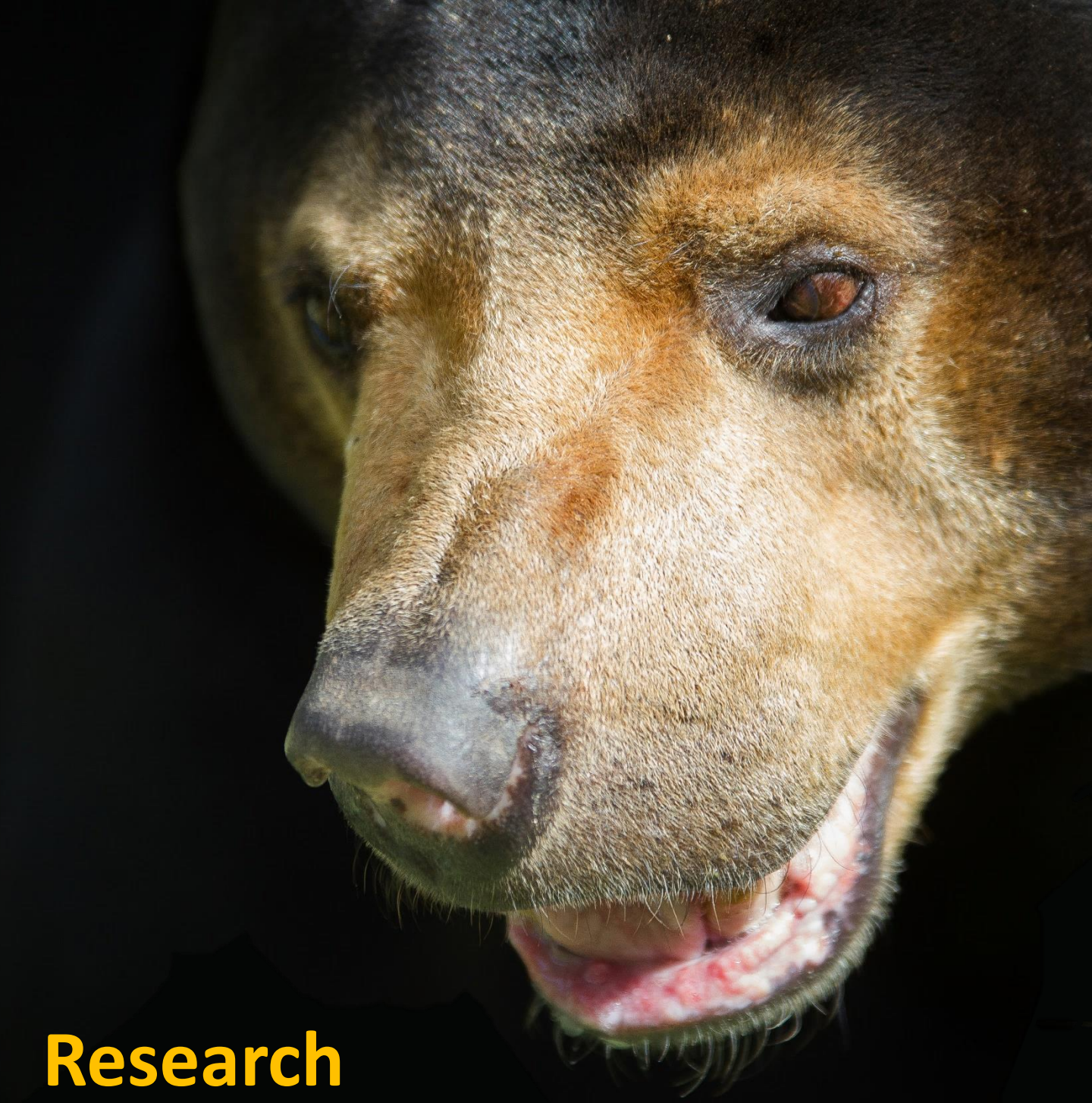

Research Prospectus:

Priority topics for *ex situ* sun bear conservation research

Edition: May 2020

OUWEHANDS ZOO FOUNDATION

IUCN SSC Species Survival Commission

Bear Specialist Group

FREE THE BEARS

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Free the Bears
Free the Bears is an international animal welfare and wildlife conservation charity headquartered in Australia. Free the Bears works with governments and non–governmental partners to build, manage and sustain bear sanctuaries and field programmes aimed at ending the suffering of captive bears whilst protecting wild bears across Southeast Asia through conservation education and research. As part of its mission to protect, preserve and enrich the lives of bears throughout the world, Free the Bears has supported the rescue of over 900 bears and currently provides care for over 200 bears in Southeast Asia, including 90 rescued sun bears in the Cambodian Bear Sanctuary, the world's largest sanctuary for sun bears.

www.freethebears.org

IUCN SSC Bear Specialist Group
The IUCN SSC Bear Specialist Group (BSG) is one of more than 140 Specialist Groups established by the Species Survival Commission (SSC), within the International Union for the Conservation of Nature (IUCN). The goal of the BSG is to promote the conservation of bears and their natural habitats across their distribution worldwide. The BSG is comprised of ~180 members including professional biologists and conservationists from governments, non-governmental organisations, universities, museums, zoos and other captive facilities. The BSG is not an advocacy or animal welfare organisation. The purpose of the BSG is to pursue science-based conservation of bears.

www.globalbearconservation.org

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Front and back cover photo credits: Free the Bears / Peter Yuen

CONTENTS

ABBREVIATIONS

AZA	Association of Zoos and Aquariums, North America
DNA	Deoxyribonucleic acid
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPSG	Conservation Planning Specialist Group
EAZA	European Association of Zoos and Aquaria
eDNA	Environmental DNA
GC/MS	Gas Chromatography Mass Spectrometry
iDNA	Invertebrate-derived DNA
IUCN	International Union for Conservation of Nature
JAZA	Japanese Association of Zoos and Aquariums
KWPLH	Kawasan Wisata Pendidikan Lingkungan Hidup
mtDNA	Mitochondrial DNA
SEAZA	Southeast Asian Zoos and Aquariums Association
SSC	Species Survival Commission
TCM	Traditional Chinese Medicine
TM	Traditional Medicine
UDCA	Ursodeoxycholic acid
ZAA	The Zoo and Aquarium Association, Australasia
ZIMS	Zoological Information Management Software

FOREWORD

Bears are a small taxonomic family (Ursidae), composed of only eight species; yet these species range from virtually the north pole to the tropics, occupying a vast diversity of habitats that include deserts, alpine grasslands, scrub, boreal and hardwood forests, and dense jungles. Despite their success in adapting to such an array of habitats, 75% of bear species are globally threatened on the IUCN Red List. Among mammalian families with eight or more species, only four have a higher percentage that are globally threatened (Schipper et al. 2008).

Exacerbating this growing threat to bears is a gap in the knowledge needed to facilitate their recovery and protection. Ironically, bears are among the best-known families of Carnivora, based on number of scientific publications per species (Brooke et al. 2014). But this statistic is deceiving, as publications are very lopsided: >80% of papers focused on brown bears (*Ursus arctos*), American black bears (*U. americanus*) and polar bears (*U. maritimus*), and in fact these three species are among the 20 most–studied carnivores in the world (Brooke et al. 2014). By sharp contrast, bears in the tropics – the very place where threats are greatest and most rapidly proliferating – have been the subject of the fewest scientific inquiries.

This was not always the case. During the 1800s, when science was in its infancy, natural history aficionados and collectors joined exploratory expeditions around the world, often in tropical regions where biodiversity was high. However, for a variety of reasons, modern wildlife studies became tilted largely to northern species, so that now, among bears, the disparity between north and south has become extreme in terms of effort, funding, capacity of researchers, and knowledge (Garshelis and Steinmetz 2015).

The sun bear (*Helarctos malayanus*), whose range is almost wholly within the tropics, may be the least studied bear species, as well as one of the most threatened. Recognizing the desperate need for conservation–integrated research on this species, the IUCN SSC Bear Specialist Group helped develop a 10–year conservation action plan for sun bears (Crudge et al. 2019). A remarkable highlight of this plan is the value and role of *ex situ* populations of sun bears in the conservation of wild bears.

There are many hindrances to understanding and thereby effectively conserving populations of wild sun bears. Some basic field techniques have not been worked out, and it is often not fruitful to conduct experiments in the field. *Ex situ* bears offer a solution, enabling experimentation in a controlled environment, with subjects that can be repeatedly observed, examined, and tested. Thus, results can be nearly field–ready, reducing the chance of failures when applied in the forest and increasing the chance that field results will be properly interpreted.

This prospectus of research concepts for *ex situ* sun bears is a valuable compendium of ideas that arose from a collaboration of researchers from the *ex situ* and *in situ* communities. It is a broad road map of practical avenues of research for better understanding sun bears. Given the greatly limited resources available for sun bear research, collaboration and coordination are essential. This prospectus provides focus and direction to ensure that sun bear research activities are effectively and efficiently aimed toward improved conservation of this species.
I encourage researchers and institutes interested in sun bear conservation, as well as facilities throughout the world that provide care to sun bears, to carefully examine this prospectus and collaborate on implementing the research activities that could help reverse the decline of this species

David Garshelis, PhD
Co–chair Bear Specialist Group

EX SITU RESEARCH PROSPECTUS

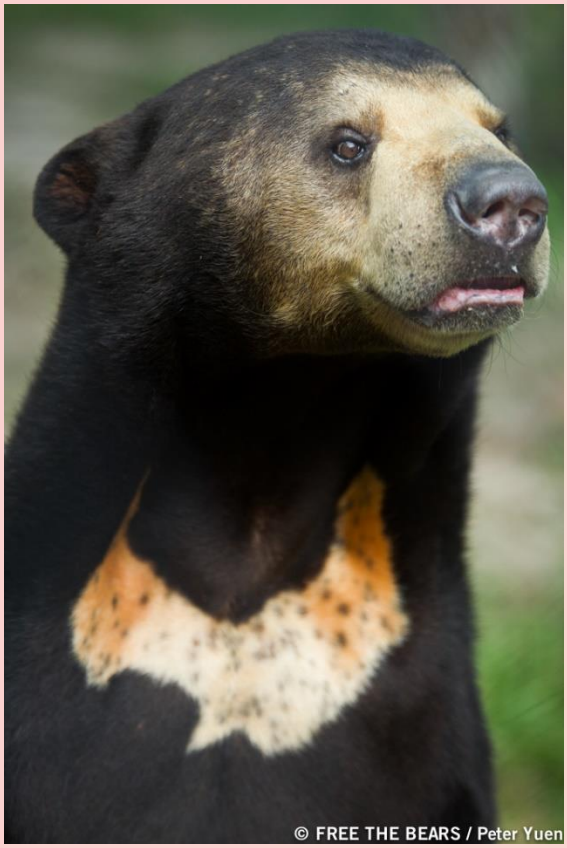
This Research Prospectus provides practical guidance on priority *ex situ* research projects capable of benefitting *in situ* species conservation. The prospectus is divided according to the research themes: Field Techniques; Behaviour; Physiology and Metabolism; Nutrition; Veterinary Health and Disease; Genetics; Forensics. A synopsis is included for each priority research project, describing the rationale, objective and potential methods.

The prospectus seeks to improve the quality and quantity of conservation directed research conducted using *ex situ* sun bears, a priority objective identified in the Sun Bear Action Plan for the long–term conservation of the Malayan sun bear. While it is recognised that priorities and feasibility will vary, the prospectus is intended to guide *ex situ* research efforts and establish new collaborations between *ex situ* facilities, universities and research institutes.

The following research questions are addressed to anyone who would like to contribute to sun bear conservation by *ex situ* research and to build a formal network of academic institutions and captive care facilities collaborating on applied research programmes to improve collaboration and effectiveness, reduce unnecessary duplication and address agreed priorities.

If you wish to contribute to this endeavour, have any questions on specific research topics, seek to get in touch with other researchers or institutions, are conducting any research or have any existing data on *ex situ* sun bears, or need access to literature, please contact Dr. Marion Schneider, *Ex situ* Management Focal Point, Sun Bear Conservation Plan Implementation Task Force: mfschneider@gmx.de.

It is envisaged that this prospectus will be updated on a regular basis as research questions are addressed and new methodologies emerge. As such, new research suggestions are being accepted on an ongoing basis and will be reviewed periodically. Topics of interest include: *ex situ* research that may benefit sun bear conservation; *in situ* research that may benefit *ex situ* sun bear welfare; and *ex situ* research with other species that may benefit sun bear conservation or welfare. If you have a research topic that you would like to submit for inclusion in the next edition of this prospectus, please complete the form in Annex 1 and send it by email to mfschneider@gmx.de.



Background

The Sun Bear Conservation Action Plan, 2019–2028 (Crudge et al. 2019), identifies as a priority objective, improving the quality and quantity of conservation directed research conducted using *ex situ* sun bears. As the first step in this process, an online survey was developed, asking *ex situ* facilities with sun bears, researchers, conservationists, *in situ* and *ex situ* bear specialists, to provide suggestions for possible research questions that can be addressed with *ex situ* sun bears for the benefit of species conservation. A workshop was held with the objective to identify, assess the feasibility of, and define criteria with which to prioritize conservation directed research needs for sun bear conservation. The results of the survey, the consultation workshop and the feedback of the sun bear community, as well as a literature review, were used to create this prospectus of priority conservation related research projects. Each project contains a synopsis, describing the rationale, objective, methods and potential conservation outcome. The prospectus is addressed to individuals and institutions interested in conducting conservation related research on captive sun bears.

Malayan sun bears

Malayan sun bears are threatened throughout their range by habitat loss and hunting. They are listed as Vulnerable on the IUCN Red List (Scotson et al. 2017). Populations are estimated to have declined by 30% over the past 30 years and are predicted to continue to decline unless abated by conservation interventions. The long–term survival of sun bears in the wild is dependent upon conservation interventions which have to be based on sound science in order to be effective. At present, sun bear conservation is, by necessity, based on sparse data and incomplete knowledge. Research of both *in situ* and *ex situ* sun bears is required in order to advance scientific knowledge and improve conservation effectiveness.

Ex situ research

Sun bear populations are kept in *ex situ* facilities such as zoos, recognised sanctuaries, wildlife rescue centres or similar facilities in their natural range states as well as in zoos around the world. These animals make up a significant population of at least 350 individuals, many of which are wild–born. This offers a valuable resource for *ex situ* research, due to ease of access and controllable environments, which is capable of benefitting *in situ* conservation of sun bears. However, a coordinated effort is required in order to fulfil the potential conservation value of *ex situ* research on this species.

Sun Bear Conservation Action Plan 2019–2028

The Sun Bear Global Status Review & Conservation Action Plan, which is the first international action plan for a terrestrial bear species, was launched in June 2019 in collaboration between Free the Bears, TRAFFIC Southeast Asia, the IUCN Species Survival Commission (SSC) Bear Specialist Group and the IUCN SSC Conservation Planning Specialist Group. The plan originated from the 1st International Symposium on Sun Bear Conservation & Management held in Kuala Lumpur, Malaysia, in September 2017. It includes the most extensive status review of the species and lays out conservation priorities to be addressed over the next 10 years. Specific experts are listed as focal points for range countries, and for various conservation actions. The Action Plan recommends that conservation directed research needs should be identified and prioritised in order to fulfil the objective of improving the quality and quantity of research efforts conducted using *ex situ* sun bears (Crudge et al. 2019).

Table 1. Demographics of the *ex situ* sun bear populations managed by regional zoo associations and organisations in range states (adapted from Crudge et al. 2019).

INSTITUTION	MALES	FEMALES	UNKNOWN	TOTAL
EAZA	13	25	0	38
AZA	10	16	0	26
ZAA	5	5	0	10
JAZA	12	13	0	25
SEAZA zoos in ZIMS	27	25	1	53
Cat Tien Bear Sanctuary, Vietnam (Free the Bears)	4	6	0	10
Cambodian Bear Sanctuary, Phnom Tamao Wildlife Rescue Centre, Cambodia (Free the Bears)	29	58	0	87
Vietnam Bear Rescue Centre, Vietnam (Animals Asia)	5	6	0	11
Bornean Sun Bear Conservation Centre, Malaysia	No data	No data	No data	44
KWPLH, East Kalimantan, Indonesia	4	2	0	6
Wildlife Friends Foundation Wildlife Rescue Centre, Petchaburi, Thailand	6	15	0	21
Samboja Lestari Sun Bear Sanctuary, East Kalimantan, Indonesia	No data	No data	No data	45
TOTAL				**374**

Prioritisation process of conservation relevant research topics

In order to contribute towards this objective, a systematic literature review has been conducted to determine the scope and outcomes of past and current sun bear research projects to provide a baseline from which to identify relevant research gaps.

The assessment and prioritisation of conservation directed research needs have been addressed through a collaborative process. An online survey was created and distributed throughout the sun bear community, including the IUCN SSC Bear Specialist Group, the sun bear population managers of EAZA, AZA and ZAA, as well as individual *in situ* and *ex situ* sun bear researchers and institutions in order to collate information on previous and ongoing research that has not been published. In addition, experts were asked to propose potential conservation related research questions and to define priority research activities for the conservation of sun bears. The online survey revealed approximately 80 potential research questions from 50 survey participants. Topics included behaviour, breeding and reproduction, diet and nutrition, field techniques, forensics, genetics, physiology and metabolism, and veterinary health and disease.

A consultation workshop was held in June 2019 at Burgers' Zoo, Arnhem, Netherlands, where a group of six key experts attended the workshop in person, and nine experts joined the workshop via skype sessions in order to reduce the need for international travel and thereby CO_2 emissions. During this workshop, all submitted research ideas were discussed and processed with respect to urgency, feasibility and conservation outcome. As a first step, participants discussed and decided which research questions shall be included for further prioritisation, with the main focus on *ex situ* research that benefits sun bear conservation. Some overlapping topics have been combined, others have been excluded due to lack of feasibility or because they did not fall within the scope of this project.

A total of 23 potential research questions have been selected and a comprehensive spreadsheet has been developed, providing details on methods and study design for each topic. Sun bears are the least studied bear species and have been the focus of few field studies. Evaluating the long-term impact of conservation interventions on the status of wild populations will require effective monitoring of this rare and elusive species. It is not surprising therefore that half of the potential research questions are focused on field techniques. Conversely, no topics were suggested under the themes of conservation education or visitor studies, although it is recognised that these can be important roles of *ex situ* populations.

In order to prioritise the research needs with regards to urgency, feasibility and conservation outcome, an overview of the identified projects was presented to a wider audience of *in situ* experts during the 2nd International Symposium on Sun Bear Conservation & Management in Kota Kinabalu, Sabah, Malaysian Borneo, in September 2019. Participants were asked to review the selected research topics and provide their feedback. The list of the selected projects was sent to *in situ* experts who couldn't attend the symposium, and who selected five high priority projects. The results of the review, the consultation workshop and the feedback of the sun bear community were used to create this research prospectus of priority conservation related research projects.

Priority topics for *ex situ* sun bear conservation research

FIELD TECHNIQUES
BEHAVIOUR
NUTRITION
HEALTH & DISEASE
PHYSIOLOGY & METABOLISM
FORENSICS/GENETICS

1. Test eDNA methods to detect wild bears

Specific research question:

What is the sensitivity of eDNA methods to detect wild sun bears?

Synopsis:

Methods to reliably monitor sun bear population trends are essential to assess the effects of threats, or of conservation actions designed to reduce threats. At present, monitoring of sun bear populations is almost nonexistent. Thus far, successfully applied methods to survey sun bear populations are bear sign transects, camera trapping and villager interviews. Many field techniques used for other bear species have shown limited success with sun bears because they are difficult to radio–collar, and no reliable technique has yet been developed to trap their short hair for DNA–based population estimates. Environmental DNA (eDNA) barcoding is a new research field within molecular ecology, which offers a non–invasive means to identify species associated with the environment from which the DNA was extracted, with comparable success to conventional methods. Unlike traditional assessment methods, where captured or recorded individuals are used to determine presence or abundance, eDNA-based biodiversity assessment relies on the ability to capture the genetic signature left behind by organisms through shedding, excreting, or decaying. eDNA extracted from water samples is relatively short lived (days), compared to soil or ice (years), which makes water eDNA a reliable method to detect the presence of a recently present species. The transport range of eDNA is extensive in rivers, with signals detectable over several kilometers. By testing eDNA samples at various distances downstream from a naturalistic sun bear enclosure and subsequent genetic analysis, the sensitivity for detection of sun bear presence can be determined. These insights could subsequently be applied to measurements obtained from ponds and rivers in natural environments to determine the probability and range for species detection in their natural habitat. eDNA barcoding could greatly enhance monitoring of priority and difficult to survey species such as sun bears.

Impact:

Provided the method is effective, eDNA barcoding provides an additional non–invasive tool for the detection of wild sun bears.

Potential study sites:

Facilities with flowing water such as creeks or rivers running through the enclosures, e.g. Tat Kuang Si Bear Rescue Centre, Free the Bears, Laos; KWPLH Balikpapan, Kalimantan, Borneo.

Duration:

Over different seasons.

Further reading:

(Taberlet et al. 2012, Ishige et al. 2017, Ushio et al. 2017, Harper et al. 2019, Sales et al. 2019, Seymour 2019)

2. Olfactory and auditory attractants / deterrents

Specific research question:

Which olfactory and auditory stimuli can be used to attract or deter sun bears?

Synopsis:

Baits and scent lures are frequently applied in the field in order to improve detections of bears by camera trapping or hair collection for genetic analysis. Conversely, scents and sounds can be effective stimuli to deter bears from cropping areas and other human settings and thus reduce human–bear conflicts. Smell is considered to be the fundamental and most important sense for ursids. Several scents and sounds are reported to be effective in attracting or repelling bears. However, reactions might vary over time, depend on species, sex, or age, and habituation might occur quickly. The use of captive animals provides an excellent opportunity for identifying a number of olfactory and auditory stimuli in a relatively short time. In order to determine the effectiveness of different scents and sounds to attract or deter sun bears, both adult and juvenile bears from both sexes shall be observed by behavioural sampling using a standardised working ethogram. The most effective methods shall be tested for several consecutive weeks to assess if and when habituation occurs.

Impact:

Attractants might improve the efficacy of camera– or hair trapping surveys. Deterrents offer inexpensive and easily applicable methods to keep bears away from crops and reduce retaliatory killing due to human–bear conflict which is anticipated to increase due to rapid human population growth, forest conversion, destruction and fragmentation.

Potential study sites:

Zoos and sanctuaries that provide the opportunity to test several individuals separately.

Duration:

Short term study, depending on the number of substances and sounds tested.

Notes:

Please see also Topic 3: Stimulation of rubbing.

Further reading:

(Miller 1980, Ternent and Garshelis 1999, Smith et al. 2000, Fredriksson 2005, Liu et al. 2005, Brook 2010, Homstol 2011, Tee et al. 2016, Anderson et al. 2019, Lenz 2020)

3. Stimulation of rubbing

Specific research question:

Which scents and materials on which surfaces elicit rubbing behaviour in sun bears, so that hairs are captured?

Synopsis:

Bears mark trees by clawing, biting, and by rubbing various parts of the body against them. Non–invasive approaches, such as hair snaring to obtain DNA for genetic analysis, are commonly used to estimate bear population size and density in other ursid species but have not been successfully applied to detect sun bears. Sun bears have shorter guard hairs than other ursids and lack underfur, which makes it difficult to capture their hairs by non–invasive hair sampling. As in other bear species, which rub neck and shoulders on trees, there are scents which elicit rubbing behaviour, but very little is known on the marking behaviour of sun bears and, compared to brown bears, American black bears, or Andean bears (*Tremarctos ornatus*), rubbing has rarely been observed in captive sun bears. There are a few successful attempts to attract sun bears to hair traps, but so far there is no reliable method to collect hairs for genetic analysis. In addition, capture probability varies with sex, age class, and season, and rubbing behaviour might differ considerably among populations, as is the case for American black bears. By applying different scents on various materials and surfaces to stimulate rubbing in sun bears of both sexes and various age classes during different seasons, their effectiveness can be tested by behavioural observations according to a standardised ethogram and additional videotaping and photographing for documentation. A successful survey requires detailed planning that also takes into account tree characteristics such as species, tree diameter, aromatic properties, bark texture, and persistence of scents on the bark. The effect of substances that achieved the best results shall be tested on several consecutive days in order to determine if and when habituation occurs.

Impact:

Provided that effective scents and surfaces can be identified, the findings might improve the effectiveness of population monitoring through hair sampling for genetic analyses.

Potential study sites:

Zoos and sanctuaries that offer opportunities to test several animals separately and provide well–structured enclosures in order to test different surfaces.

Duration:

Dependent on pre–studies, coordination, and number of stimuli and surfaces tested.

Notes:

Please see also: Topic 2 – Olfactory and auditory attractants / deterrents, since there might be some overlapping regarding testing of olfactory attractants; Topic 4 – Standardising a hair capture protocol for genetic monitoring of sun bears; and Topic 5 – Hair morphology as a tool for species identification.

Further reading:

(Green and Mattson 2003, Liu et al. 2005, Kendall and McKelvey 2008, Karamanlidis et al. 2010, Nie et al. 2012, Clapham et al. 2013;2014, Sato et al. 2014, Tee et al. 2016, Lenz 2020)

4. Standardising a hair capture protocol for genetic monitoring of sun bears

Specific research question:

Which device is most reliable to capture sun bear hairs?

Synopsis:

Site–specific information regarding sun bear occurrence is scarce and there are few reliable estimates of population status or trends. Non–invasive hair sampling for genetic analyses and population monitoring has successful been applied in other ursids as they are readily detected by hair collected from rubbed trees. Rub stations, structures saturated with scent lures, are reported to exploit the natural tree rubbing behaviour in many bear species. However, despite a few successful attempts to snag sun bear hairs from rubbed trees, currently there is no reliable method to capture their short and sleek hair regularly and suitable for genetic analyses. For the method to be effective, the collection structure must permit or promote use by the animal, the sample device must snag the hair, and the resulting hair samples must contain useful DNA. Follicles are the best source of DNA and it has to be taken into account that DNA degradation may be more rapid in warm, wet environments such as sun bear habitat. The goal of this project is to establish a standard hair sampling protocol to obtain sun bear hairs that provide good quality DNA, through the development and testing of various hair trapping devices (e.g. brush like or wooden structures of different types treated with scents which elicit rubbing, barbed wires or adhesive tape) over different seasons. Testing of various hair capture devices in captivity and subsequent genetic analyses will help develop a standard technique that can successfully be applied in the wild.

Impact:

A standard hair trapping protocol that allows for reliable collection of suitable genetic material to obtain insights into the population status, distribution, and genetics of sun bears in their natural habitat will significantly improve wild population monitoring and management.

Potential study sites:

Zoos and sanctuaries that provide the opportunity to test several animals separately and provide well–structured enclosures in order to test different apparatuses.

Duration:

Dependent on pre–studies, coordination, and number of apparatuses tested.

Notes:

Please see also: Topic 2 – Olfactory and auditory attractants / deterrents; and Topic 3 – Stimulation of rubbing.

Further reading:

(Taberlet et al. 1997, Green and Mattson 2003, Kendall and McKelvey 2008, Clapham et al. 2013, Goossens and Salgado-Lynn 2013, Clapham et al. 2014, Sato et al. 2014, Lamb et al. 2016, Patkó et al. 2016, Tee et al. 2016, Lenz 2020).

5. Hair morphology as a tool for species identification

Specific research question:

Is hair morphology diagnostic for identification of sun bears / Asiatic black bears?

Synopsis:

Asiatic black bears (*Ursus thibetanus*) and sun bears co–occur in northeast India, Myanmar, Thailand, Laos, Cambodia, Vietnam, and perhaps Bangladesh and southern China. Non–invasive genetic sampling methods are instrumental in providing robust population abundance and density estimates of bears. Species identification, as well as population characteristics such as abundance, can be accomplished through DNA analysis from hair samples but are expensive and often require permissions to be exported for analyses. Before the use of hair traps for genetic analyses for species identification was applied, keys were used to identify species through the microscopic analysis of hair shaft morphology. Hairs differ between sun bears and Asiatic black at least in length and underwool, but hairs of closely related species are often difficult to distinguish. An identification key has been provided on the basis of the structure of dorsal guard hairs for the four different Indian species of the family Ursidae. However, besides seasonal changes, hairs from different parts of the body may differ regarding their morphology. In order to test if there are significant differences regarding morphology in hairs taken from different body parts, hairs from a variety of individuals of both sexes and different age classes shall be collected from various body parts according to a protocol.

Impact:

Provided the method will prove to be conducted as easily and with comparable reliability to genetic analysis, using hair morphology could provide another useful and inexpensive tool for non–invasive species identification and population monitoring.

Potential study sites:

Living collections, where hair samples can be collected opportunistically or where bears can eventually be trained for hair collection.

Duration:

Long term study, including different seasons, dependent on opportunities such as training, immobilisation or death of animals.

Notes:

Hairs can be shaved, or better collected by using tweezers in case hairs with roots are needed for other studies. This study could be conducted together with Topic 3 – Stimulation of rubbing; and Topic 4 – Standardising a hair capture protocol for genetic monitoring of sun bears.

Further reading:

(Moore et al. 1974, De and Chakraborty 2006, Chattha et al. 2011, Knecht 2012)

6. Auditory detection

Specific research question:

Is it possible to detect sun bears by auditory sensor?

Synopsis:

Methods frequently applied to survey wild sun bears are sign surveys, camera trapping and hair trapping for genetic analyses. Bioacoustic approaches to locate and identify animals can be used in habitats where visual location is difficult, such as dense vegetation in tropical forests, and have been shown to be useful to detect elusive animals. Since almost all vocal species possess unique acoustic patterns that differ significantly following a common structure typical of the species, by using acoustic analysis methods, it is possible to identify species emitting vocalisations such as insects, frogs, birds and mammals. Acoustic recording devices require special features such as being wireless, waterproof, easily transportable, with large memory capacities and not easy to be destroyed by wild animals, but provide a simple and non–invasive tool for the detection of wildlife. The purpose of this project is to test whether it is possible to detect wild sun bears using automatic acoustic survey systems and to validate if species–specific vocalisations are sufficiently distinctive to classify detected sounds and assign them to species or intraspecific age classes. By opportunistically audiotaping sympatric Asian bear species, e.g. sun bears and Asiatic black bears, of different sexes and age classes during periods, when vocalisations are probable (e.g. when searching for food, when cubs are nursed or bottle fed, when social encounters are to be expected), and recording the context within which the sound has been recorded, a database shall be established that can be used to test the efficacy of auditory sensors and recorded sounds.

The method can then be applied to detect bear presence by acoustically monitoring sun bears in the wild.

Impact:

Provided the method is successful, it offers another non–invasive tool to improve the detectability of sun bears in the wild.

Potential study sites:

Facilities in range countries with many bears, preferably at least sun bears and Asiatic black bears, which provide adequate background sound and low traffic noise.

Duration:

Short–term study, dependent on the number of individuals in the facility.

Notes:

The project requires a highly sensitive taping and sonographic equipment; taped bear vocalisations from the Tembrock sound archive, Humboldt University, Berlin, Germany might be requested for sound identification.

Further reading:

(Huetz and Aubin 2002, Hartwig 2005, Peters et al. 2007)

7. Identifying signs of different species and their decay rates

Specific research question:

Which signs left by sympatric species are sufficiently different to allow for species identification?

Synopsis:

Sign surveys are a commonly used tool for monitoring Asian bears. Sun bears leave abundant signs that can be used to confirm bear presence, particularly insect feeding sites such as opened termite mounts, dug holes, torn–open rotten logs, broken bees' nests, and claw marks on climbed trees. However, much of the sun bear range overlaps with that of Asiatic black bears and often the signs of these two species cannot be reliably distinguished. Although it is possible to differentiate between both species by measuring the widths of fresh claw marks on climbed trees, signs from Asiatic black bear cubs and adult sun bears are often confounded. Using scats for species identification in the tropics is also problematic due to the quick degradation of faeces by insects and erosion by rain. To better distinguish signs of the two species, all signs deposited by bears of different sex and age classes from both species, like claw marks at trees, scratch marks at holes or feeding sites, hair, nests, and faeces shall be sampled and their decay rates over time shall be monitored. In addition, description of signs, photos, as well as individual differences of the bears in terms of size and weight shall be recorded and assigned to differences in bear sign characteristics.

Impact:

A method to reliably distinguish bear signs left from sympatric species would considerably improve wild population monitoring.

Potential study sites:

Zoos and sanctuaries in range countries keeping the required species at best in naturalistic enclosures, which offer the possibility to shift and lock in animals in order to inspect signs.

Duration:

The planned project is a long–term study which requires cooperation and coordination between different facilities in range countries.

Notes:

The project requires clear and detailed sampling protocols for each different type of sign.

Further reading:

(De and Chakraborty 2006, Fredriksson and Steinmetz 2007, Steinmetz et al. 2007, Heinemeyer et al. 2008, Steinmetz and Garshelis 2008, Ngoprasert et al. 2011, Steinmetz 2011, Steinmetz et al. 2011, Fredriksson 2013)

8. Test tracking units / Validation of radio signals for collars

Specific research question:

Development and calibration of a proper tracking unit design for sun bears.

Synopsis:

Patterns of landscape use and habitat selection in sun bears are poorly known which hinders the development of conservation actions within the landscape. Radio telemetry, which is frequently used for other bear species, has shown limited success with sun bears since they are difficult to radio collar. Ear transmitters, which have been applied in male polar bears and male grizzly bears, which cannot be fitted with radio collars due to the width of their neck in relation to their skull, are not appropriate for sun bears due to their thick and small ears, and have been shown to lead to severe infections. The aim of this project is to develop prototypes of collars or attachments with a programmed breakaway mechanism, which are more suited to sun bear morphology, in partnership with tracking unit engineers, and to test the efficacy of these devices prior to using them on wild bears. Based on the assumption that different locomotory patterns such as digging, climbing, walking, and running result in different radio signals, it is required to calibrate those devices by assigning different behaviours to activity sensor readings of radio collars. It is recommended to conduct direct observations by continuous behavioural recording in two collared individuals (adult and subadult). Collars that contain both activity sensors and camera would be ideal to assign signals to certain behavioural categories.

Impact:

Radio collars designed for sun bears would enable tracking of individuals to gain insight into their habitat use and ecology.

Potential study sites:

Zoos and Rescue centres, e.g. Free the Bears, Ouwehand Dierenpark Rhenen, Netherlands.

Duration:

A few weeks once a collar is fitted during immobilisation; in case prior training for radio collaring is required, more time shall be arranged.

Notes:

Only solitary housed animals shall be included in the study; collars can be attached when bears are immobilised for health checks; eventually animals can be trained to fit the radio collar.

Further reading:

(Gervasi et al. 2006, Kays et al. 2011, Schmidt-Burbach and Officer 2014, Ware et al. 2015, Cattet 2018)

9. Identification of species sharing the habitat by their scats; eventually monitoring of decay rates

Specific research question:

Do size and shape of faeces differ significantly between species (sun bears and Asiatic black bears) fed with the same diet?

Synopsis:

Sun bears are among the most difficult species to study in the wild due to their large individual ranges, low population densities, and their elusive behaviour. Commonly used tools for monitoring sun bears are sign surveys. However, signs from sun bears and Asiatic black bears, which live sympatrically in a great proportion of their range in mainland Southeast Asia, are often indistinguishable. It has been shown that scats can be assigned to sun bears and Asiatic black bears respectively, if sufficiently different food items are consumed, i.e. predominately insects in the sun bear diet and mostly fruits in the diet of Asiatic black bears, leading to the question whether identification of species–specific scats in overlapping areas where the food composition is more similar, is still possible based on the size and shape of the scat. In addition, the use of species identification of sympatric bear species through scats samples might be limited in the tropics, due to the rapid degradation of faeces by insects and decay rates that vary with season. Based on the assumption that faecal samples differ in size and shape between species and individuals of varying size and during different seasons, the study aims at determining if it is possible to differentiate sympatric living species using diameter and shape of scat samples, by using captive bears under controlled and comparable conditions regarding diet composition. It is recommended to feed the same diet to at least six adults and six juveniles of each species housed in the same institution in a range country, to take photos and measurements to record scat diameter and shape and analyse the measured data for significant differences. In addition, scats shall be placed on natural ground during various climate conditions to monitor decay rates of faeces during different seasons.

Impact:

Provided that scats from both species can be reliably differentiated, the method would provide another useful tool to distinguish signs of sympatric species.

Potential study sites:

Free the Bears, in case decay rates are included, because it is the only facility in range states with sufficient numbers of both species; otherwise any facility keeping sufficient numbers of both species.

Duration:

The study should cover at least dry and wet season.

Notes:

A pre–test could be conducted in a zoo keeping both species and if the assignment of scats to species is successful, the study can be extended.

Further reading:

(Augeri 2005, Ngoprasert et al. 2011, Powell 2011, Steinmetz et al. 2011, Fredriksson 2012, Islam et al. 2013, Steinmetz et al. 2013, Teo 2013, Sethy and Chauhan 2018)

10. Test iDNA methods to detect wild sun bears

Specific research question:

Is the analysis of iDNA a reliable method for detecting wild bear populations?

Synopsis:

DNA analyses from invertebrate–derived DNA (iDNA) has recently been promoted as a powerful tool for cost– and time efficient monitoring of wildlife. While originally applied to identify any mammalian species present in an area, it should also allow for targeted detection of species. In order to test the utility of using invertebrate–derived DNA to detect sun bears, an experimental set–up shall be designed, testing various invertebrate species (e.g. leeches, mosquitos, carrion flies) and various trap designs. It is recommended to test the various trap designs at different distances from the source DNA (i.e. bear or bear faeces) to determine the potential sample area size and to use invertebrates with known contact to source DNA to test detectability since contact with source over time.

Impact:

Provided that iDNA can reliably be used to detect sun bears, this provides another method to detect sun bear presence.

Potential study sites:

Zoos and sanctuaries with bear species in countries that have invertebrates that occur naturally in sun bear range states (or representative species), ideally with surrounding habitat that allows the movement of invertebrates; facilities with no other wild or captive bears in the immediate vicinity (5 km) which might affect the distance experiments.

Duration:

The study shall include dry and wet season.

Notes:

The project can be conducted as a number of studies over different seasons, with different invertebrate species, trap designs, etc.

Further reading:

(Calvignac-Spencer et al. 2013, Schnell et al. 2015, Schubert et al. 2015, Lee et al. 2016, Bagnall 2017, Abrams et al. 2019, Drinkwater et al. 2019)

11. Test fresh bear claw marks for detectable DNA

Specific research question:

Do fresh bear claw marks on trees contain detectible bear DNA?

Synopsis:

Sun bears are among the most difficult species to study in the wild due to their large individual ranges, low population densities, and their elusive behaviour. Sun bears leave abundant signs that can be used to confirm bear presence and commonly used tools for monitoring sun bears are sign surveys. However, signs from sun bears and Asiatic black bears, which live sympatrically in a great proportion of their range in mainland Southeast Asia, are often indistinguishable. Although it is possible to differentiate between both species by measuring the widths of fresh claw marks on climbed trees, signs from Asiatic black bear cubs and adult sun bears are often confounded. Claw marks are the most common type of sign in sun bear sign surveys. The signs they leave on climbed trees might be possible sources of DNA. This project aims at examining if sun bear DNA can be derived from fresh claw mark scratches on trees by analysing samples taken from claw marks on various tree types during different seasons. Provided that very fresh samples provide suitable DNA, subsequent tests shall be made in order to evaluate the success rate of DNA detection over time.

Impact:

If effective, this provides a useful method to distinguish between claw marks of sun bears and Asiatic black bears.

Potential study sites:

Institutions in range states under natural climate conditions which provide the opportunity to climb trees. Tat Kuang Si, Laos, Free the Bears; BSBCC, Sabah, Malaysian Borneo.

Duration:

The study should cover different seasons.

Notes:

Potential to observe deposition of fresh bear sign during Topic 14 - Under which conditions do sun bears climb?

The reliability and expense of this method should be evaluated against the claw mark measurement method developed by Steinmetz and Garshelis (2008).

Further reading:

(Steinmetz and Garshelis 2008;2010)

12. Validation of usefulness of stable isotopes in faeces to determine the feeding niche of sympatric species

Specific research question:

To which degree do stable isotope signatures differ between diets?

Synopsis:

Stable isotope analysis has proven to be a useful tool in reconstructing diets, characterizing trophic relationships, elucidating patterns of resource allocation, and constructing food webs. Diets, and thus alterations in food consumption, can be differentiated from faeces (e.g. herbivorous versus insectivorous food) since they are reflected in the stable isotope signal of a species. The method can therefore be used to understand diet– and habitat–related changes in animals as well as to distinguish between scats from different species. The purpose of this project is to test the potential of stable–isotope analysis to estimate sun bear diet composition and to determine whether and to which degree small dietary differences are reflected in the isotope patterns of sympatric tropical bear species, such as Asiatic black bears and sun bears, by analysing stable isotopes from faecal and food samples of the different species. The study shall include 2–3 individuals per species. Feeding trials shall consist of defined types of diets, which differ between species e.g. in the amount of meat and insects, for at least six days and scat samples shall be collected on day six. Likewise, food samples shall be collected for isotope analyses. Provided that dietary differences are sufficiently reflected in scats, this might represent a method to relatively quickly obtain information on feeding ecology, niche overlap and segregation from different regions which is important to predict survival chances and to help planning corridors between fragment patches to extend the available habitat for the less dominant species where ranges overlap.

Impact:

Stable isotope analysis might provide a relatively quick method to identify feeding ecology in different habitats and niches of sympatric species.

Potential study sites:

European zoos with the possibility to shift and lock animals indoors to collect faecal samples, e.g. Burgers' Zoo Arnhem, Netherlands; Cologne Zoo, Germany; Berlin Tierpark, Germany.

Duration:

A few weeks of data collection and subsequent testing.

Notes:

Provided that sufficient hairs can be obtained, the stable isotope method could also be tested for hair samples, which requires knowledge on the previous diets. Stable isotope analyses can be conducted at various institutions such as the University Göttingen, Germany. Include tests on differences in size, shape and appearance of scats between the species (Topic 9); inclusion of microbiome analyses or at least include sampling for such a study.

Further reading:

(Darimont and Reimchen 2002, Boecklen et al. 2011, Blumenthal et al. 2012, Lam et al. 2013b, Han et al. 2019)

13. Identification of distinct sensitive periods for learning experiences during behavioural ontogeny, which are relevant for the development of survival skills

Specific research question:

At which age do sensitive periods for different behaviours occur and how long do they persist?

Synopsis:

Conservation breeding and reintroduction programmes provide an important resource for conservation through the management of populations of threatened species in zoos and, where appropriate, to re–establish populations in the wild. The success of reintroductions is highly dependent on the survival skills of an animal obtained during ontogeny, such as foraging and selection of food, climbing, avoidance from predators, dominant conspecifics, and humans. Provided that the release of young confiscated or captive bred bears for conservation purposes will be considered in the future, research on behavioural ontogeny is required to determine sensitive periods during which important survival skills are learned. Little is known about the behavioural development of sun bear cubs. A study on a sun bear cub in a zoo environment over the first three months of development revealed that first explorative behaviours occurred around the age of two months. A recent report on two captive sun bear cubs showed that between 4-6 months the distance to the mother increased but no indications of the development of neophobia could be found. Thus, research on behavioural ontogeny, which is relevant for the development of survival skills, during the cubs' first year of age is essential in order to determine limited distinct time frames during which important survival skills are acquired. In order to achieve that goal, both video recordings and direct behavioural observations of captive born cubs from different mothers as well as very young rescued bears shall be conducted based on an ethogram focussing on: explorative behaviours; foraging and food selection; following and avoidance behaviour; awareness towards new objects and humans; and shall also include well designed novel objects tests.

Impact:

The findings might help to inform management and provide husbandry recommendations on key periods and keeping requirements relevant for success of potential future releases, if reintroduction of captive sun bears is considered an option for conservation.

Potential study sites:

Zoos breeding sun bears; rehabilitation centres, which receive cubs at a very young age.

Duration:

Long–term opportunistic study for an adequate sample size since both births in zoos and hand raising in rescue centres at a very young age are rare.

Notes:

The former rearing history of mothers should be known.

Further reading:

(Fredriksson 1998, Gilbert 1999, Pazhetnov and Pazhetnov 2005, Peters et al. 2007, Hall and Swaisgood 2009, Skripova 2013, Spiero 2019)

14. Under which conditions do sun bears climb?

Specific research question:

What is the underlying motivation for sun bears to climb trees in differing contexts?

Synopsis:

Sign based surveys provide a potentially powerful method to detect habitat use of elusive animals that occur at low densities, such as sun bears. Density of bear signs on climbing trees, such as nests and claw marks, can potentially be used as an index of abundance. Sun bears are semi–arboreal animals, well adapted to climb trees and leave abundant signs that can be used to confirm bear presence, including claw marks on trees climbed to feed on fruits and invertebrates, to rest on, for behavioural thermoregulation, and avoidance from predators, more dominant conspecifics and humans. It has been reported that sun bears use a wide variety of tree species from various families to climb and to feed on. However, there are no quantitative data focussing on the underlying motivations of climbing in different contexts. Since climbing represents an appetitive behaviour which can lead to various end acts, such as feeding, resting, or protection, the strength of their underlying motivation partly determines its frequency. This project aims at better understanding what trees sun bears select for climbing and whether the motivation for climbing varies with forest type, season, food availability, fruiting tree density, altitude, latitude etc., in order to improve interpretation of bear sign observation data and how they are related to abundance and habitat use. Through the conduction of a literature review, collection of keeper information, preliminary ad libitum behavioural observations, and subsequent dedicated experiments, conditions and stimuli that elicit climbing in sun bears can be elucidated. The study should include adult and subadult animals of both sexes in several facilities during different seasons.

Impact:

The results might lead to a better understanding and interpretation of bear sign observation data and how they relate to abundance and habitat use.

Potential study sites:

Facilities housing sun bears of the required age classes that provide sufficient climbing opportunities.

Duration:

Depends on the knowledge gaps identified and the number of subsequent experimental studies. At least one wet and one dry season shall be included.

Notes:

There might be some overlap with Topic 11 - Test fresh bear claw marks for detectable DNA, from which further information could be derived.

Further reading:

(Steffen 1996, Wong 2002a, Steinmetz and Garshelis 2008;2010, Steinmetz et al. 2011, Fredriksson 2012, Cheah 2013a, Steinmetz et al. 2013, Barber 2018, Lee et al. 2019)

15. Digestive efficiency and effects of an oil palm fruit–dominated diet

Specific research question:

Is it possible that an oil palm fruit–dominated diet can cause nutritional imbalances and shifts of blood values in wild sun bears?

Synopsis:

Sun bears are opportunistic omnivores consuming a wide variety of food items including fruits and insects. During multi–annually periodic mast fruiting events, fruits make up most of their diet, providing the opportunity to build up or recover fat and energy reserves for the prolonged inter–mast intervals. Commercial hunting and habitat degradation through logging and conversion into oil palm plantations are the main threats to sun bears. Recent studies have found that sun bears living adjacent to oil palm plantations use them to consume oil palm fruits. Camera trap photos of sun bears living near oil palm plantations and actual weights reveal that some individuals are indeed fatter than bears with no access to oil palm fruits. However, oil palm fruits do not provide the full range of nutrients that meet the requirements of sun bears, which could lead to nutritional imbalances, in particular with respect to macro– and microelements which might have an effect on health and reproduction. In order to examine if the intake of diets dominated by one fruit – in particular oil palm fruits – cause nutritional imbalances and shifts of blood values, digestibility trials with increasing proportions of oil palm fruits, weight recordings, and ideally blood samplings after each trial shall be conducted. In addition, feeding trials to determine nutrient digestibility of different fruits generally consumed by sun bears (including identification of those parts which are consumed to make sure that only these are analysed) shall be implemented, accompanied by recordings of body weights and blood sampling prior and after each tested fruit.

Impact:

Given the diversity of fruits and insects in the diet of sun bears in forests that have not been disturbed by humans, it is expected that the extensive loss, degradation, and fragmentation of lowland forests, including loss of many fruit producing trees, will negatively impact this species. The study will help asses potential health risks for sun bears feeding on an unbalanced diet rich in carbohydrates. Understanding how sun bears cope in close vicinity to agricultural plantations is required to fully understand their impact on the species in order to develop conservation strategies and to assess future population viability.

Potential study sites:

Zoos and sanctuaries in countries where ripe whole oil palm fruits are available and which have the possibility to keep animals separated; trained animals are obligatory for blood sampling.

Duration:

Per diet 5 days of adaptation to the test diet, followed by 5 sampling days; total time depends on the number of steps and the proportion of oil palm fruits in the diet considered maximum.

15. Digestive efficiency and effects of an oil palm fruit–dominated diet (continued)

Notes:

The project needs thorough ethical considerations weighing the benefits of results against potential health risks for bears in the trials, though wild bears feeding mainly on palm fruits apparently thrive. This study could also be used to test whether the stable isotope method provides reliable information on the food components (Topic 12) and whether the scats differ between the species in size, shape and appearance (Topic 9), although the latter requires the inclusion of other species.

Further reading:

(Hoffmann et al. , McConkey and Galetti 1999, Wong 2002b, Normua et al. 2004, Fredriksson 2005, Wong et al. 2005, Fredriksson et al. 2006, Steinmetz 2011, Steinmetz et al. 2011, Fredriksson 2012, Cheah 2013b, Steinmetz et al. 2013)

16. Digestive efficiency of an insect–dominated diet

Specific research question:

What is the digestive efficiency of a diet with increasing amounts of insects and lowered amounts of fruits?

Synopsis:

The aseasonal rainforest in Malaysia, Sumatra and Borneo experience synchronised masting events, followed by inter–mast periods with little fruiting. During these inter–mast periods, sun bears rely largely on insects. However, they seem unable to maintain body mass for extended periods on a diet of insects, and some die of starvation. In certain regions, insects might be the main source of proteins for sun bears which are relevant for reproduction, specifically for lactation and growth, during which protein requirements are highest. Nutrient composition of insects consumed by sun bears and digestibility tests of diets with increasing amounts of insects are necessary to assess the relevance of insects in sun bear diet. At least six adult, non–breeding individuals housed in facilities in range countries (and if possible also not yet fully grown animals) shall be included. The analyses of insects should include their fat composition, as it differs from that of endotherms and is thought to have positive effects on digestion in vertebrates.

Impact:

The findings provide the basis for predicting dietary requirements of wild sun bears and lead to a better understanding of their ecological niche, habitat suitability, coping strategies and their limitations in times of low fruit availability.

Potential study sites:

Zoos or sanctuaries which provide the opportunity to keep animals separated and provide adequate storage capacity for food and scat samples. Scales are necessary to record body weights. If blood samples are considered, trained animals and safe training cages are required.

Duration:

Per diet five days of adaptation, followed by five sampling days; the total duration depends on the number of steps: e.g. 5% insects; 10% insects; 20% of insects on a dry matter basis; the availability of insects will set the upper limit.

Notes:

Bears will lose weight on a diet dominated by insects and reduced amount of fruits. The threshold of accepted weight loss needs to be determined a priori or very fat bears shall be used for the trials.

This study could also be used to test whether the stable isotope method provides reliable information on the food components (Topic 12) and whether the scats differ between the species in size, shape and appearance (Topic 9), although the latter requires the inclusion of other species.

Further reading:

(Riese 2001, Wong 2002a, Normua et al. 2004, Wong et al. 2005, Fredriksson et al. 2006, Fredriksson et al. 2007, Steinmetz et al. 2013, Sethy and Chauhan 2018)

17. Sun bear infectious disease susceptibility

Specific research question:

Assessment of sun bear infectious disease susceptibility.

Synopsis:

A range of infectious diseases have been described in bear species. Most reports arise from captive individuals, and often involve bears as aberrant hosts due to captivity bringing them into contact with other species. Examples of viral, bacterial, fungal and parasitic disease can be found in the literature. Studies involving wild bear populations are dominated by serological surveys, indicating exposure to pathogens rather than documenting clinical disease. Relatively little is known about infectious disease threats to sun bears, with a small number of published case reports (e.g. ursid herpesvirus, infectious canine hepatitis, dermatophytosis, gastrointestinal parasitism). Outbreaks of disease in *ex situ* populations have shown sun bears are susceptible to a number of pathogens for which they are unlikely to be natural hosts (e.g. tuberculosis, avian influenza, foot–and–mouth disease). Currently, there is no published information on infectious disease susceptibility in wild sun bears. Infectious disease can be a conservation risk, particularly when coupled with the well–recognised drivers of population decline. Shrinking habitats and increased encroachment by humans and other species amplify disease threats, which can in turn contribute to species decline. There are also important conservation considerations related to the risk of re–releasing potentially infectious individuals from captivity to the wild. Given the lack of information on naturally occurring diseases in wild sun bears, and the challenges around sample collection and disease monitoring in wild sun bear populations, baseline data collection and disease surveillance using *ex situ* populations are useful for understanding pathogen diversity and disease–related risks in sun bears. To prevent or mitigate future population declines, research efforts should be aimed at identifying both the diseases of potential importance to large carnivores and the ecological conditions associated with their spread and severity. Disease investigation efforts in *ex situ* populations, as well as considerations for potential cross–species transmission, can help serve this purpose, and inform disease surveillance efforts in wild populations where possible.

Impact:

Understanding of the risks to wild populations (naturally occurring and potentially introduced) and thus improve conservation strategies and inform re–release risk assessments.

Potential study sites:

Wildlife rescue centres and zoos housing sun bears (and other species) with (or with potential to develop) capacity for disease investigation.

Duration:

Long term study.

Notes:

Collaboration is needed between veterinarians, managers, researchers and laboratories on diagnostic and surveillance methods.

Further reading:

(Groves 1969, Williams and Thorne 1996, Murray et al. 1999, Blake and Collins 2002, Smith et al. 2006, McNamara 2007, Pedersen et al. 2007, Bourne et al. 2010, Goodnight and Emanuelson 2012, Lam et al. 2013a, MacPhee and Greenwood 2013, Officer et al. 2014)

18. Identification of factors relevant for breeding success

Specific research question:

What factors trigger or prevent reproduction in sun bears?

Synopsis:

Zoos can contribute to species conservation through coordinated breeding programmes for endangered species to form viable populations that can benefit *in situ* conservation efforts by supporting demographic and genetic backup to wild populations. However, reproductive success of the *ex situ* population of sun bears has been very low and the global zoo population is not self–sustaining, and contributing factors have not been systematically identified. Husbandry and keeping conditions, such as group size and composition, might affect breeding success. While sun bears are solitary in the wild, they are often kept in breeding pairs or groups consisting of unrelated females and reproductive success has been very low. It has been reported that in groups with two unrelated females, just one had regular cycles, whereas the other female did not cycle and showed elevated faecal glucocorticosteroids metabolites (GCM), indicating that there is an impact of social stress on reproduction. However, several other females in zoos obviously resumed normal cycling as they produced offspring. The question is whether there are additional factors which affect cycling and under which conditions females might resume cycling. Hormone monitoring is a well–established tool for evaluating endocrine activity of wildlife, and has substantially enhanced captive management and propagation of a number of endangered species as it allows more effective determination of how social and environmental aspects affect reproductive success. In order to identify key factors for successful reproduction in captive sun bears, non–invasive hormonal monitoring of faecal sexual and stress hormones of both females and males in different social settings shall be implemented, accompanied by comparisons of behaviour and husbandry conditions of breeding and non–breeding pairs in zoos. It is also recommended to conduct veterinary exams of the reproductive tracts of non–breeding animals. By identifying relevant factors, *ex situ* breeding can be improved and better planned by population managers. Furthermore, the findings allow for the assessment of the reproductive status and stress levels of *in situ* populations.

Sun bears at Burgers' Zoo, 2020 © Joke Kok

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18. Identification of factors relevant for breeding success (continued)

Impact:

Maintenance of reserve populations; opportunity to increase information on the variability of the sexual cycle; monitoring reproduction status of wild populations.

Also important for adjusting group size and composition and eventually temporary separation of sexes, if breeding for release in range countries becomes a conservation option in the future.

Duration:

Long term study.

Notes:

Some aspects, like regular faecal sampling, might be limited to facilities with sufficient storage capacity and personnel for regular sampling.
Introduction of new breeding partners should be conducted by experienced keepers according to introduction protocols.

Sun bears at Burgers' Zoo, 2020 © Joke Kok

Potential study sites:

As many institutions keeping both sexes as possible. Appropriate facilities to separate / join sexes for prolonged periods, with vet facilities. Freezer for faeces storage is required.

Further reading:

(Müller 1998, Schwarzenberger et al. 2004, Hesterman et al. 2005, Anton 2006, Goeritz et al. 2006, Knauf 2006, Frederick et al. 2010, Frederick et al. 2013, Schwarzenberger and Brown 2013)

19. Thermoregulation in sun bears

Specific research question:

Autonomic and behavioural thermoregulation in different climate zones and its energetic costs.

Synopsis:

Forest loss and conversion to croplands and palm oil plantations are major threats to sun bears which are a forest dependent species. Trees are not only necessary to forage but also for behavioural thermoregulation as they provide both shade and a cooler microclimate through transpiration of plants. Little is known about thermoregulation in sun bears and their associated energetic costs. A study conducted in sun bears in European zoos using a combination of infrared thermography and behavioural observations revealed that above the upper critical temperature of 28 °C, sun bears reduce exploration and avoid direct solar radiation. In their main natural habitat, where daily temperatures can raise above 28 °C, shade is of utmost importance to avoid overheating while foraging, whereas in less dense plantations, where temperatures raise up to 35 °C, the available shade might be insufficient, as sun bears avoid open palm oil plantations during the day, independent of the presence of humans. The objective of this project is to evaluate whether the reported critical temperature thresholds are comparable to those in tropical climate conditions, using a combination of infrared thermography and simultaneous behavioural observations in climatically differing regions and during all seasons based on the methods used in the study described above. Quantifying energetic costs under the threats sun bears are facing in the wild, like habitat destruction, fragmentation and conversion, is important for population management and conservation.

Impact:

The results might provide information necessary on the thermal requirements of sun bears with respect to the species potential to cope with the effects of global warming and habitat degradation and conversion into oil palm plantations which are occurring in their natural habitat and conclusions can be derived regarding the relevance of forests for *in situ* conservation. Knowledge of critical temperature thresholds in their natural habitat helps to predict the effect of habitat changes on sun bear presence / absence and to plan e.g. corridors and habitat improvements.

Potential study sites:

Zoos and rescue centres in range countries with diverse and structured enclosures that provide sufficient options for behavioural thermoregulation; e.g. Free the Bears Cambodia.

Duration:

At least one year.

Notes:

Thermographic measurements have to be made without fences or glass between the animal and the infrared camera.

Further reading:

(Normua et al. 2004, Cheah 2013b, Schneider 2015, Schneider et al. in press)

20. Determination of GCM levels and hair cortisol levels indicating stress

Specific research question:

What are the average glucocorticoid metabolites and hair cortisol levels under stressing conditions?

Synopsis:

Evaluation of physiological stress by measuring glucocorticoids, particularly levels of glucocorticoid metabolites in faeces, and hair cortisol, is a common and often used method. There is a relationship between glucocorticoid concentrations and disturbance such as changes in habitat, food abundance, exposure to humans, chronic stress in bile farms, or other substandard captive conditions. Whereas the release of glucocorticosteroids from the adrenal glands as a fast response to acute stress is an essential physiological process that helps the animal to respond appropriately to the situation, permanent exposure to stress may induce associated prolonged periods of high cortisol concentrations and can negatively affect physical health, growth, reproduction and immune system. Persistently elevated glucocorticoid levels are therefore indicative of chronic stress and disturbed welfare. The measurement of hair cortisol is increasingly used to understand the effect of natural and anthropogenic stressors on wild animals in the long term, but it is potentially confounded by individual, seasonal and sex–dependent variations in baseline cortisol levels. The purpose of the project is to assess baseline cortisol levels in sun bears by faecal glucocorticoid metabolites and hair cortisol concentration measurements. Transfer of an animal in a new situation is generally considered as a reliable stressor and is associated with elevated stress levels. Analysing samples taken during and after rescue of bears might help assess baseline cortisol levels in sun bears in order to be able to define which cortisol levels are indicative for stress. Collection of faeces and hair at suitable opportunities during health checks or before and after transport, from as many individuals as possible from different age classes, sex and reproductive status is required. In order to determine these baseline patterns, and to validate hair cortisol concentration analysis, hair samples from sun bears shall be collected opportunistically for several months and correlated with occurring stressful events such as transfers. Faecal samples should be taken regularly at least several days prior and several weeks after a stressing event, preferably fresh samples taken at the same time of the day. Data can be supported by behavioural observations and detailed information on individual animals.

Impact:

Improved ability to understand stress indicators, measured in faeces and hair, and understanding the impact of environmental changes and anthropogenic disturbance on bears is critical to conservation.

Potential study sites:

Rescue centres with a vet lab, e.g. Free the Bears.

Duration:

Unpredictable; depends on number of occasions for taking samples.

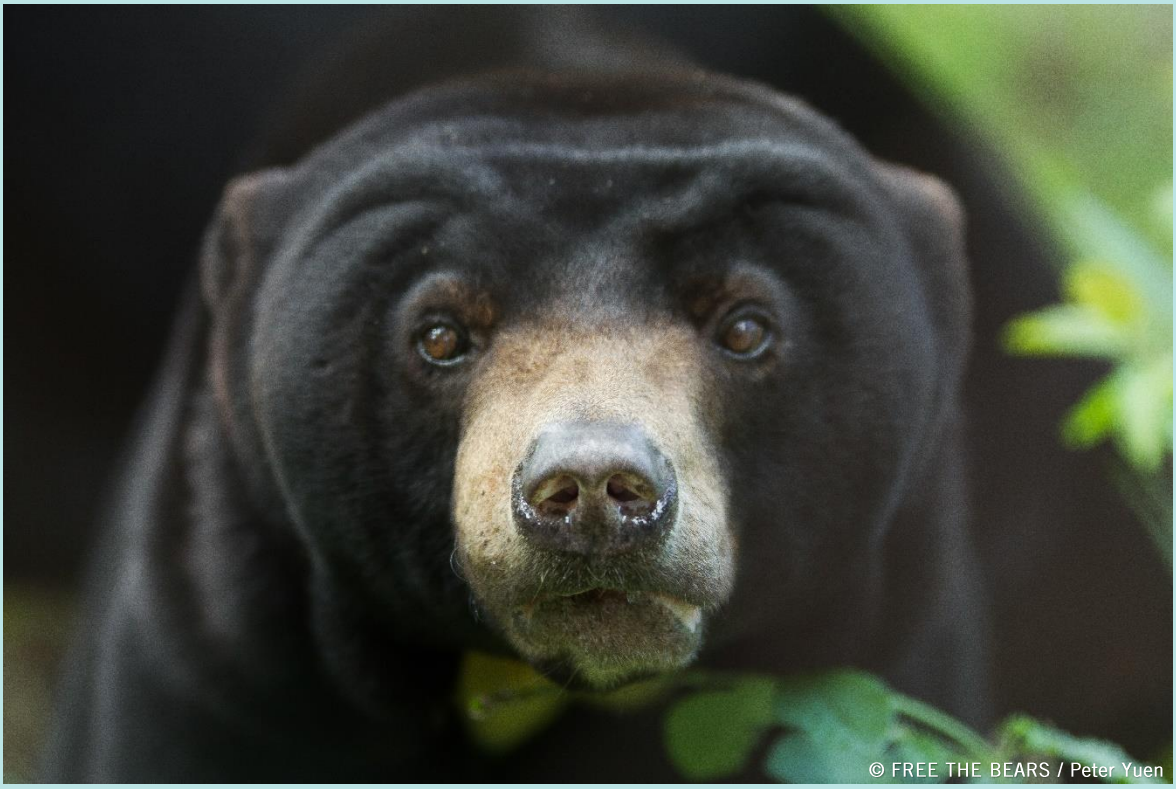
20. Determination of GCM levels and hair cortisol levels indicating stress (continued)

Notes:

A freezer to store faeces and dry storage of hairs in aluminium foil and paper envelope is required.

Further reading:

(Millspaugh and Washburn 2004, Owen et al. 2005, Bechshøft et al. 2012, Frederick et al. 2013, Malcolm et al. 2013, Cattet et al. 2014, Narayan et al. 2018, Dalerum et al. 2020, Hein et al. 2020)



21. Validation of techniques to analyse TCM

Specific research question:

Are there species–specific signature curves which identify bear parts or derivatives in TCM?

Synopsis:

Beside habitat destruction and fragmentation, trade in bear parts and derivatives is a major threat to sun bears. There is consumer demand for many kinds of wild bear products including, but not limited to, bear bile, sold as raw bile stored in vials, gallbladder, powdered bear bile, flakes, and ointments. Trade data on bear parts from Southeast Asia are mainly an undefinable mixture of Asiatic black bears and sun bears, unless it is known for certain that they originate from regions where only sun bears occur. Gallbladders and bile from different bear species cannot be differentiated, except through genetic analysis. According to literature, there are species–specific signatures in the bile composition. Using DNA analysis, it is possible to identify the species and geographical origin (i.e. population) of a forensic sample, and to also individualise the sample with high levels of probability. The aim of this project is to test if there are specific signature curves, which can be detected even in processed material of confiscated illicit bear products by forensic analysis of sun bear DNA and to subject them to different methods of chemical analyses, e.g. Gas Chromatography Mass Spectrometry (GC/MS) for detection of bear derivatives. Samples of bile or gallbladder and other tissues from ursids shall be obtained whenever the opportunity arises e.g. post mortem or from specific surgery.

Impact:

The method might greatly improve law enforcement regarding illegal trade of bear derivatives.

Potential study sites:

Living collections / dead animals / law enforcement agencies. Feasible in zoos and sanctuaries with autopsy rooms, e.g. Animals Asia, Free the Bears, U.S. Fish and Wildlife Service, Zoos.

Duration:

Unpredictable; depends on number of opportunistically obtained samples.

Notes:

Tissue samples or bile could be used for other projects; e.g. Topic 22 - Components of sun bear bile in comparison to bile of other ursids. Protocol for sampling and storing tissues and gall bladders is urgently needed.

Further reading:

(Hagey et al. 1993, Lin et al. 1997, Peppin et al. 2008a, Peppin et al. 2008b, Yeh et al. 2008, Shepherd and Shepherd 2010, Calderon 2012)

22. Components of sun bear bile in comparison to bile of other ursids

Specific research question:

Does the sun bear bile contain substantial amounts of medicinally effective components?

Synopsis:

The illegal trade of bears and bear parts and derivatives is a major threat to sun bears. Whereas the use of Asiatic black bear bile in Traditional Medicine traces back over 2000 years, widespread use and trade in sun bear bile as a medicinal product is much more recent. Though sun bears are less present in bear bile farming operations than Asiatic black bears, they are commonly poached from the wild to obtain gallbladder. Unlike Asiatic black bears, where the medicinal effects of bile are proven, there is no evidence confirming the medicinal effectiveness of sun bear bile. According to literature, sun bears seem to produce much lower levels of the effective components UDCA (ursodeoxycholic acid) than Asiatic black bears. Due to the small sample size used in an earlier study (n=2), it seems reasonable to quantify bile composition in sun bears and compare it to other ursid species to provide evidence for a lack of medicinal efficacy in sun bear bile. In order to achieve this goal, samples of gallbladder and bile of different bear species shall be collected opportunistically, recording data of origin where possible for future analysis.

Impact:

The findings might provide arguments against the medicinal use of sun bear bile which can be implemented in both law enforcement and conservation education.

Potential study sites:

Feasible in zoos and sanctuaries with autopsy rooms, e.g. Animals Asia, Free the Bears, U.S. Fish and Wildlife Service.

Duration:

Unpredictable; depends on the number of samples obtained.

Notes:

Use samples of bile for Topic 21 - Validation of techniques to analyse TCM. Sampling and storage protocols are needed.

Further reading:

(Hagey et al. 1993, Solá et al. 2006, Wang et al. 2011, Livingstone and Shepherd 2014, Crudge et al. 2018, Livingstone et al. 2018, Davis et al. 2020)

23. Population genetics

Specific research question:

What is the population structure and landscape genetics of sun bears across their range?

Synopsis:

At present, only one species of sun bear is recognised, under the name *Helarctos malayanus*, with the Bornean form considered a subspecies (*Helarctos malayanus euryspilus*), having some distinct morphological characteristics. In a first study of sun bears using nuclear microsatellites, two genetically and geographically distinct populations could be identified in Cambodia. The two populations have, at best, moderate genetic diversity and show signs of inbreeding. It appears that, at least until the recent past, there has been genetic exchange between these populations. Thus, it is necessary to obtain a better understanding of the barriers to gene flow, and to what extent these can be reduced if necessary. Recent mtDNA analysis suggests a phylogeographic split between a mainland Southeast Asian and Sunda clade at the Isthmus of Kra, in Thailand. To put these findings in the context of the entire sun bear meta population, the development of a reference database of the sun bear populations across its distribution range is required (e.g. to gain knowledge regarding the genetic exchange with sun bear populations in Vietnam, Laos and Thailand; and potentially better understand trade routes). Therefore, further microsatellite–based research on sun bears is recommended to develop such a reference database. In order to detect genetic differences between populations, opportunistic sampling of hairs, blood and other tissues for DNA analyses from captive sun bears of known origin from the complete sun bear range is required. In addition to identifying evolutionary significant units, with the addition of geo–referenced data, this reference database could also serve as a forensic tool to combat the illegal wildlife trade that is a significant threat to this species.

Impact:

Identifying evolutionary significant units.

Potential study sites:

Zoos and sanctuaries in range countries with animals of known geographic origin, e.g. Free the Bears / BSBCC, Sabah, Malaysian Borneo / KWPLH Balikpapan, Kalimantan, Indonesian Borneo.

Duration:

Unpredictable, depends on sampling opportunities.

Notes:

Storage requirements vary depending on type of sample, e.g. dry storage of hair in aluminium foil and paper envelopes; freezer for faeces; Longmire's solution for ambient storage.

Further reading:

(Zhang 1996, Meijaard 2004, Onuma et al. 2006, Kunde 2017, Kunde et al. 2019)

References

Abrams, J. F., L. A. Hörig, R. Brozovic, J. Axtner, A. Crampton-Platt, A. Mohamed, S. T. Wong, R. Sollmann, D. W. Yu, and A. Wilting. 2019. Shifting up a gear with iDNA: From mammal detection events to standardised surveys. Journal of Applied Ecology 56:1637-1648.

Anderson, C. C., Z. Wang, and Z. J. Farris. 2019. Comparison of Scent Lures on Captive Fosa (*Cryptoprocta ferox*): Implications for Field Methods. Journal of Zoological Research 3:19-29.

Anton, R. 2006. Effekt von Umgruppierungen auf das Sozialverhalten und die Aktivität der Malaienbärenweibchen des Kölner Zoos (Effect of re-grouping on social behaviour and activity of female Malayan sun bears at the Cologne Zoo). Examination paper, Cologne University, Germany, 126 pp.

Augeri, D. M. 2005. On the biogeographic ecology of the Malayan sun bear. Doctoral thesis, University of Cambridge Cambridge, United Kingdom, 331 pp.

Bagnall, A. J. 2017. Use of iDNA in detecting elusive mammals: a case study on the Indonesian island of Seram. Dissertation, University of Edinburgh, 92 pp.

Barber, J. 2018. Effects of food distribution and external factors on the activity budgets of captive sun bears (*Helarctos malayanus*). MSc thesis, Sonoma State University. California, 27 pp.

Bechshøft, T. Ø., F. F. Riget, C. Sonne, R. Letcher, D. Muir, M. Novak, E. Henchey, J. Meyer, I. Eulaers, and V. Jaspers. 2012. Measuring environmental stress in East Greenland polar bears, 1892–1927 and 1988–2009: What does hair cortisol tell us? Environment international 45:15-21.

Blake, C., and D. Collins. Captive ursids: results and selected findings of a multi-institutional survey. 2002.

Blumenthal, S. A., K. L. Chritz, J. M. Rothman, and T. E. Cerling. 2012. Detecting intraannual dietary variability in wild mountain gorillas by stable isotope analysis of feces. Proceedings of the National Academy of Sciences 109:21277-21282.

Boecklen, W. J., C. T. Yarnes, B. A. Cook, and A. C. James. 2011. On the use of stable isotopes in trophic ecology. Annual review of ecology, evolution, and systematics 42:411-440.

Bourne, D., J. Cracknell, and H. Bacon. 2010. Veterinary issues related to bears (Ursidae). International Zoo Yearbook 44:16-32.

Brook, T. 2010. Can olfactory attractants be used to optimise detectability of sun bear *Helarctos malayanus*? University of Sunshine Coast, 22 pp.

Brooke, Z. M., J. Bielby, K. Nambiar, and C. Carbone. 2014. Correlates of research effort in carnivores: body size, range size and diet matter. PLoS ONE 9.

Calderon, L. 2012. Chromatography: The Most Versatile Method of Chemical Analysis. BoD–Books on Demand.

Calvignac-Spencer, S., K. Merkel, N. Kutzner, H. Kühl, C. Boesch, P. M. Kappeler, S. Metzger, G. Schubert, and F. H. Leendertz. 2013. Carrion fly-derived DNA as a tool for comprehensive and cost-effective assessment of mammalian biodiversity. Molecular ecology 22:915-924.

Cattet, M. 2018. Capture, Handling and Release of Bears Standard Operating Procedure. NWT, Wildlife Care Comittee, 44 pp.

Cattet, M., B. J. Macbeth, D. M. Janz, A. Zedrosser, J. E. Swenson, M. Dumond, and G. B. Stenhouse. 2014. Quantifying long-term stress in brown bears with the hair cortisol concentration: a biomarker that may be confounded by rapid changes in response to capture and handling. Conservation Physiology 2:cou026.

Chattha, S. A., K. M. Anjum, M. Altaf, and M. Z. Yousaf. 2011. Hair mounting technique: helpful in conservation of carnivores. FUUAST Journal of Biology 1:53-59.

Cheah, C. 2013a. The ecology of Malayan sun bears (*Helarctos malayanus*) at the Krau Wildlife Reserve, Pahang, Malaysia and adjacent plantations. University Putra Malaysia.

Cheah, C. 2013b. Oil Palm Dominates the Diet of Sun Bears at the Krau Wildlife Reserve, Malaysia. What are the Implications for the Conservation of Sun Bears? Int Bear News 22:15-16.

Clapham, M., O. T. Nevin, A. D. Ramsey, and F. Rosell. 2013. The function of strategic tree selectivity in the chemical signalling of brown bears. Animal Behaviour 85:1351-1357.

_____. 2014. Scent-marking investment and motor patterns are affected by the age and sex of wild brown bears. Animal Behaviour 94:107-116.

Crudge, B., C. Lees, M. Hunt, R. Steinmetz, G. Fredriksson, and D. Garshelis. 2019. Sun bears: Global status review & conservation action plan, 2019-2028. IUCN SSC Bear Specialist Group / IUCN SSC Conservation Planning Specialist Group / Free the Bears / TRAFFIC, 97 pp.

Crudge, B., T. Nguyen, and T. T. Cao. 2018. The challenges and conservation implications of bear bile farming in Viet Nam. Oryx:1-8.

Dalerum, F., A. Ganswindt, R. Palme, C. Bettega, M. d. M. Delgado, M. Dehnhard, S. Freire, R. G. González, J. Marcos, and M. Miranda. 2020. Methodological considerations for using faecal glucocorticoid metabolite concentrations as an indicator of physiological stress in the brown bear (*Ursus arctos*).

Darimont, C. T., and T. E. Reimchen. 2002. Intra-hair stable isotope analysis implies seasonal shift to salmon in gray wolf diet. Canadian Journal of Zoology 80:1638-1642.

Davis, C., L. Gaffi, T. Zaw, G. Mussoni, and J. A. Glikman. 2020. Possible Evidence for a Lack of Medicinal Efficacy in Sun Bear Bile? Int Bear News 29:15-16.

De, J., and R. Chakraborty. 2006. Identification of dorsal guard hairs of four Indian species of bear (Mammalia: Carnivora: Ursidae). Rec. Zool. Surv. India 106:19-26.

Drinkwater, R., I. B. Schnell, K. Bohmann, H. Bernard, G. Veron, E. Clare, M. T. P. Gilbert, and S. J. Rossiter. 2019. Using metabarcoding to compare the suitability of two blood-feeding leech species for sampling mammalian diversity in North Borneo. Molecular ecology resources 19:105-117.

Frederick, C., K. Hunt, R. Kyes, D. Collins, B. Durrant, J. Ha, and S. K. Wasser. 2013. Social influences on the estrous cycle of the captive sun bear (*Helarctos malayanus*). Zoo Biol 32:581-591.

Frederick, C., R. Kyes, K. Hunt, D. Collins, B. Durrant, and S. K. Wasser. 2010. Methods of estrus detection and correlates of the reproductive cycle in the sun bear (*Helarctos malayanus*). Theriogenology 74:1121-1135.

Fredriksson, G. 1998. Monitoring the adaptation process of reintroduced sun bears (*Ursus (Helarctos) malayanus euryspilus*), East Kalimantan, Indonesia. Report.

Fredriksson, G. 2005. Human-sun bear conflicts in east Kalimantan, Indonesian Borneo. Ursus 16:130-137.

Fredriksson, G. 2013. Sign Surveys for Monitoring Asiatic Black Bears and Sun Bears Across Their Ranges: Steps Towards Developing a Sign Survey Manual. Int Bear News 22:14.

Fredriksson, G., L. Danielsen, and J. Swenson. 2007. Impacts of El Nino related drought and forest fires on sun bear fruit resources in lowland dipterocarp forest of East Borneo. Pages 249-264 in Plant Conservation and Biodiversity. Springer.

Fredriksson, G., and R. Steinmetz. 2007. Bear sign survey training course. Phnom Tamao and Bokor National Park Cambodia 23:27.

Fredriksson, G. M. 2012. Effects of El Niño and large-scale forest fires on the ecology and conservation of Malayan sun bears (*Helarctos malayanus*) in East Kalimantan, Indonesian Borneo. Dissertation, Dissertation, Amsterdam, Netherlands, 204 pp.

Fredriksson, G. M., S. A. Wich, and Trisno. 2006. Frugivory in sun bears (*Helarctos malayanus*) is linked to El Niño-related fluctuations in fruiting phenology, East Kalimantan, Indonesia. Biological Journal of the Linnean Society 89:489-508.

Garshelis, D., and R. Steinmetz. 2015. Publication gradient among bear species tied to conservation needs. Int Bear News 24(2): 7-9.

Gervasi, V., S. Brunberg, and J. E. Swenson. 2006. An individual-based method to measure animal activity levels: a test on brown bears. Wildlife Society Bulletin 34:1314-1319.

Gilbert, B. K. 1999. Opportunities for social learning in bears. Mammalian social learning: comparative and ecological perspectives (HO Box and KR Gibson, eds.). Cambridge University Press, Cambridge, United Kingdom:225-235.

Goeritz, F., R. , K. Hermes, V. Jewgenow, P. Pozivil, Ratanakorn, L. Kolter, and T. B. Hildebrandt. 2006. High incidence of cysts of the cervix uteri in captive Malayan sun bears. American Proceedings Association of Zoo Veterinarians Annual Conference, Tampa, Florida, 114-115.

Goodnight, A. L., and K. Emanuelson. 2012. Two cases of canine adenovirus type 1 infection in Malayan sun bears (*Helarctos malayanus*) at the Oakland Zoo, California. Proceedings from the Annual Conference of the American Association of Zoo Veterinarians, Oakland, California, October 21-26:77.

Goossens, B., and M. Salgado-Lynn. 2013. Advances and difficulties of molecular tools for carnivore conservation in the tropics. Raffles Bulletin of Zoology.
Green, G. I., and D. J. Mattson. 2003. Tree rubbing by Yellowstone grizzly bears *Ursus arctos*. Wildlife Biology 9:1-9.
Groves, M. G. 1969. Griseofulvin treatment of Microsporum canis infection in Malayan sun bears (*Helarctos malayanus*). Journal of the American Veterinary Medical Association 155:1090-1092.
Hagey, L. R., D. L. Crombie, E. Espinosa, M. C. Carey, H. Igimi, and A. F. Hofmann. 1993. Ursodeoxycholic acid in the Ursidae: biliary bile acids of bears, pandas, and related carnivores. J Lipid Res 34:1911-1917.
Hall, S. S., and R. R. Swaisgood. 2009. Maternal care and cub development in the sun bear. Ursus 20:143-152.
Han, H., W. Wei, Y. Hu, Y. Nie, X. Ji, L. Yan, Z. Zhang, X. Shi, L. Zhu, and Y. Luo. 2019. Diet evolution and habitat contraction of giant pandas via stable isotope analysis. Current Biology 29:664-669. e662.
Harper, L. R., L. L. Handley, A. I. Carpenter, M. Ghazali, C. Di Muri, C. J. Macgregor, T. W. Logan, A. Law, T. Breithaupt, and D. S. Read. 2019. Environmental DNA (eDNA) metabarcoding of pond water as a tool to survey conservation and management priority mammals. Biological Conservation 238:108225.
Hartwig, S. 2005. Individual acoustic identification as a non-invasive conservation tool: an approach to the conservation of the African wild dog *Lycaon pictus* (Temminck, 1820). Bioacoustics 15:35-50.
Hein, A., R. Palme, K. Baumgartner, L. von Fersen, B. Woelfing, A. D. Greenwood, T. Bechshoft, and U. Siebert. 2020. Faecal glucocorticoid metabolites as a measure of adrenocortical activity in polar bears (*Ursus maritimus*). Conservation Physiology 8.
Heinemeyer, K. S., T. J. Ulizio, and R. L. Harrison. 2008. Natural sign: tracks and scats. Noninvasive survey methods for carnivores:45-74.
Hesterman, H., S. Wasser, and J. Cockrem. 2005. Longitudinal monitoring of fecal testosterone in male Malayan sun bears (*U. malayanus*). Zoo Biology: Published in affiliation with the American Zoo and Aquarium Association 24:403-417.
Hoffmann, S., L. Kolter, and J. Pallauf. Effect of crude fibre on the nutrition of captive Malayan sun bears (*Helarctos malayanus*) - preliminary results. 2005. 16th International Conference on Bear Research and Management, Riva del Garda, Italy, 80-81.
Homstol, L. 2011. Applications of learning theory to human-bear conflict: the efficacy of aversive conditioning and conditioned taste aversion. MSc thesis, University of Alberta, 83 pp.
Huetz, C., and T. Aubin. 2002. Bioacoustics approaches to locate and identify animals in terrestrial environments. Sensors for ecology, towards integrated knowledge of ecosystems. JJ Le Galliard, JM Guarini, F. Gaill (eds.). CNRS, Paris:83-96.
Ishige, T., M. Miya, M. Ushio, T. Sado, M. Ushioda, K. Maebashi, R. Yonechi, P. Lagan, and H. Matsubayashi. 2017. Tropical-forest mammals as detected by environmental DNA at natural saltlicks in Borneo. Biological Conservation 210:281-285.
Islam, M. A., M. Uddin, M. A. Aziz, S. B. Muzaffar, S. Chakma, S. U. Chowdhury, G. W. Chowdhury, M. A. Rashid, S. Mohsanin, and I. Jahan. 2013. Status of bears in Bangladesh: going, going, gone? Ursus 24:83-91.
Karamanlidis, A. A., E. Drosopoulou, M. de Gabriel Hernando, L. Georgiadis, L. Krambokoukis, S. Pllaha, A. Zedrosser, and Z. Scouras. 2010. Noninvasive genetic studies of brown bears using power poles. European Journal of Wildlife Research 56:693-702.
Kays, R., S. Tilak, M. Crofoot, T. Fountain, D. Obando, A. Ortega, F. Kuemmeth, J. Mandel, G. Swenson, and T. Lambert. 2011. Tracking animal location and activity with an automated radio telemetry system in a tropical rainforest. The Computer Journal 54:1931-1948.
Kendall, K. C., and K. S. McKelvey. 2008. Hair collection. Noninvasive survey methods for carnivores 106:141-182.
Knauf, T. 2006. Vergleichende Studien zur Reproduktionsbiologie bei Großbären.
Knecht, L. 2012. The use of hair morphology in the identification of mammals. Wildlife Forensics:129-143.

Kunde, M. N. 2017. *Ex-situ* and *In-situ* Conservation Approach for the Malayan Sun Bear (*Helarctos malayanus*). Griffith University, Queensland.

Kunde, M. N., R. F. Martins, J. Premier, J. Fickel, and D. W. Förster. 2019. Population and landscape genetic analysis of the Malayan sun bear *Helarctos malayanus*. Conservation Genetics:1-13.

Lam, L., M. M. Garner, C. L. Miller, V. E. Milne, K. A. Cook, G. Riggs, J. F. Grillo, A. L. Childress, and J. F. Wellehan Jr. 2013a. A novel gammaherpesvirus found in oral squamous cell carcinomas in sun bears (*Helarctos malayanus*). Journal of Veterinary Diagnostic Investigation 25:99-106.

Lam, M. M.-Y., D. Martin-Creuzburg, K.-O. Rothhaupt, K. Safi, E. Yohannes, and I. Salvarina. 2013b. Tracking diet preferences of bats using stable isotope and fatty acid signatures of faeces. PLoS ONE 8(12): e83452.

Lamb, C. T., D. A. Walsh, and G. Mowat. 2016. Factors influencing detection of grizzly bears at genetic sampling sites. Ursus 27:31-44.

Lee, D. C., V. J. Powell, and J. A. Lindsell. 2019. Understanding landscape and plot-scale habitat utilisation by Malayan sun bear (*Helarctos malayanus*) in degraded lowland forest. Acta Oecologica 96:1-9.

Lee, P.-S., H. M. Gan, G. R. Clements, and J.-J. Wilson. 2016. Field calibration of blowfly-derived DNA against traditional methods for assessing mammal diversity in tropical forests. Genome 59:1008-1022.

Lenz, T. 2020. Behavioral reactions of *Helarctos malayanus* to olfactory stimuli. BSc. thesis, University of Cologne, Germany, 60 pp

Lin, D., H. Chang, C. Chang, and C. Chen. 1997. Identification and differentiation of bear bile used in medicinal products in Taiwan. Journal of Forensic Science 42:817-823.

Liu, D., G. Zhang, R. Wei, H. Zhang, J. Fang, and R. Sun. 2005. Behavioral responsiveness of captive giant pandas (*Ailuropoda melanoleuca*) to substrate odors from conspecifics of the opposite sex. in Chemical Signals in Vertebrates 10. Springer, 101-109.

Livingstone, E., L. Gomez, and J. Bouhuys. 2018. A review of bear farming and bear trade in Lao People's Democratic Republic. Global Ecology and Conservation 13:e00380.

Livingstone, E., and C. R. Shepherd. 2014. Bear farms in Lao PDR expand illegally and fail to conserve wild bears. Oryx 50:176-184.

MacPhee, R. D., and A. D. Greenwood. 2013. Infectious disease, endangerment, and extinction. International journal of evolutionary biology 2013.

Malcolm, K., W. McShea, T. Van Deelen, H. Bacon, F. Liu, S. Putman, X. Zhu, and J. Brown. 2013. Analyses of fecal and hair glucocorticoids to evaluate short-and long-term stress and recovery of Asiatic black bears (*Ursus thibetanus*) removed from bile farms in China. General and comparative endocrinology 185:97-106.

McConkey, K., and M. Galetti. 1999. Seed dispersal by the sun bear *Helarctos malayanus* in Central Borneo. Journal of Tropical Ecology 15:237-241.

McNamara, T. 2007. The role of zoos in biosurveillance. International Zoo Yearbook 41:12-15.

Meijaard, E. 2004. Craniometric differences among Malayan sun bears (*Ursus malayanus*); evolutionary and taxonomic implications.

Miller, G. D. 1980. Behavioral and physiological characteristics of grizzly and polar bears and their relation to bear repellents.

Millspaugh, J. J., and B. E. Washburn. 2004. Use of fecal glucocorticoid metabolite measures in conservation biology research: considerations for application and interpretation. General and comparative endocrinology 138:189-199.

Moore, T. D., L. E. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Department.

Müller, N. 1998. Einfluß eines fremden Männchens auf das Sozial- und Fortpflanzungsverhalten der Malaienbären des Kölner Zoo (Effect of a new male on the social and reproduction behaviour of sun bears at the Cologne zoo). Diploma thesis, University of Cologne, Germany, 40 pp.

Murray, D. L., C. A. Kapke, J. F. Evermann, and T. K. Fuller. 1999. Infectious disease and the conservation of free-ranging large carnivores. Animal Conservation forum, Cambridge University Press 2:241-254.

Narayan, E., A. Willis, R. Thompson, M. Hunter-Ishikawa, and T. Bendixsen. 2018. Evaluating physiological stress in Asiatic black bears (*Ursus thibetanus*) rescued from bile farms in Vietnam. Animal welfare 27:295-303.

Ngoprasert, D., R. Steinmetz, D. H. Reed, T. Savini, and G. A. Gale. 2011. Influence of fruit on habitat selection of Asian bears in a tropical forest. The Journal of Wildlife Management 75:588-595.

Nie, Y., R. R. Swaisgood, Z. Zhang, Y. Hu, Y. Ma, and F. Wei. 2012. Giant panda scent-marking strategies in the wild: role of season, sex and marking surface. Animal behaviour 84:39-44.

Normua, F., S. Higashi, L. Ambu, and M. Mohamed. 2004. Notes on oil palm plantation use and seasonal spatial relationships of sun bears in Sabah, Malaysia. Ursus 15:227-231.

Officer, K., N. T. Lan, L. Wicker, N. T. Hoa, A. Weegenaar, J. Robinson, Y. Ryoji, and P. Loukopoulos. 2014. Foot-and-mouth disease in Asiatic black bears (*Ursus thibetanus*). Journal of Veterinary Diagnostic Investigation 26:705-713.

Onuma, M., M. Suzuki, and N. Ohtaishi. 2006. Possible conservation units of the sun bear (*Helarctos malayanus*) in Sarawak based on variation of mtDNA control region. Jpn J Vet Res 54:135-139.

Owen, M. A., N. M. Czekala, R. R. Swaisgood, K. Steinman, and D. G. Lindburg. 2005. Seasonal and diurnal dynamics of glucocorticoids and behavior in giant pandas. Ursus 16:208-221.

Patkó, L., N. Ujhegyi, and M. Heltai. 2016. More hair than wit: a review on carnivore related hair collecting methods. Acta Zool Bulg 68:5-13.

Pazhetnov, V. S., and S. V. Pazhetnov. 2005. Re-introduction of orphan brown bear cubs. in Kolter, L. and J. van Dijk (Eds.): Rehabilitation and release of bears. Zoologischer Garten Köln, 53-61.

Pedersen, A. B., K. E. Jones, C. L. Nunn, and S. Altizer. 2007. Infectious diseases and extinction risk in wild mammals. Conservation biology 21:1269-1279.

Peppin, L., R. McEwing, G. Carvalho, and R. Ogden. 2008a. A DNA-Based Approach for the Forensic Identification of Asiatic Black Bear (*Ursus thibetanus*) in a Traditional Asian Medicine. Journal of forensic sciences 53:1358-1362.

Peppin, L., R. McEwing, S. Webster, A. Rogers, D. Nicholls, and R. Ogden. 2008b. Development of a field test for the detection of illegal bear products. Endangered Species Research 9:263-270.

Peters, G., M. Owen, and L. Rogers. 2007. Humming in bears: a peculiar sustained mammalian vocalization. Acta Theriologica 52:379-389.

Powell, V. 2011. Resource use and habitat utilization of Malayan sun bear (*Helarctos malayanus*) in Harapan Rainforest, Sumatra. End of Project Report, International Association for Bear Research and Management, 14 pp.

Riese, R. 2001. Ernährung von Malaienbären (*Helarctos malayanus*) (Feeding and nutrition of Malayan sun bears (*Helarctos malayanus*)). Diploma thesis, Cologne University, Germany, 100 pp.

Sales, N. G., M. B. McKenzie, J. Drake, L. R. Harper, S. S. Browett, I. Coscia, O. S. Wangensteen, C. Baillie, E. Bryce, and D. A. Dawson. 2019. Fishing for mammals: landscape-level monitoring of terrestrial and semi-aquatic communities using eDNA from lotic ecosystems. bioRxiv:629758.

Sato, Y., C. Kamiishi, T. Tokaji, M. Mori, S. Koizumi, K. Kobayashi, T. Itoh, W. Sonohara, M. B. Takada, and T. Urata. 2014. Selection of rub trees by brown bears (*Ursus arctos*) in Hokkaido, Japan. Acta theriologica 59:129-137.

Schipper, J., J. S. Chanson, F. Chiozza, N. A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A. S. Rodrigues, S. N. Stuart, and H. J. Temple. 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. Science 322:225-230.

Schmidt-Burbach, J., and K. Officer. 2014. Suitability and health hazards of RFID tags in captive bears. WSPA, AAF, 14 pp.

Schneider, M. 2015. Behavioural and autonomic thermoregulation in Malayan sun bears (*Helarctos malayanus*) and polar bears (*Ursus maritimus*). Dissertation, Cologne University, Germany, 80 pp.

Schneider, M., T. Ziegler, and L. Kolter. in press. Thermoregulation in Malayan sun bears (*Helarctos malayanus*) and its consequences for *in situ* conservation. Journal of Thermal Biology.

Schnell, I. B., R. Sollmann, S. Calvignac-Spencer, M. E. Siddall, W. Y. Douglas, A. Wilting, and M. T. P. Gilbert. 2015. iDNA from terrestrial haematophagous leeches as a wildlife surveying and monitoring tool–prospects, pitfalls and avenues to be developed. Frontiers in zoology 12:24.

Schubert, G., M. Stockhausen, C. Hoffmann, K. Merkel, L. Vigilant, F. H. Leendertz, and S. Calvignac-Spencer. 2015. Targeted detection of mammalian species using carrion fly-derived DNA. Molecular ecology resources 15:285-294.

Schwarzenberger, F., and J. Brown. 2013. Hormone monitoring: an important tool for the breeding management of wildlife species. Wien Tierärztl. Monat. 100:209-225.

Schwarzenberger, F., G. Fredriksson, K. Schaller, and L. Kolter. 2004. Fecal steroid analysis for monitoring reproduction in the sun bear (*Helarctos malayanus*). Theriogenology 62:1677-1692.

Scotson, L., G. Fredriksson, D. Augeri, C. Cheah, D. Ngoprasert, and W. Wai-Ming. 2017. *Helarctos malayanus*. The IUCN Red List of Threatened Species 2017.: e.T9760A45033547.

Sethy, J., and N. P. Chauhan. 2018. Dietary preference of Malayan sun bear *Helarctos malayanus* in Namdapha Tiger Reserve, Arunachal Pradesh, India. Wildlife Biology (1).

Seymour, M. 2019. Rapid progression and future of environmental DNA research. Communications biology 2:1-3.

Shepherd, C. R., and L. A. Shepherd. 2010. The poaching and trade of Malayan sun bears in Peninsular Malaysia. Traffic Bulletin 23:49-52.

Skripova, K. 2013. The behavior of Asiatic black bear cubs (*Ursus (Selenarctos) thibetanus G. Guvier, 1823*) in the process of adaptation to the natural environment. Contemporary Problems of Ecology 6:113-120.

Smith, K. F., D. F. Sax, and K. D. Lafferty. 2006. Evidence for the role of infectious disease in species extinction and endangerment. Conservation biology 20:1349-1357.

Smith, M. E., J. D. Linnell, J. Odden, and J. E. Swenson. 2000. Review of methods to reduce livestock depredation II. Aversive conditioning, deterrents and repellents. Acta Agriculturae Scandinavica, Section A-Animal Science 50:304-315.

Solá, S., D. L. Garshelis, J. D. Amaral, K. V. Noyce, P. L. Coy, C. J. Steer, P. A. Iaizzo, and C. M. Rodrigues. 2006. Plasma levels of ursodeoxycholic acid in black bears, *Ursus americanus*: seasonal changes. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology 143:204-208.

Spiero, I. 2019. The Development of Explorative Behaviour and Neophobia in Captive Malayan Sun Bears (*Helarctos malayanus*). Report, Radboud University, Nijmegen, Netherlands, 27 pp.

Steffen, M. 1996. Sozialverhalten und Raum-Struktur-Nutzung von Malaienbären (*Helarctos malayanus*) in Abhängigkeit von der Gruppenzusammensetzung (Social behaviour and use of space and structure in Malayan sun bears (*Helarctos malayanus*) in relation to group composition). Diploma thesis, University of Cologne, Germany, 176 pp.

Steinmetz, R. 2011. Ecology and distribution of sympatric Asiatic black bears and sun bears in the tropical dry forest ecosystem of Southeast Asia. Dry forests of Asia: Conservation and ecology. Smithsonian Institution Press, Washington, DC, USA:249-273.

Steinmetz, R., and D. L. Garshelis. 2008. Distinguishing Asiatic black bears and sun bears by claw marks on climbed trees. The Journal of Wildlife Management 72:814-821.

_____. 2010. Estimating ages of bear claw marks in Southeast Asian tropical forests as an aid to population monitoring. Ursus 21:143-154.

Steinmetz, R., D. L. Garshelis, W. Chutipong, and N. Seuaturien. 2011. The shared preference niche of sympatric Asiatic black bears and sun bears in a tropical forest mosaic. PLoS ONE 6:e14509.

Steinmetz, R., D. L. Garshelis, W. Chutipong, and N. Seuaturien. 2013. Foraging ecology and coexistence of Asiatic black bears and sun bears in a seasonal tropical forest in Southeast Asia. Journal of Mammalogy 94:1-18.

Steinmetz, R., M. Hunt, G. Fredriksson, and A. Olsson. 2007. Bear Sign - Survey Training Held in Cambodia. International Bear News 16:6-7.

Taberlet, P., J. J. Camarra, S. Griffin, E. Uhres, O. Hanotte, L. Waits, C. Dubois-Paganon, T. Burke, and J. Bouvet. 1997. Noninvasive genetic tracking of the endangered Pyrenean brown bear population. Molecular ecology 6:869-876.

Taberlet, P., E. Coissac, M. Hajibabaei, and L. H. Rieseberg. 2012. Environmental DNA. Molecular ecology 21:1789-1793.

Tee, T. L., S. Ratnayeke, F. T. van Manen, S. T. Wong, and S. Sharp. 2016. Individual Identification in Sun Bears: Testing Methods to Capture Chest Marks and Hair Samples. Int Bear News 25:25-26.

Teo, S. 2013. Habitat use by Malayan sun bears (*Helarctos malayanus*) in the lowland rainforests of Sabah, Malaysian Borneo. M. Sc. thesis, National Pingtung University of Science and Technology.

Ternent, M. A., and D. L. Garshelis. 1999. Taste-aversion conditioning to reduce nuisance activity by black bears in a Minnesota military reservation. Wildlife Society Bulletin:720-728.
Ushio, M., H. Fukuda, T. Inoue, K. Makoto, O. Kishida, K. Sato, K. Murata, M. Nikaido, T. Sado, Y. Sato, M. Takeshita, W. Iwasaki, H. Yamanaka, M. Kondoh, and M. Miya. 2017. Environmental DNA enables detection of terrestrial mammals from forest pond water. Molecular ecology resources 17:e63-e75.
Wang, N., Y. Feng, T. N. Xie, W. Su, M. Zhu, O. Chow, Y. Zhang, K.-M. Ng, C.-H. Leung, and Y. Tong. 2011. Chemical and biological analysis of active free and conjugated bile acids in animal bile using HPLC-ELSD and MTT methods. Experimental and therapeutic medicine 2:125-130.
Ware, J. V., K. D. Rode, A. M. Pagano, J. Bromaghin, C. T. Robbins, J. Erlenbach, S. Jensen, A. Cutting, N. Nicassio-Hiskey, and A. Hash. 2015. Validation of mercury tip-switch and accelerometer activity sensors for identifying resting and active behavior in bears. Ursus:86-96.
Williams, E., and E. Thorne. 1996. Infectious and parasitic diseases of captive carnivores, with special emphasis on the black-footed ferret (*Mustela nigripes*). Revue scientifique et technique-Office international des epizooties 15:91-104.
Wong, S. 2002a. The ecology of Malayan sun bear (*Helarctos malayanus*) in the Lowland Tropical Forest of Borneo. M. Sc. thesis, University of Montana, 153 pp.
Wong, S. T., C. Servheen, L. Ambu, and A. Norhayati. 2005. Impacts of fruit production cycles on Malayan sun bears and bearded pigs in lowland tropical forest of Sabah, Malaysian Borneo. Journal of Tropical Ecology 21:627-639.
Wong, S. T., Servheen, C., Ambu, L. 2002b. Food habits of Malayan sun bears in lowland tropical forest of Borneo. Ursus 13:127-136.
Yeh, Y. H., D. F. Hwang, J. F. Deng, and Y. T. Lee. 2008. Toxycology of bile salts in animals. Toxin Reviews 27:1-26.
Zhang, Y. 1996. Genetic variability and conservation relevance of the sun bear as revealed by DNA sequences. Zoological research 17:459-468.

APPENDIX: Research topic submission form

Notes:

Complete a separate form for each proposed research topic.

Send completed forms by email to Dr. Marion Schneider, Ex situ Management Focal Point, Sun Bear Conservation Action Plan Implementation Task Force, at mfschneider@gmx.de.

Submitted proposed research topics will be reviewed periodically.

- -

First Name: ___________________

Surname: _____________________

Affiliation(s): ____

Email address: _____________________________

Select focus of proposed topic (*Check <u>one only</u>*):

Idea for *ex situ* research that may benefit sun bear conservation ☐

Idea for *in situ* research that may benefit *ex situ* sun bear welfare ☐

Idea for *ex situ* research with other species that may benefit sun bear conservation or welfare ☐

Select theme(s) (*Check all that apply*):

Breeding and reproduction ☐	Behaviour ☐	Diet and Nutrition ☐
Conservation education ☐	Energetics ☐	Population Monitoring ☐
Population management ☐	Genetics ☐	Forensics ☐
Physiology and metabolism ☐	Disease ☐	Field techniques ☐
Methods ☐	Visitor studies ☐	
Other(specify):________________		

Research question:

____

Further details/rationale:

____

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____

____

Potential welfare or conservation outcome:

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Further reading/comments (*Please attach relevant PDFs to the email with this form*):

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