking: Spatial and behavioral patterns of scent marking in wild diademed sifaka (Propithecus diadema). International Journal of Primatology. https://doi.org/10.1007/s10764-022-00292-0

Lutermann, H., Schmelting, B., Radespiel, U., Ehresmann, P., & Zimmermann, E. (2006). The role of survival for the evolution of female philopatry in a solitary forager, the grey mouse lemur (Microcebus murinus). Proceedings of the Royal Society B: Biological Sciences, 273, 2527–2533. https://doi.org/10.1098/rspb.2006.3603

Mahaboubi, S., Randrianambinina, B., Rakotondravony, R., Scheumann, M., Zimmermann, E., & Rasoloharjaona, S. (2015). First characterization of the vocal acoustic of Otto’s sportive lemur Lepilemur otto (Craul et al., 2007) with remarks on its abundance. Lemur News, 19, 16–21 http://www.aeecl.org/lemurnews/lemurnews2015_19.pdf
Maille, A., Jaschke, N., Joly, M., Scheumann, M., Blois-Heulin, C., & Zimmermann, E. (2013). Does a nonprimate mammal, the Northern tree shrew (*Tupaia belangeri*), exhibit paw preference in two forms of a grasping task? *Journal of Comparative Psychology, 127*(1), 14–23. https://doi.org/10.1037/a0029238

Masters, J. C., Rayner, R. J., Ludewick, H., Zimmermann, E., Molez-Verriere, N., Vincent, F., & Nash, L. T. (1994). Phylogenetic relationships among the Galaginae as indicated by erythrocytic allozymes. *Primates, 35*(2), 177–190. https://doi.org/10.1007/Bf02382053

Mendez-Cardenas, M. G., & Zimmermann, E. (2009). Duetting—a mechanism to strengthen pair bonds in a dispersed pair-living primate (*Lepilemur edwardsii*). *American Journal of Physical Anthropology, 139*(4), 523–532. https://doi.org/10.1002/ajpa.21017

Pastorini, J., Martin, R. D., Ehresmann, P., Zimmermann, E., & Forstner, M. R. J. (2001). Molecular phylogeny of the lemur family cheirogaleidae (primates) based on mitochondrial DNA sequences. *Molecular Phylogenetics and Evolution, 19*(1), 45–56.

Radespiel, U., Dal Secco, V., Drögemüller, C., Braune, P., Labes, E., & Zimmermann, E. (2002). Sex -ual selection, multiple mating and paternity in captive mouse lemurs (*Microcebus murinus*). *Animal Behaviour, 63*, 259–268. https://doi.org/10.1006/anbe.2001.0040

Radespiel, U., Ehresmann, P., & Zimmermann, E. (2001a). Dynamics of estrous synchrony in captive gray mouse lemurs (*Microcebus murinus*). *International Journal of Primatology, 22*(1), 71–90. https://doi.org/10.1023/A:1026466015443

Radespiel, U., & Zimmermann, E. (2001b). Female dominance in captive gray mouse lemurs (*Microcebus murinus*). *American Journal of Primatology, 54*(4), 181–192. https://doi.org/10.1002/ajp.1029

Radespiel, U., & Zimmermann, E. (2003). The influence of familiarity, age, experience and female mate choice on pregnancies in captive grey mouse lemurs. *Behaviour, 140*, 301–318. https://doi.org/10.1163/156853903321826648

Radespiel, U., Sarikaya, Z., Zimmermann, E., & Bruford, M. W. (2001). Sociogenetic structure in a free-living nocturnal primate population: Sex-specific differences in the grey mouse lemur (*Microcebus murinus*). *Behavioral Ecology and Sociobiology, 50*(6), 493–502. https://doi.org/10.1007/s002650100402

Radespiel, U., Cepok, S., Zietemann, V., & Zimmermann, E. (1998). Sex-specific usage patterns of sleeping sites in grey mouse lemurs (*Microcebus murinus*) in Northwestern Madagascar. *American Journal of Primatology, 46*(1), 77–84. https://doi.org/10.1002/(SICI)1098-2345(1998)46:1<77::AID-APJ6>3.0.CO;2-S

Radespiel, U., Lutermann, H., Schmelting, B., Bruford, M. W., & Zimmermann, E. (2003a). Species-specific usage of sleeping sites in two sympatric mouse lemur species (*Microcebus murinus* and *M. ravelobensis*) in northwestern Madagascar. *American Journal of Primatology, 59*(4), 139–151. https://doi.org/10.1002/ajp.10071

Radespiel, U., Butynski, T. M. (2013). Galago senegalensis Northern lesser galago (Senegal lesser galago, Senegal lesser bushbaby). In T. M. Butynski, J. Kingdon, & J. Kalina (Eds.), *Mammals of Africa. Vol. II. Primates* (pp. 425–429). Bloomsbury Publishing.

Radespiel, U., & Zimmermann, E. (2001a). Dynamics of estrous synchrony in captive gray mouse lemurs (*Microcebus murinus*). *International Journal of Primatology, 22*(1), 71–90. https://doi.org/10.1023/A:1026466015443

Radespiel, U., & Zimmermann, E. (2001b). Female dominance in captive gray mouse lemurs (*Microcebus murinus*). *American Journal of Primatology, 54*(4), 181–192. https://doi.org/10.1002/ajp.1029

Radespiel, U., & Zimmermann, E. (2003). The influence of familiarity, age, experience and female mate choice on pregnancies in captive grey mouse lemurs. *Behaviour, 140*, 301–318. https://doi.org/10.1163/156853903321826648

Radespiel, U., Dal Secco, V., Drögemüller, C., Braune, P., Labes, E., & Zimmermann, E. (2002). Sexual selection, multiple mating and paternity in grey mouse lemurs, *Microcebus murinus*. *Animal Behaviour, 63*, 259–268. https://doi.org/10.1006/anbe.2001.1924

Radespiel, U., Ehresmann, P., & Zimmermann, E. (2003a). Species-specific usage of sleeping sites in two sympatric mouse lemur species (*Microcebus murinus* and *M. ravelobensis*) in northwestern Madagascar. *American Journal of Primatology, 59*(4), 139–151. https://doi.org/10.1002/ajp.10071
Radespiel, U., Jurić, M., & Zimmermann, E. (2009). Sociogenetic structures, dispersals, and the risk of inbreeding in a small nocturnal lemur, the golden-brown mouse lemur (Microcebus ravelobensis). *Behaviour, 146*(4-5), 607–628. https://doi.org/10.1163/156853909X42637Z

Radespiel, U., Scheumann, M., & Schmidtke, D. (2019). Prof. Dr. rer. nat. Elke Zimmermann. *International Journal of Primatology, 40*(6), 589–591. https://doi.org/10.1002/ajp.20108-8

Radespiel, U., Rakotondravony, R., Rasoloharjaona, S., & Randrianambinina, B. (2021). A 24-Year record of female reproductive dynamics in two sympatric mouse lemur species in Northwestern Madagascar. *International Journal of Primatology. https://doi.org/10.1007/s10764-021-00261-z*

Rakotoarison, N., Zimmermann, H., & Zimmermann, E. (1997). First discovery of the hairy-eared dwarf lemur (Allocebus trichotis) in a highland rain forest of eastern Madagascar. *Folia Primatologica, 68*(2), 86–94. https://doi.org/10.1159/000157235

Ramanankirahina, R., Joly, M., & Zimmermann, E. (2016). The role of acoustic signaling for spacing and group coordination in a nocturnal, pair-living primate, the western woolly lemur (Avahi occidentalis). *American Journal of Physical Anthropology, 159*(3), 466–477. https://doi.org/10.1002/ajpa.22898

Randrianambinina, B., Rakotondravony, D., Radespiel, U., & Zimmermann, E. (2003a). Seasonal changes in general activity, body mass and reproduction of two small nocturnal primates: A comparison of the golden brown mouse lemur (Microcebus ravelobensis) in Northwestern Madagascar and the brown mouse lemur (Microcebus rufus) in Eastern Madagascar. *Primates, 44*(4), 321–331. https://doi.org/10.1007/s10329-003-0046-8

Randrianambinina, B., Rasoloharjaona, S., Rakotosamimanana, B., & Zimmermann, E. (2003b). Inventaires des communautés lémuriennes dans la réserve spéciale de Bora au nord-ouest et la forêt dominanle de Mahilaka-Maromandia au nord de Madagascar. *Lemur News, 8*, 15–18.

Randrianambinina, B., Mbotizafy, S., Rasoloharjaona, S., Ravoahangimalalaa, R. O., & Zimmermann, E. (2007). Seasonality in reproduction of Lepilemur edwardsi. *International Journal of Primatology, 28*(4), 783–790. https://doi.org/10.1007/s10764-007-9158-0

Randrianambinina, B., Rasoloharjaona, S., Rakotondravony, R., Zimmermann, E., & Radespiel, U. (2010). Abundance and conservation status of two newly described lemur species in northwestern Madagascar (Microcebus danfossi, Lepilemur grewcockorum). *Madagascar Conservation & Development, 5*(2), 95–102 http://www.mwc-info.net/en/services/Journal_PDFs/Issue5-2/MCD_2010_vol5_iss2_lemurs.pdf

Randrianarison, R. M., Lutz, M., Torti, V., Tan, C., Bonadonna, G., Randrianambinina, B., ..., Giacomina, C. (2022). Feeding ecology and regurgitation-reingestion behavior of the critically endangered *Indri indri* in the Maroamizaha Protected Area, eastern Madagascar. *International Journal of Primatology.*

Rasoloharjaona, S., Rakotosamimanana, B., & Zimmermann, E. (2000). Infanticide by a male Milne-Edwards’ sportive lemur (Lepilemur edwardsi) in Ampijoroa, NW-Madagascar. *International Journal of Primatology, 21*(1), 41–45. https://doi.org/10.1023/A:1005419528718

Rasoloharjaona, S., Rakotosamimanana, B., Randrianambinina, B., & Zimmermann, E. (2003). Pair-specific usage of sleeping sites and their implications for social organization in a nocturnal Malagasy primate, the Milne Edwards’ sportive lemur (Lepilemur edwardsi). *American Journal of Physical Anthropology, 122*(3), 251–258.

Rasoloharjaona, S., Randrianambinina, B., Rakotosamimanana, B., & Zimmermann, E. (2005). Inventaires des lémuriens dans la forêt d’Andranovelona / Madirovalo (nord ouest de Madagascar), les “savoka” de Manehoko, la réserve de Lokobe, la réserve spéciale de l’Ankarana, et la réserve spéciale d’Analamerana, au nord de Madagascar. *Lemur News, 10*, 8–11.

Rasoloharjaona, S., Randrianambinina, B., Braune, P., & Zimmermann, E. (2006). Loud calling, spacing, and cohesiveness in a nocturnal primate, the Milne Edwards’ sportive lemur (Lepilemur edwardsi). *American Journal of Physical Anthropology, 129*(4), 591–600. https://doi.org/10.1002/ajpa.20342

Rasoloharjaona, S., Randrianambinina, B., & Zimmermann, E. (2008). Sleeping site ecology in a rainforest dwelling nocturnal lemur (Lepilemur mustelinus): Implications for sociality and conservation. *American Journal of Primatology, 70*(3), 247–253. https://doi.org/10.1002/ajpa.20487
Schmidtke, D., Ammersdorfer, S., Joly, M., & Zimmermann, E. (2018a). First comparative approach to touchscreen-based visual object-location paired-associates learning in humans (Homo sapiens) and a nonhuman primate (Microcebus murinus). Journal of Comparative Psychology, 132(3), 315–325. https://doi.org/10.1037/com0000116

Schmidtke, D., Lempp, C., Dubicanac, M., Radespiel, U., Zimmermann, E., Baumgartner, W., ... Rogers, J. (2018b). Spontaneous spongiform brainstem degeneration in a young mouse lemur (Microcebus murinus) with conspicuous behavioral, motor, growth, and ocular pathologies. Comparative Medicine, 68(6), 489–495. https://doi.org/10.30802/AALAS-CM-18-000019

Schmidtke, D., Zimmermann, E., Trouche, S. G., Fontes, P., Verdier, J. M., & Mestre-Frances, N. (2020). Linking cognition to age and amyloid-beta burden in the brain of a nonhuman primate (Microcebus murinus). Neurobiology of Aging, 94, 207–216. https://doi.org/10.1016/j.neurobiaging.2020.03.025

Schopf, C., Zimmermann, E., Tunsmeyer, J., Kastner, S. B. R., Hubka, P., & Kral, A. (2014). Hearing and age-related changes in the gray mouse lemur. Jaro-Journal of the Association for Research in Otolaryngology, 15(6), 993–1005. https://doi.org/10.1007/s10162-014-0478-4

Schopf, C., Schmidt, S., & Zimmermann, E. (2016). Moderate evidence for a Lombard effect in a phylogenetically basal primate. Peerj, 4, e2328. https://doi.org/10.7717/peerj.2328

Schulze, H., Benirschke, K., Doyle, G. A., Johann, A., Meier, B., Wirth, R., & Zimmermann, E. (1998). A ‘checklist’ of possible items for prosimian husbandry manuals and research. Folia Primatologica, 69(Suppl.1), 152–170. https://doi.org/10.1159/000052709

Steffens, T. S., Ramsay, M. S., Andriatsitohaina, B., Cosby, A. E., Lehman, S. M., Rakotondravony, R., ... Radespiel, U. (2022). Shifting biogeographic patterns of Microcebus ravelobensis and M. murinus. International Journal of Primatology. https://doi.org/10.1007/s10764-022-00287-x
Zimmermann, E. (1989a). Aspects of reproduction and behavioral and vocal development in Senegal bushbabies (Galago senegalensis). *International Journal of Primatology, 10*(1), 1–16. https://doi.org/10.1007/BF02735700

Zimmermann, E. (1989b). Reproduction, physical growth and behavioral development in slow loris (Nycticebus coucang, Lorisidae). *Human Evolution, 4*(2-3), 171–179.

Zimmermann, E. (1990a). Behavioral signals and reproduction modes in the neotropical frog family Dendrobatidae. In W. Hanke (Ed.), *Fortschritte der Zoologie, Vol. 38: Biology and physiology of amphibians* (pp. 61–73). Gustav Fischer Verlag.

Zimmermann, E. (1990b). Differentiation of vocalizations in bushbabies (Galaginae, Prosimiae, Primates) and the significance for assessing phylogenetic relationships. *Zeitschrift für Zoologische Systematik und Evolutionsforschung, 28*(3), 217–239. https://doi.org/10.1111/j.1439-0469.1990.tb00377.x

Zimmermann, E. (1991). Ontogeny of acoustic communication in prosimian primates. In A. Ebara, O. Takenaka, & M. Iwamoto (Eds.), *Primate today* (pp. 337–340). Elsevier.

Zimmermann, E. (1992). Vocal communication by non-human primates. In S. Jones, R. Martin, & D. Pilbeam (Eds.), *The Cambridge encyclopedia of human evolution* (pp. 124–127). Cambridge University Press.

Zimmermann, E. (1993). Behavioral measures of auditory-thresholds in developing tree shrews (Tupaia belangeri). *Journal of the Acoustical Society of America, 94*(6), 3071–3075. https://doi.org/10.1121/1.407268

Zimmermann, A. (1995). Artificial neural networks for analysis and recognition of primate vocal communication. In E. Zimmermann, J. D. Newman, & U. Jürgens (Eds.), *Current topics in primate vocal communication* (pp. 29–46). Springer. https://doi.org/10.1007/978-1-4757-9930-9_2

Zimmermann, E. (1995a). Acoustic communication in nocturnal prosimians. In L. Alterman, G. A. Doyle, & M. K. Izard (Eds.), *Creatures of the dark: The nocturnal prosimians* (pp. 311–330). Plenum Press.

Zimmermann, E. (1996). Castration affects the emission of an ultrasonic vocalization in a nocturnal primate, the grey mouse lemur (*Microcebus murinus*). *Physiology & Behavior, 60*(3), 693–697. http://www.sciencedirect.com/science/article/pii/003193849681674X

Zimmermann, E. (1998). *Waldgeister der Tropen - die nachaktiven Lemuren Madagaskars*. Biologie in unserer Zeit, 28, 294–303.

Zimmermann, E. (2001). *Dialects in lemurs*. In D. Macdonald (Ed.), *The new encyclopaedia of mammals* (p. 319). Oxford University Press.

Zimmermann, E. (2010). *Vocal expression of emotion in a nocturnal prosimian primate group, mouse lemurs*. In S. M. Brudzynski (Ed.), *Handbook of mammalian vocalization: An integrative neuroscience approach* (pp. 215–225). Academic Press http://www.elsevier.com/wps/find/bookdescription.cws_home/719106/description#description

Zimmermann, E. (2013). Primate serenades: Call variation, species diversity, and adaptation in nocturnal strepsirhines. In J. Masters, M. Gamba, & F. Génin (Eds.), *Leaping ahead: Advances in prosimian biology* (pp. 287–295). Springer. https://doi.org/10.1007/978-1-4614-4511-1_32

Zimmermann, E. (2016). Acoustic divergence in communication of cheirogaleids with special emphasis to mouse lemurs. In S. M. Lehman, U. Radespiel, & E. Zimmermann (Eds.), *The Dwarf and Mouse Lemurs of Madagascar: Biology, Behavior and Conservation Biogeography of the Cheirogaleidae* (pp. 405–421). Cambridge University Press. https://doi.org/10.1017/CBO9781139871822.022

Zimmermann, E. (2017). Evolutionary origins of primate vocal communication: Diversity, flexibility, and complexity of vocalizations in basal primates. Springer, Cham, 2017. 109-140. In R. Quam, M. Ramsier, R. Fay, & A. Popper (Eds.), *Primate hearing and communication. Springer Handbook of Auditory Research* (Vol. 63, pp. 109–140). Springer.

Zimmermann, E. (2018). High frequency/ultrasonic Communication in Basal Primates, the Mouse and Dwarf Lemurs of Madagascar. In S. M. Brudzynski (Ed.), *Handbook of ultrasonic vocalization: A window into the emotional brain* (Vol. 25, pp. 521–533). Academic Press. https://doi.org/10.1016/B978-0-12-809600-0.00048-2

Zimmermann, E., & Hafen, T. G. (2001). Colony specificity in a social call of mouse lemurs (*Microcebus ssp.*). *American Journal of Primatology, 54*(3), 129–141. https://doi.org/10.1002/ajp.1018
Zimmermann, E., & Lerch, C. (1993). The complex acoustic design of an advertisement call in male mouse lemurs (Microcebus murinus, Prosimii, Primates) and sources of its variation. Ethology, 93, 211–224.

Zimmermann, E., & Radespiel, U. (2013). Primate life histories. In W. Henke & I. Tattersal (Eds.), Handbook of paleoanthropology (pp. 1–58). Springer. https://doi.org/10.1007/978-3-642-27800-6_38-7

Zimmermann, E., & Radespiel, U. (2014). Species concepts, diversity, and evolution in primates: Lessons to be learned from mouse lemurs. Evolutionary Anthropology, 23(1), 11–14. https://doi.org/10.1002/evan.21388

Zimmermann, E., & Rahmann, H. (1985). Acoustic key stimulus alters H-3 2-deoxyglucose uptake in the brain of the frog Phyllobates tricolor. Naturwissenschaften, 72(10), 543–545. https://doi.org/10.1007/Bf00367604

Zimmermann, E., & Rahmann, H. (1987). Acoustic communication in the poison-arrow frog Phyllobates tricolor - Advertisement calls and their effects on behavior and metabolic brain activity of recipients. Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology, 160(5), 693–702. https://doi.org/10.1007/Bf00619414

Zimmermann, H., & Zimmermann, E. (1977). Unsere Kleinaffen: Plumploris, Totenköpfchen, Zwergmeerkatzen. Aquarien Magazin, 8, 328–339.

Zimmermann, H., & Zimmermann, E. (1980). Durch Nachzucht erhalten: Der Baumsteiger Dendrobates leucomelas. Aquarien Magazin, 5, 211–217.

Zimmermann, H., & Zimmermann, E. (1981). Sozialverhalten, Fortpflanzungsverhalten und Zucht der Färberfrösche (Dendrobates histrionicus und D. lehmanni) sowie einiger anderer Dendrobatiden. Aquarien Magazin, 3, 83–99.

Zimmermann, H., & Zimmermann, E. (1985). Zur Fortpflanzungsstrategie des Pfeilgiftfrosches Phyllobates terribilis Myers, Daly & Malkin, 1978 (Salientia: Dendrobatidae). Salamandra, 21(4), 281–297.

Zimmermann, H., & Zimmermann, E. (1987). Mindestanforderungen für eine artgerechte Haltung einiger tropischer Anurenarten. Zeitschrift des Kölner Zoos, 30(2), 61–71.

Zimmermann, H., & Zimmermann, E. (1988a). Etho-Taxonomie und zoogeographische Artengruppenbildung bei Pfeilgiftfröschen (Anura: Dendrobatidae). Salamandra, 24, 125–160.

Zimmermann, H., & Zimmermann, E. (1988b). Zucht und Artenerhaltung von Anuren am Beispiel der Pfeilgiftfrösche (Dendrobatidae). In H. G. Horn (Ed.), Erfolge und Probleme bei der Zucht von Wildtieren in menschlicher Obhut (pp. 133–148). BNA.

Zimmermann, E., & Zimmermann, H. (1994). Reproductive strategies, breeding and conservation of tropical frogs: Dart-poison frogs and Malagasy poison frogs. In J. B. Murphy, K. Adler, & J. T. Collins (Eds.), Captive management and conservation of amphibians and reptiles: Contributions to herpetology (pp. 255–266). SSAR Publ.

Zimmermann, E., Zimmermann, P., & Zimmermann, A. (1979). Soziale Kommunikation bei Plumploris (Nycticebus coucang). Zeitschrift des Kölner Zoos, 22, 25–36.

Zimmermann, E., Zimmermann, P., & Zimmermann, A. (1980). Vergleich einiger Kommunikationsformen fünf nonhumaner Primatenarten (Galago senegalensis, Nycticebus coucang, Callithrix jacchus, Saimiri sciureus, Miopithecus talapoin). Zeitschrift des Kölner Zoos, 23(1), 3–20.

Zimmermann, E., Bearder, S. K., Doyle, G. A., & Andersson, A. (1988). Variations in vocal patterns of Senegal and South African lesser bushbabys and their implications for taxonomic relationships. Folia Primatologica, 51, 87–105.

Zimmermann, H., Zimmermann, E., & Zimmermann, P. (1990). Feldstudien im Biotop vom Goldfröschchen, Mantella aurantiaca, im tropischen Regenwald Ost-Madagaskars. Herpetofauna, 12(64), 21–24.

Zimmermann, E., Cepok, S., Rakotoarison, N., Ziemann, V., & Radespiel, U. (1998). Sympatric mouse lemurs in north-west Madagascar: A new rufous mouse lemur species (Microcebus ravelobensis). Folia Primatologica, 69(2), 106–114. https://doi.org/10.1159/000021571

Zimmermann, E., Masters, J., & Rumpler, Y. (2000a). Introduction to diversity and speciation in the Prosimii. International Journal of Primatology, 21(5), 789–791. https://doi.org/10.1023/A:1005553408094

Zimmermann, E., Vorobieva, E., Wrogemann, D., & Hafen, T. (2000b). Use of vocal fingerprinting for specific discrimination of gray (Microcebus murinus) and rufous mouse lemurs (Microcebus rufus). International Journal of Primatology, 21(5), 837–852. https://doi.org/10.1023/A:1005594625841
Zimmermann, E., Radespiel, U., Mestre-Francés, N., & Verdier, J.-M. (2016). Life history variation in mouse lemurs (*Microcebus murinus, M. lehilahytsara*): The effect of environmental and phylogenetic determinants. In S. M. Lehman, U. Radespiel, & E. Zimmermann (Eds.), *The dwarf and mouse lemurs of Madagascar: Biology, behavior and conservation biogeography of the cheirogaleidae* (pp. 174–194). Cambridge University Press.