DER ZOOLOGISCHE GARTEN

THE ZOOLOGICAL GARDEN

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- news from zoological gardens
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Die Auswirkungen der Beweidung mit Niederländischen Landziegen und Bentheimer Landschafen in einem verwilderten Heidegebiet

Der Effekt von Beweidung auf die heidespezifische Vegetation in dem mit Spätblühender Traubenkirsche überwucherten „Wacholderhain am Kloster Bardel“

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Zusammenfassung

Die vorliegende Studie ist ein gutes Beispiel dafür, wie Zoologische Gärten Artenschutz mit regionalem Naturschutz verbinden können. Das Landschaftsschutzgebiet „Wacholderhain am Kloster Bardel“ ist ein Heidegebiet, das durch die Spätblühende Traubenkirsche (*Prunus serotina*) überwuchert wurde, wodurch wertvoller Lebensraum verschwindet. Durch unterschiedliche Pflegemaßnahmen wurde die Traubenkirsche größtenteils aus dem Gebiet entfernt. In dieser Studie wurde anhand von Vegetationsaufnahmen der Zustand der Vegetation in dem Gebiet untersucht. Spannend zu verfolgen ist, wie die Sukzession der Flächen in nur drei Jahren nach einer Abplaggaktion in Richtung der Heidelandschaft voranschreitet. Allerdings gibt es immer noch Bedrohungen durch Vergrasung sowie Wurzelbrut, Stockausschläge und Neukeimung der Spätblühenden Traubenkirsche. Seit dem Beginn eines Beweidungsmanagements durch den Tierpark Nordhorn ist sowohl die Vergrasung der Heideflächen als auch die Überwucherung durch die Spätblühenden Traubenkirsche nachweislich zurückgegangen. Deshalb wird auch in Zukunft ein gutes Beweidungsmanagement notwendig sein, um eine weitere Zunahme der charakteristischen Arten der armen Sandböden zu ermöglichen.

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Einleitung

Formulieren Zoos heute ihre Aufgaben oder Ziele, erwähnen sie nicht selten das Vier-Säulen-Modell, welches von Heini Hediger schon vor ca. fünfzig Jahren benannt wurde (Hediger, 1973). Auch der Tierpark Nordhorn verschreibt sich diesen vier Aufgabenfeldern: Artenschutz, Bildung, Erholung und Forschung – verbindet diese aber sehr konsequent mit einem fünften Thema, der Regionalität. Regionales Denken und Handeln wird auch in anderen gesellschaftlichen Bereichen in den letzten Jahren immer präsenter, sodass Regionalität in den Medien schon regelmäßig als ein Megatrend betitelt wird. Die Verknüpfung dieses Themas mit allen vier oben genannten Schwerpunkten – Artenschutz, Bildung, Erholung und Forschung – führte dazu, dass der Tierpark Nordhorn nicht nur in der Grafschaft Bentheim, sondern auch weit darüber hinaus als *Regionales Arten- und Naturschutzzentrum* wahrgenommen wird. In dieser Funktion fördert der Tierpark in-situ-Artenschutz direkt vor Ort und betreut zum Beispiel 170 ha Naturschutzflächen unterschiedlicher Landschaftsformen. Einen Schwerpunkt bildet hierbei die Erhaltung der besonders für diese Region typischen Wacholderheiden durch den Einsatz tierparkeigener Schaf- und Ziegenherden (Kramer & Lünterbusch, 2015).

Viele Heideflächen in Europa sind durch die frühere landwirtschaftliche Landnutzung, der Plaggeneschwirtschaft, entstanden. Die dürftigen, nährstoffarmen Böden mit Zwergsträuchern und Wald bildeten einen idealen Lebensraum für viele lichtliebende Pflanzen und Tiere. Gegenwärtig ist viel Heideland in Europa verschwunden und damit ein entscheidender Lebensraum für daran angepasste Tier- und Pflanzenarten. Gründe für den Rückgang sind die zunehmende Intensivierung der Landwirtschaft, Aufforstung und der Bau von Straßen, Gewerbe- oder Siedlungsraum. Invasive Pflanzenarten, sogenannte Neophyten, spielen ebenfalls eine Rolle (Fagúndez, 2013). Dies ist auch im Wacholderhain am Kloster Bardel im Nordwesten Deutschlands der Fall. Der Wacholderhain Bardel ist ein 10 Hektar großes Landschaftsschutzgebiet und befindet sich in einem Decksandgebiet an der deutsch-niederländischen Grenze im Südwesten der Grafschaft Bentheim. Naturräumlich gehört es zum nordwestlichsten Bereich der westfälischen Bucht. Das Gebiet ist bekannt für die zahlreichen Wacholdersträucher (*Juniperus communis*). Vor einigen Jahren drohte das Heidegebiet jedoch durch eine invasive Art, die Spätblühende Traubenkirsche (*Prunus serotina*), vollständig überwuchert zu werden. Innerhalb weniger Jahre bildet sie dichte Gebüsche und beschattet somit in kurzer Zeit selbst die hoch wachsenden Wacholdersträucher und führt so zum Absterben der Wacholder. Im Jahr 2015 wurde der Tierpark Nordhorn von der Naturschutzstiftung der Grafschaft Bentheim mit der Betreuung dieses Gebiets beauftragt und erste Maßnahmen zur Entfernung der Spätblühenden Traubenkirsche wurden durchgeführt. Die großen Exemplare der Spätblühenden Traubenkirsche wurden im gesamten Gebiet gefällt, kombiniert mit Maßnahmen wie Abplaggen und „auf den Stock setzen“. Alljährlich findet eine ehrenamtliche Pflegeaktion des Flächeneigentümers, dem Missionsgymnasium St. Antonius, statt (Lünterbusch, 2014; Uphaus et al., 2016). Um das Gebiet aber langfristig vor dem erneuten massiven Auftreten der Traubenkirsche zu schützen und definierte Zielarten zu fördern, wurde gemeinsam von der Naturschutzstiftung des Landkreises Grafschaft Bentheim und dem Tierpark Nordhorn ein Beweidungskonzept erarbeitet. Dieses sieht vor, dass bestimmte Flächen ganzjährig mit Ziegen und während des Sommers mit Schafen beweidet werden sollen. Bei der konkreten Auswahl der Ziegen- bzw. Schafrasse bot sich dem Tierpark als anerkannter Archepark der GEH (Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen e. V.) die Gelegenheit nicht nur zur Erhaltungszucht bedrohter

Haustierrassen beizutragen, sondern mit diesen auch im Naturschutz zu arbeiten. Da für diese Art der Landschaftspflege nur genügsame und robuste Rassen in Frage kamen, fiel die Wahl zum einen auf die Niederländische Landziege und zum anderen auf das Bentheimer Landschaf.

Die Niederländische Landziege (Abb. 1) ist eine alte und ursprüngliche Ziegenrasse aus den Niederlanden, die dort früher sehr weit verbreitet, aber 1950 nahezu verschwunden war.

Abb. 1: Niederländische Landziegen. Foto: Franz Frieling
Fig. 1: Dutch landrace goat. Photo: Franz Frieling

Es ist vor allem den Bemühungen der Zoos in Rotterdam und Emmen (Niederlande) zu verdanken, dass es heute vor allem in den Niederlanden und vereinzelt auch in Deutschland wieder über 2000 Exemplare im Herdbuch gibt (LFNL, 2023). Aufgrund ihrer Robustheit ist diese Rasse besonders für die Landschaftspflege in kargen Gebieten geeignet. Ziegen sind vom intermediären Fresstyp; sie fressen Gräser und Kräuter, ergänzt durch Blätter und Zweige (Mekel, 2019). Im Frühjahr und Sommer wird auf Heideflächen hauptsächlich Pfeifengras gefressen, während später im Jahr auf Heidekraut umgestellt wird. Außerdem werden Bäume das ganze Jahr über gefressen (Oosterveld & Slim, 1986; Harteisen, 2003). Da die Landziegen sich mit ihren Vorderbeinen an Bäumen aufrichten, um die höheren Äste zu erreichen, können die Bäume schwer beschädigt werden (Burkart, 2003). Ziegen bevorzugen Laubbäume gegenüber Nadelbäumen (Harteisen, 2003). Die Knospen, Blätter und jungen Zweige werden im Frühjahr und Sommer gefressen, danach wird die Baumrinde von den Ziegen abgeschält (Oosterveld & Slim, 1986; Marabini, 2014). Der Einsatz von Ziegen in Heidegebieten führt daher zu einer Abnahme der Baumbestände in der Fläche (Seifert et al., 2014).

Neben den Niederländischen Landziegen werden auch Bentheimer Landschafe (Abb. 2) im Wacholderhain Bardel eingesetzt. Das Bentheimer Landschaf ist eine heute stark bedrohte Rasse, die vor über einhundert Jahren zahlreich in der Grafschaft Bentheim, dem Emsland und angrenzenden niederländischen Regionen für den Einsatz auf kargen Flächen gezüchtet wurde.

Abb. 2: Bentheimer Landschafe. Foto: Franz Frieling
Fig. 2: Bentheim sheep. Photo: Franz Frieling

Nach einem Tiefpunkt in den 1970er-Jahren – damals gab es nur noch etwa 50 Zuchttiere – ist der Bestand heute wieder auf fast 4.000 gemeldete Zuchttiere gestiegen (Land unter e. V., 2023). Auch der Tierpark Nordhorn hat einen großen Anteil an dem Erhalt dieser genügsamen und robusten Landschaftspfleger und gibt damit ein gutes Beispiel für die Bedeutung moderner Zoos, nicht nur für bedrohte Wildtierarten, sondern ebenfalls für den Erhalt seltener Haustierrassen (Kögler, 2021). Im Gegensatz zu Ziegen sind Schafe selektive Weidetiere (Kramer & Lünterbusch, 2015). Beispielsweise fressen sie bevorzugt die jungen, blättrigen Gräser mit hohem Energiewert. Diese Gräser werden bodennah abgebissen (Dallinga & Tjaden, 1981). Gehölze werden hauptsächlich im zeitigen Frühjahr gefressen, wie z. B. die jungen Austriebe von Birken- und Brombeersträuchern. Schafe können in Heidegebieten zu einer Abnahme bestimmter Gräser und zu einer Zunahme junger Zwergstrauchheiden und anderer Heidepflanzen führen (Verbeek et al., 2006), aber auch eine Entwicklung in Richtung Borstgrasrasen bewirken (Ellenberg, 1996).

Die Ziele der vorliegenden Studie sind zum einen die vegetationskundliche Aufnahme der vom Tierpark betreuten Flächen, um einen Überblick zu bekommen, welche (bedrohten) Arten durch die bisher vorgenommenen Maßnahmen gefördert wurden, zum anderen soll hier gezeigt werden, dass der Einsatz von Ziegen und Schafen einen entscheidenden Unterschied bei der langfristigen Bekämpfung der Spätblühenden Traubenkirsche macht. Hierzu werden Vegetationsaufnahmen beweideter Flächen mit denen vergleichbarer unbeweideter Flächen verglichen.

Material und Methode

In dem Untersuchungsgebiet wurden 32 Vegetationsaufnahmen durchgeführt, die sich über die *Birken-Eichenwald*-Bereiche (blau), die *Binnendünen* (gelb), die *Trockene Heide* (grün), *Wacholdergebüsch* (violett) und eine *Alte Ackerfläche* (rot) erstreckten (Abb. 3 und Tab. 1). Die ehemalige Ackerfläche gehört nicht zum Landschaftsschutzgebiet. Dort wurden jedoch 2018 im Rahmen einer Ausgleichs- und Ersatzmaßnahme 30 cm des Oberbodens abgebaggert. Im angrenzenden niederländischen Gebiet wurden drei Aufnahmen gemacht, um die Wirkung von Beweidung und Nicht-Beweidung auf die Spätblühende Traubenkirsche im Birken-Eichenwald zu vergleichen. Die Vegetationsaufnahmen wurden nach der Tansley-Methode durchgeführt, wobei die Koordinaten des Zentrums jedes Versuchsfeldes aufgezeichnet wurden. Anschließend wurden die Vegetationsaufnahmen nach Pflanzengesellschaften (= Assoziationen) sortiert. (Schaminée et al., 1995).

Abb. 3: Übersicht der Vegetationsaufnahmen, siehe Tabelle 1 für die Legende.
Fig. 3: Overview on the releves, see table 1 for legends.

Tab.1: Vegetationsaufnahme.
Tab. 1: Releve.

Untergebiet	**Maßnahmen**	**Beweidungsregime**	**Boden**	**Farbe** (Abb. 3)
Alte Ackerfläche	30 cm A-Horizont (Mutterboden) abgetragen (2018)	-	Regosol aus Kulturboden	Rot
Binnendünen	Traubenkirschen gerodet (2014) Abgeplaggt (2015/2016) Jährlich händisch junge Traubenkirschen und Brombeeren entfernt	Ziegen und Schafe	Regosol	Gelb
Trockene Heide	Traubenkirschen gerodet (2014) Abgeplaggt (2015/2016) Jährlich händisch junge Traubenkirschen und Brombeeren entfernt	Ziegen und Schafe	Podsol	Grün
Wacholdergebüsch	Teilweise abgeplaggt, teilweise Traubenkirsche gefällt oder gerodet	Ziegen	Podsol/Regosol	Violett
Birken-Eichenwald	Teilweise abgeplaggt, teilweise Traubenkirsche gefällt	Ziegen	Podsol	Blau
Niederländische Fläche	Traubenkirsche gefällt/auf den Stock gesetzt	-	Podsol	Blau(N)

Ergebnisse

Alte Ackerfläche

Auf der ehemaligen Ackerfläche (Abb. 4) wurden Pflanzen gefunden, die am Beginn der Sukzession stehen. So wurden zum Beispiel die Pionierarten Frühe Haferschmiele (*Aira praecox*), Nelken-Haferschmiele (*Aira caryophyllea*) und Zwerg-Filzkraut (*Filago minima*) gefunden, die alle zur Assoziation Pionierrasen der Frühen Haferschmiele gehören; eine in Nordwestdeutschland verbreitete Pflanzengesellschaft auf trockenen, sauren bis neutralen Sandböden (Schröder, 1989; Nowak & Nowak, 2013).

Abb. 4: Aufnahme auf der ehemaligen Ackerfläche. Foto: Jetske van den Berg
Fig 4: Releve of the formerly agriculture crop land. Photo: Jetske van den Berg

Auf Teilen der Ackerfläche wurden Pflanzen gefunden, die bereits weiter in der Sukzession stehen und die auch auf den Binnendünen gefunden werden konnten, darunter Silbergras (*Corynephorus canescens*) und Nacktstängeliger Bauernsenf (*Teesdalia nudicaulis*) der Assoziation Frühlingsspörgel-Silbergras-Rasen sowie das Berg-Sandglöckchen (*Jasione montana*).

Außerdem wurden auf der ehemaligen Ackerfläche auch Arten wie Kanadisches Berufkraut (*Conyza canadensis*), Wolliges Honiggras (*Holcus lanatus*), Deutsches Weidelgras (*Lolium perenne*), Wiesen-Lieschgras (*Phleum pratense*) und Spitzahorn (*Acer platanoides*) gefunden. Diese Arten wachsen alle auf nährstoffreichen Böden. Das rührt vermutlich daher, dass an den Stellen, an denen diese Pflanzen wachsen, durch die über viele Jahre erfolgte Düngung trotz des Abtragens des Oberbodens noch viele Nährstoffe im Boden vorhanden sind. Wenn diese Pflanzen weiter expandieren, können sie die hier erwünschten Pflanzen verdrängen. Um dem entgegenzuwirken,

empfiehlt es sich, im Frühjahr einige Schafe auf der ehemaligen Ackerfläche einzusetzen. Schafe sind sehr wählerische Weidetiere, die mit ihrem sensiblen Maul in der Lage sind, die energiereichen Gräser zu selektieren und zu verbeißen (Dallinga & Tjaden, 1981; Elbersen et al., 2003). Wegen der steifen und behaarten Stiele wird das Wollige Honiggras, wenn es älter ist, von den Schafen nicht gerne gefressen. Wolliges Honiggras wird jedoch im Winter aufgenommen, wenn weniger Futter vorhanden ist (Dallinga & Tjaden, 1981). Bei Bedarf könnte im Winter eine geringe Anzahl Schafe zur Bekämpfung des Wolligen Honiggras eingesetzt werden. Um eine Überweidung zu verhindern, müssen die Schafe rechtzeitig aus der Fläche entfernt werden, da dies sonst zu Problemen für die erwünschten Pflanzen führen kann (Wallis de Vries, 2004).

Binnendünen

Aufgrund des aufgetürmten Sandes und des nährstoffarmen Regosolbodens bieten die Binnendünen (Abb. 5) ideale Wachstumsbedingungen für Pflanzen aus der Assoziation Frühlingsspörgel-Silbergras-Rasen (Schröder, 1989; Horsthuis & Schamineé, 1993).

Abb. 5: Aufnahme auf der Binnendünen. Foto: Jetske van den Berg
Fig. 5: Releve of the inland dunes. Photo: Jetske van den Berg

Hier werden auch Arten wie Besenheide (*Calluna vulgaris*) gefunden, welche typisch für die trockene Heide sind. Dies könnte auf den Beginn der Sukzession in Richtung von Sandginsterheidevegetation hindeuten, einer weiteren Assoziation der in Nordwestdeutschland verbreiteten sauren, nährstoffarmen Sandböden.

Bemerkenswerte Artenfunde in den Vegetationsaufnahmen dieser gefährdeten Pflanzengesellschaft waren neben dem Silbergras (*Corynephorus canescens*) und dem Frühlingsspörgel

(*Spergula morisonii*) z. B. der Bauernsenf (*Teesdalia nudicaulis*), die Frühlingsschmiele (*Aira praecox*) und die Quirlige Knorpelmiere (*Illecebrum verticillatum*).

Die am häufigsten anzutreffende Art war jedoch die Draht-Schmiele (*Deschampsia flexuosa*). Die Draht-Schmiele ist keine typische Art für Frühlingsspörgel-Silbergras-Rasen, wächst aber auch auf trockenen, sauren, nährstoffarmen Sandböden. Eine Zunahme der Draht-Schmiele kann durch eine hohe Stickstoffdeposition verursacht werden (Bokdam & Gleichman, 1989). Bei großen Mengen an Draht-Schmiele besteht die Gefahr, dass die ursprüngliche Vegetation überwuchert wird, was zu einer Degeneration der Assoziation Frühlingsspörgel-Silbergras-Rasen führt (Schröder, 1989). Draht-Schmiele wird das ganze Jahr über durch Schafe gefressen, ist aber fast nur im Winter Teil der Ernährung von Ziegen, was Schafe zu einem geeigneteren Weidetier für die Binnendünen macht (Dallinga & Tjaden, 1981; Bokdam & Gleichman, 1989; de Vries & van Eekeren, 2007).

Trockene Heide

Auf den Heiden auf Podsolböden (Abb. 6) wurden Pflanzen der Assoziation Sandginsterheide gefunden. Die Charakterarten für diese Pflanzengesellschaft, Behaarter Ginster (*Genista pilosa*) und Quendel-Seide (*Cuscuta epithymum*), wurden jeweils nur selten gefunden.

Abb. 6: Aufnahme auf den Heiden auf Podsolböden. Foto: Jetske van den Berg
Fig. 6: Releve of heathland and podsol. Foto: Jetske van den Berg

Neben der bestandsbildenden Besenheide (*Calluna vulgaris*) wurden die anderen charakteristischen Arten seltener – weniger stet – angetroffen. Die Gesellschaft ist noch nicht optimal entwickelt, was sich damit erklären lässt, dass das Areal erst im Jahr 2015/2016 abgeplaggt

wurde. Neben den typischen Arten für Trockenheide wurden stellenweise auch typische Arten für Feuchtheide gefunden, wie z. B. die Glockenheide (*Erica tetralix*), die Sparrige Binse (*Juncus squarrosus*) und die Pillen-Segge (*Carex pilulifera*). Auch Trittzeiger wie das Borstgras (*Nardus stricta*) und der Dreizahn (*Danthonia decumbens*) treten vereinzelt auf.

Auch Kaktusmoos (*Campylopus introflexus*) und Draht-Schmiele wurden häufig auf der trockenen Heide angetroffen. Das neophytische Kaktusmoos bildet dichte Teppiche, die anderen Arten das Keimen erschweren. Insbesondere die Erdflechtenarten (*Cladonia* und *Cetraria*) werden durch das massive Vorkommen von Kaktusmoos bedroht (Biermann & Daniels, 1997). In geringerem Maße wird auch die Keimung von Birken (*Betula*) beeinträchtigt, obwohl eigentlich Birken von dem abgeplaggten Boden profitieren, da sie ein passendes Keimbett finden. Überwucherung durch Drahtschmiele und Birke kann durch den Einsatz von Schafen verhindert werden. Es ist ratsam, die Schafe im Frühjahr auf der trockenen Heide weiden zu lassen. Holzige Anteile werden hauptsächlich im Frühjahr von den Schafen gefressen, da dann noch keine harte Verholzung eingetreten ist (Verbeek et al., 2006; Fottner et al., 2004). Leider verbeißen die Schafe die bitterschmeckenden Sand-Birken (*Betula pendula*) weniger effektiv als die Moor-Birke (*Betula pubescens*) (Beyer, 1968).

Wacholdergebüsch

Die Aufnahmen mit Wacholdergebüschen auf den Binnendünen neben der trockenen Heide (Abb. 7) gehören der Pflanzengesellschaft Gabelzahnmoos-Wacholder-Gebüsch an. Diese Assoziation findet man in den trockenen, nährstoffarmen, sauren Flugsand- und Heidelandschaften Nordwestdeutschlands und den Niederlanden (Neuhäusl et al., 1985; Pott, 1995; Hommel et al., 2007). Gebiete mit Gabelzahnmoos-Wacholder-Gebüsch sind mit Perioden von extensiver Beweidung in der Vergangenheit verbunden (Hommel et al., 2007).

Abb. 7: Aufnahme auf der Wacholderheide. Foto: Jetske van den Berg
Fig. 7: Releve of juniper-heathland. Photo: Jetske van den Berg

Die Spätblühende Traubenkirsche stellt ein großes Problem für die Wacholdergebüsche (*Juniperus communis*) dar. Die Spätblühende Traubenkirsche wurde nicht an Stellen gefunden, an denen das Wacholdergebüsch so dicht war, dass für die Spätblühende Traubenkirsche nicht genügend Licht zur Keimung zur Verfügung steht, und sie fehlte an Stellen, an denen zuvor abgeplaggt wurde oder wo sie händisch gerodet wurde. Der Nachteil des Abplaggens ist jedoch, dass sich an diesen Stellen schnell das Kaktusmoos festgesetzt hat. In den Wacholderbeständen findet seit 2014 einmal jährlich im Rahmen der Niedersächsischen Naturschutzwoche für Kinder eine ehrenamtliche Pflegeaktion des Flächeneigentümers, dem Missionsgymnasium St. Antonius aus Bentheim/Bardel, statt (GreenCut, 2023).

Der niedrigste Anteil an Spätblühender Traubenkirsche wurde auf den Flächen gefunden, auf denen die Spätblühende Traubenkirsche zuvor auf den Stock gesetzt und dann mit Ziegen

Tab. 2: Die Testfelder, auf denen Spätblühende Traubenkirsche gefunden wurde.

Tab. 2: Testing area with Black cherry.

Versuchsfeld	Beweidungsregime	Andere Maßnahmen	%-Bedeckung Spätblühende Traubenkirsche	% Vegetative/ Adult	% blattlos	% Sämling/ juvenil	Geschätzte durch-schnittliche Höhe in cm
Wacholder Trockene Heide 1	Ziegen seit 2016	Traubenkirsche auf den Stock gesetzt in 2015	3	100	0	0	30
Wacholder Trockene Heide 2	Ziegen seit 2016	Keine	8	80	0	20	70
Wacholder Binnendü-nen 1	Ziegen seit 2016	Große Exemplare der Traubenkirsche mit Bagger entfernt	20	98	0	2	40
Wacholder Binnendü-nen 2	Ziegen seit 2016	Keine	10	80	0	20	30
Wacholder Binnendünen 3	Ziegen seit 2016	Keine	25	98	0	2	75
Birken-Eichenwald 1	Ziegen seit 2016	Traubenkirsche auf den Stock gesetzt in 2015	30	60	40	0	75
Birken-Eichenwald 2	Ziegen seit 2016	Traubenkirsche auf den Stock gesetzt in 2015	35	85	10	5	50
Birken-Eichenwald 3	Ziegen seit 2016	Traubenkirsche auf den Stock gesetzt in 2015	40	85	5	10	100
Niederländi-sche Fläche 1	Keine	Traubenkirsche auf den Stock gesetzt in 2015	45	95	0	5	150
Niederländi-sche Fläche 2	Keine	Traubenkirsche auf den Stock gesetzt in 2015	50	95	0	5	150
Niederländi-sche Fläche 3	Keine	Traubenkirsche auf den Stock gesetzt in 2015	40	95	0	5	150

nachbeweidet wurden (Tab. 2). Dies kann durch die Entnahme der samentragenden Individuen in diesen Flächen in Kombination mit dem Verbiss, der händischen Nachpflege und einer dichten Baumschicht erklärt werden. Die höchsten Prozentsätze an Traubenkirsche wurden auf den Binnendünen beobachtet.

Schafe allerdings fressen nur die Sämlinge und jungen Blätter der Spätblühenden Traubenkirsche und sind daher nicht effektiv genug, um die Traubenkirsche zu bekämpfen (Heyne, 2003). Ziegen hingegen können genutzt werden, um die Waldbildung zu verhindern. Sie fressen das ganze Jahr über Blätter und Zweige, mit einer Vorliebe für Spätblühende Traubenkirsche, trotz der enthaltenden Blausäure, besonders im Juli und August (Kivit & van Diepen, 2007). Die Niederländischen Landziegen schälen auch die dickeren Stämme der Traubenkirsche mit den Zähnen.

Abb. 8: Aufnahme im Wald. Foto: Jetske van den Berg.
Fig. 8: Releve in the forest. Photo: Jetske van den Berg

Birken-Eichenwald

Die Aufnahmen im Wald (Abb. 8) sind der Birken-Stieleichenwald-Assoziation zuzurechnen. Dies ist eine Pflanzengesellschaft der sauren, nährstoffarmen Sandböden Nordwestdeutschlands. Diese Assoziation ist mit Ausnahme der Moosschicht relativ artenarm (Pott, 1995; Schaminée et al. 2002).

Beispiele typischer Arten für diese Assoziation sind Draht-Schmiele und Stieleiche (*Quercus robur*). Am Ruheplatz der Ziegen, der sich ebenfalls in diesem Waldstück befindet, treten als Störzeiger mehr Gräser auf als in den anderen Aufnahmen: Wolliges Honiggras (*Holcus lanatus*), Einjähriges Rispengras (*Poa annua*) und Deutsches Weidelgras (*Lolium perenne*), die von

der Nährstoffanreicherung durch den Ziegenkot und von dem höheren Lichtangebot durch die Entnahme der Traubenkirschen profitieren.

Auch im Birken-Eichenwald war die Spätblühende Traubenkirsche zahlreich vorhanden. Der größte Anteil an Spätblühender Traubenkirsche wurde in der „Niederländischen Fläche“ gefunden. In dieser Fläche ist die Traubenkirsche nur 2015 auf den Stock gesetzt worden, aber es hat keine Beweidung stattgefunden. Hier wurden die Exemplare im Durchschnitt größer als in den Untersuchungsfeldern im Wachoderhain Bardel, wo die Traubenkirsche auch auf den Stock gesetzt wurde, danach aber eine Beweidung durch Ziegen stattfand (Tab. 2). Bei den Aufnahmen im Wacholderhain Bardel wurde ein geringerer Anteil adulter Exemplare gefunden und es wurden Individuen ohne Blätter und mit Fraßschäden entdeckt. Darüber hinaus gab es in der Niederländischen Fläche mehr Sträucher wie Brombeeren (*Rubus* spec.), Roteichen (*Quercus rubra*) und Kupfer-Felsenbirnen (*Amelanchier lamarckii*) sowie mehr Vergrasung durch die Draht-Schmiele. Dies lässt sich auch dadurch erklären, dass es in dieser Fläche keine Beweidung gibt. Diese Ergebnisse bestätigen die Vermutung, dass Landziegen effektiv den Bewuchs durch die Spätblühende Traubenkirsche bekämpfen.

Diskussion

Der Wacholderhain Bardel ist eine botanisch interessante Fläche, da hier mehr als 60 unterschiedliche Arten (ohne Moose und Flechten) in mindestens fünf verschiedenen Pflanzengesellschaften vorkommen. Zusätzlich sind in dem Gebiet verschiedene Sukzessionsstadien/Übergangsstadien zwischen Silikatmagerrasen, Heide, Wacholderhain und Eichen-Birken-Wald zu finden. Aber es muss beachtet werden, dass ohne ein intensives Pflegemanagement diese artenreiche Vegetation verloren zu gehen droht. Im Jahr 2014 – vor den Entkusselungs- und Abplaggmaßnahmen – wurden im Rahmen des Experimental-Unterrichtes am Missionsgymnasium mit Dr. Lünterbusch Vegetationsaufnahmen im Wacholderhain durchgeführt. Unter dem lichten Schirm der Waldkieferkronen gab es eine zweite, ca. 10 m hohe Baumschicht aus Traubenkirschen. In den Bereichen, wo sich am Boden nur noch abgestorbene Wacholderbüsche befanden, lag die Traubenkirschenbedeckung im Mai bei weit über 75 %. In den anderen Bereichen lag sie zwischen 25 und 75%, so dass nicht alle Wacholdersträucher abstarben, aber in der Vitalität stark eingeschränkt waren. Dies äußerte sich in geringen Jahreszuwächsen und sehr geringem Fruchtansatz. Die Schülerinnen und Schüler ermittelten im Mai unter den alten Traubenkirschenkronen eine *Prunus*-Keimlingsdichte zwischen 280 und 300! Im Verlauf des Sommers starb ein Großteil dieser Keimlinge dann am Lichtmangel ab. Zum Glück hatten Samen vieler ursprünglicher Arten in der Diasporenbank im Boden überdauert und diese Arten konnten sich nach der Keimung aufgrund der vorgestellten Pflegemaßnahmen etablieren.

Anders stellt sich dies bei der niederländischen Vergleichsfläche dar. Hier wurden die alten Traubenkirschen nur auf den Stock gesetzt und es wurde nicht abgeplaggt. So konnten die Wurzelstöcke sowie die Keimlinge wieder austreiben bzw. weiterwachsen, ohne dass sie durch die Beweidung mit den Tieren des Tierparks beeinträchtigt wurden, anders als auf den übrigen Untersuchungsflächen. Daher hatte die Traubenkirsche im Untersuchungszeitraum auf der niederländischen Vergleichsfläche, Birken-Eichenwald ausgenommen, eine sehr viel größere Bedeckung als bei den Aufnahmen im Wacholderhain Bardel. Darüber hinaus gab es in der niederländischen Fläche mehr Sträucher wie Brombeeren, Roteichen und Kupfer-Felsenbirnen sowie mehr Vergrasung durch Drahtschmiele. Dies lässt sich ebenso durch die fehlende Beweidung erklären. Bezogen auf die Beweidungsart muss bedacht werden, dass

Schafe nur die Sämlinge und die jungen Blätter der Spätblühenden Traubenkirsche fressen und somit alleine nicht effektiv genug sind, um die Traubenkirsche nachhaltig zu bekämpfen (Heyne, 2003). Ziegen hingegen fressen das ganze Jahr über Blätter und Zweige – mit einer Vorliebe für Spätblühende Traubenkirsche, insbesondere im Juli und August – und können daher besser genutzt werden, um die Waldbildung zu verhindern (Kivit & van Diepen, 2007). Nach dem Verzehr der Blätter und Zweige werden die Stämme von den Ziegen geschält und die Borke verzehrt (Oosterveld & Slim, 1986; Marabini, 2014). Die Ziegen schälen allerdings auch gerne Wacholder, der daher in den Beweidungsflächen extra gegen Verbiss geschützt werden sollte (Haumann, 1998).

Durch das Entfernen der Spätblühenden Traubenkirsche hatte die heidespezifische Vegetation mehr Gelegenheit, sich zu entwickeln. Auf der in 2018 abgeplaggten alten Ackerfläche stellte sich im Untersuchungsjahr 2019 heraus, dass bereits spezifische Pionierrasen der Frühen Haferschmiele vorhanden waren und bereits eine Sukzession in Richtung der Assoziation Frühlingsspörgel-Silbergras-Rasen stattfand. Auch auf den anderen Versuchsfeldern fand eine Sukzession statt, die der Heideentwicklung entspricht. Geht die Sukzession jedoch zu schnell voran, kann dies zu Lasten der Offenheit des Areals gehen. Übermäßiges Wachstum von Gräsern und Gehölzen sollte daher verhindert werden. Auf einigen Teilen der alten Ackerfläche und der Binnendünen fand eine Vergrasung statt und auf der Trockenheide wurde Aufwuchs von jungen Birken beobachtet. An diesen Orten scheint es ratsam, für kurze Zeit dort Schafe zur Landschaftspflege zu verwenden. Schafe können aufgrund ihres feineren Mauls selektiv grasen und bodennahe Gräser besser aufnehmen (Elbersen et al., 2003).

Eine gezielte Verwendung von Bentheimer Landschafen und Niederländischen Landziegen als Weidetiere im Wacholderhain Bardel führte auf diese Weise zu einem abwechslungs- und artenreichen Heidegebiet. Dieses Gebiet ist nicht nur attraktiv für gefährdete Pflanzen und Tiere, sondern lockt auch viele Spaziergänger und Schaulustige auf die ausgezäunten Wanderwege, die sich an den interessanten Weidetieren in der idyllischen Heidelandschaft erfreuen. Regelmäßige Untersuchungen der Dungkäferfauna belegen den hohen Wert der Weidetierhaltung in diesem Gebiet für den Artenschutz.

Eine einzigartige Kooperation aus sehr unterschiedlichen Partnern, wie dem Tierpark Nordhorn, der Naturschutzstiftung der Grafschaft Bentheim, dem Missionsgymnasium St. Antonius und der Unteren Naturschutzbehörde der Grafschaft Bentheim haben mit finanzieller Unterstützung der Heinz Sielmann Stiftung und der Feinbrennerei Sasse (Projekt Grafschafter Kräuterwacholder) diese positive Entwicklung eines völlig mit Traubenkirsche verbuschten Wacholderhains zu einer Vorzeige-Heidelandschaft ermöglicht.

Abstract

The protected area (Category V by IUCN) “Wacholderhain am Kloster Bardel” is a heathland that has been overgrown by black cherry (*Prunus serotina*). The black cherry was largely removed from the area through various maintenance measures. In this study, the state of the vegetation in Wacholderhain Bardel was examined using vegetation surveys. The results show how the succession of the area progresses in the direction of heathland in just three years after a plowing action. However, the heathland still faces threats like overgrassing, growth of root sprouts, coppice shooting and the germination of new black cherry. The black cherry has declined sharply due to grazing by Dutch landrace goats. Good grazing management will therefore also be necessary in the future to enable a further increase in the species characteristic of dry heathlands.

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Japan's Native Domestic Animals – A Living Cultural Heritage –

Alte Japanische Haustierrassen – ein lebendes Kuturerbe

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Abstract

The authors provide an overview of the history and current situation of traditional Japanese domestic animals. Most of the breeds were originally imported from abroad and kept and bred on the various Japanese Islands for specific purposes and uses, with too less exchanges of animals and breeding experiences in the past. Therefore, the geographical isolation from island to island led to the preservation of unique indigenous breeds. Very often, not only economic efficiency but the animal's beauty was the main purpose of breeding. In retrospect, all of these old breeds are not characterized by very high productivity levels and thus, no high economic value. However, they are good examples of being regarded as living cultural assets that have been inherited and therefore should be preserved for future generations. Through breeding and education programs, zoos can also make an important contribution to the preservation of these old, traditional livestock breeds.

Keywords: Asahiyama Zoo, Chabo, goldfish, Japanese cattle, Japanese chicken, Japanese dog, Japanese horse, Japanese pig, Japanese quail, Koi, Okinawa Zoo, Onaga-*dori*, Shiba-*inu*, Toyama Family Park.

Introduction

For zoologists, Japan is an interesting country, because many different endemic wild-ranging species or subspecies live on its various islands. Many local species originally came to

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northern Japan from north Eurasia and to southern Japan from the Philippines and Taiwan. Due to their long isolation in the Japanese archipelago, they have evolved and developed into new endemic species or subspecies. Good examples are the Japanese raccoon-dog (*Nyctereutes viverrinus*) with 2 subspecies in northern Japan or the Iriomote cat (*Prionailurus bengalensis iriomotensis*) and the Ryukyu Yellow-margined box-turtle (*Cuora flavomarginata evelynae*) in southern Japan. Not only these originally immigrated animals, but also the isolated survivors of a formerly widespread animal group can be found in some Japanese habitats today. Good examples in this case are the Amami rabbit (*Pentalagus furnessi*), which is closely related to the African Bushman hare (*Bunolagus monticularis*) and the Ryukyu Long-tailed tree rat (*Diplothrix legata*), which is the only surviving species of this genus (Lange & Tai, 2013, 2017).

Similar to wildlife species which are isolated on the various islands, domestic animals were introduced especially from Korea and China (Eppstein, 1969) and they were distributed by humans to different Japanese islands. As the islands are isolated, the domestic livestock animals were bred on each island with different goals, so today they represent different typical breeds, which are now endemic to each island and originally found only here.

This is the history of almost all existing Japanese livestock breeds (FAO, 2023). Only two Japanese wild animal species were domesticated in Japan, i.e. Japanese quail (*Coturnix japonic*a) and Japanese Koi (colored carp; *Cyprinus carpio*).

Especially birds and fishes show a large diversity and adaptability for new breeding purposes, which ultimately serve as evidence of human cultural preferences. But despite all of these good breeding successes, animal welfare should remain the most important breeding goal. All the other domestic animals in Japan have been introduced from abroad over centuries from the north or the south, and have been kept and bred for different purposes with their cultural backgrounds (Shoda, 2006). Some of them are quite rare or unfortunately even extinct today. Here, we would like to introduce the country's domestic animals more generally by referring to a few good examples.

Japanese quail (*Coturnix japonica*)

The Japanese quail (Fig. 1) which is smaller than the European quail (*Coturnix coturnix*), is an endemic wild species in Japan. This quail has been kept and bred as a domestic animal until today. In the Meiji era, in around 1910, people kept this wild bird as a source of food and sometimes as a medicine for heart or lung diseases.

Especially their eggs were considered to be effective against such diseases. Even before the Meiji era, in the Edo period, the people enjoyed the birds' singing. Japanese quail is nowadays a useful breed and also a joyful and really popular bird, so people are competing over the decoration of their cages (Hubrecht & Kirkwood, 2010). As their breeding is still very popular, its wild descendant has been protected by law in Japan since 2013.

Koi (*Cyprinus carpio*)

Today, kois (Fig. 2) are kept by enthusiasts worldwide in their private tanks and garden ponds. But the domestication of kois started in Japan. Their different breeds, like the Japanese chicken breeds too, are a good example of how much Japanese people place more emphasis on beautify than on body size or economic efficiency or benefits when 'breeding their varieties'. Kois are one of the best examples of such a Japanese national trait, even if the probability of producing the appropriate color patterns is not so high.

Fig. 1: Japanese quail. All Photos: Motofumi Tai.

Fig. 2: Koi, colored carp.

Japanese Horse, "*uma*"

Horses have been kept all over Japan, with different breeds in each region from Hokkaido in the north to the Okinawa area in the south. However, there are still 8 Japanese horse breeds in Japan. Today they are used as tourist attraction such as horse riding for children, and also as animals for touch therapy, and not only for work. All the Japanese horse breeds, which Japanese people call "*uma*", are smaller than most European breeds since originally the Japanese people were not so tall. Japanese horses have an average shoulder height of around 130cm. In the ancient times, however, warriors preferred more active and aggressive characteristics than just their running speed. In the beginning of the 5th century, the Emperor received the horse from Korea, which is considered to be the oldest description of horses in Japan. Currently an overall population of less than 2000 *uma* of the 8 breeds of Japanese horses exists (MAAF, 2022; FAO, 2023).

Kiso-*uma*

Kiso-*uma* (Fig. 3) is the only indigenous breed existing in Honshū, the main island of Japan. This breed is now kept in Nagano and Gifu prefectures, which are quite famous as good farming areas. Since ancient times, this breed was used as war cavalry. But once they almost faced extinction from crossbreeding. Fortunately, one Kiso-*uma* was found, kept as a sacred stallion in a shrine, as well as the Kiso-*uma* daughter. These both Kiso-*uma* saved this breed from extinction and nowadays 133 Kiso-*uma* exist (2022). The by far largest farm of Kiso-*uma* is in Kiso, Nagano prefecture, but a few Kiso-*uma* are also kept in Japanese zoos.

Fig. 3: Kiso-*uma* is the only indigenous horse breed in Honshū Island.

Yonaguni-*uma*, and horse racing in Okinawa

Yonaguni-*uma* (Fig. 4), a rather small type of breed, is kept on Yonaguni-jima Island in the southeast of Okinawa. Originally, they were used for cargo transportation, mainly rice and also sugar cane. At the same time, the horse was the only means of transportation on such a small island. In the old times, there were several more breeds in the Okinawa area, and each small island had its local breed. Traditional Okinawa horse racing took place on each island or region in Okinawa. In this contest, the horses competed not only in their running speed or time, but also in their beauty of running as well as in their decorations. Recently, Okinawa Zoo revived this horse racing on the zoo's premises.

However, today 110 Yonaguni-*uma* still exist in 2022.

Fig. 4: The small Yonaguni-*uma* is found in the Yonaguni Island, southeast of Okinawa.

Noma-*uma*

Noma-*uma* (Fig. 5) is kept in the Noma area of Iyo, now Ehime prefecture, on Shikoku Island. It is a quite small type of breed. The Lord of Iyo convinced his citizens to breed big horses for military and for the government (feudal clan) to purchase. The rest of the small horses were used in farming. This is the origin of this breed. The farmers used this horse for cargo transportation, mainly satsuma, Japanese orange, which is a very famous product in this area. Likewise Yonaguni-*uma*, these types of small horses can walk through the orange farm or windbreak of trees in Okinawa. This breed once declined to 5 Noma-*uma*, but has now increased to 48 Noma-*uma* (2022). Currently, a few zoos are also keeping this breed.

Fig. 5: The Noma-*uma* is bred in Shikoku Island.

Japanese Cattle, "*gyu/ushi*"

Nowadays many foreigners are familiar with branded beef names as "Kobe-beef" or "Matsuzaka-beef" as Japanese beef with more fat than normal cattle beef. These beef brands are from black haired cattle, called "*kuroge wagyu*" in Japanese. This *wagyu* is kept all over Japan and each region has a different brand name such as Kobe beef from Hyogo prefecture or Matsuzaka beef from Mie prefecture. The origin of *wagyu* is in Japan with just 2 breeds. Since the 6th century, the Japanese people started to keep and breed Japanese cattle, which were originally imported from the Korean peninsula.

But because of buddhism, which was introduced to Japan in 676 CE, the Emperor decided to prohibit the use of meat and milk deriving from cattle. Since then, Japanese people used cattle only for labor and transportation in farming and harvestings.

Today, less than 100 Japanese cattle are being kept in Kagoshima prefecture and also in Yamaguchi prefecture.

Kuchinoshima-*gyu*, the only feral cattle in Japan

Kuchinoshima-*gyu* (Fig. 6) is the only feral cattle in Japan. They are living on Kuchinoshima island of Kagoshima prefecture. This cattle breed was originally brought to this island in 1918. Some individuals escaped and became "wild" cattle again. Due to this isolation they have preserved their original characteristics.

Primarily their hair is almost black, but some of them have white spots, too. This variety of spotted cattle is used more for celebrations and other similar occasions. Since they are used more as working cattle, their hind legs are rather poorly developed. Their meat is lean and contains no fat in between their muscles. Nowadays, it is estimated that 30-100 animals still live on the islands in protected areas and a few Kuchinoshima-*gyu* are kept in zoos and universities too (Akishinonomya & Komiya, 2009).

Fig. 6: The Kuchinoshima-gyu, found in Kagoshima prefecture, is the only feral cattle in Japan.

Mishima-*ushi*

Mishima-*ushi* (picture 07) is also only kept on the isolated small island of Mishima in Yamaguchi prefecture. They are quite small and have black, rather brownish hair. This is the original characteristics of Japanese cattle. And it is the reason for them and their habitat to be designated a Natural Monument of Japan in 1928. They are mainly used for working in farming, and sometimes exported to Honshū, the main island. Once they had decreased to around 30 Mishima-*ushi*, but the Mishima-*ushi* Conservation Society was established in 1967 and today 80 Mishima-*ushi* are kept on the island (FAO, 2023). Their meat is quite lean with muscle fibers that may contain fat, which is later refined into the famous Wagyu.

Fig. 7: The Mishima-ushi is only kept on the small Mishima Island in the Yamaguchi Prefecture.

Japanese pig

From the Jomon period (c.14000-300 BCE), Japanese people exploited wild boar. This is well known from bones excavated from several ruins throughout Japan. Since after the Yayoi period (c.300 BCE - c.250 BCE), domestic pigs, which were introduced from the Korean peninsula, became more popular in Japan. However, pigs were no longer kept after the Emperor decided in 675 CE to prohibit slaughtering animals. Only a few remote islands like Okinawa not directly affected by this order. Therefore, only in Ryukyu, now Okinawa prefecture, and the Southwest Islands, people never stopped keeping pigs. Today only one breed continues to be preserved in Okinawa as an indigenous Japanese livestock, which is probably better be described as Okinawan native livestock (Akishinonomya & Komiya, 2009).

Japanese pig "Shima-*wa*:" in Okinawa

In the 14th century, rather small bodied black pigs with hanging bellies and sunken backs were introduced from China to the Southwestern Islands of Japan. After the Meiji era, several breeds from Europe were crossbred with the traditional breed, so that the genuine breed was almost extinct (Akishinonomya & Komiya, 2009). However, few pigs with original traits of this breed were rediscovered in Okinawa and other small islands. These helped to revive the original Japa-

nese/Okinawa livestock pig, named "Shima-*wa:"* (Fig. 8). This Shima-*wa*: has recently become quite famous as a pork brand. But the pigs are rather difficult to keep, because they require more time to grow up than mixed breeds. This means their husbandry and breeding cost more time and money, which forms a threat for the continuous keeping of this breed (Akishinonomya & Komiya, 2009).

All other ungulate breeds, which are kept today in Japan, are imported from abroad and have never been transformed into a typical Japanese breed.

Fig. 8: The Shima-*wa*: in Okinawa is the only indigenous Japanese pig breed.

Japanese dog

Since more than 10.000 years ago, dogs have been kept by people who lived in Japan. It is obvious that dogs are very important as helpers for hunting in the Jomon period, as well as guard dogs and as companions today. On the other hand, people also appear to have eaten dog meat, since the Yayoi period, because the bones excavated from the ruins from that period are very fragmented. This indicates that the behavior and diet of Japanese people have changed during the course of the Yayoi era.

As the Japanese archipelago is quite isolated from other countries, and even regions inside the country are also quite isolated from each other, dogs were kept genuine, for a long period of time. But after the Meiji era, so many other European breeds were imported. Until today, 6 Japanese dog breeds are designated as National treasure, and some other breeds like the Daito-*ken*, Kawakami-*ken* and Ryukyu-*ken* are definitely Japanese breeds, too, but not yet registered as National Treasure (Akishinonomya & Komiya, 2009).

Shiba-*inu* & Ryukyu-*ken*

Shiba-*inu* (Fig. 9) is the generic name for all small Japanese dog breeds. Originally this breed helped hunting for hares and pheasants, and some other small wild animals. Their bones have

been found in ruins of the Jomon period, and these bones are quite similar to this breed. Up to date there are several types of Shiba-*inu* in each different region, which are kept and preserved by each society. Shiba-*inu* is the most popular and famous breed among Japanese dogs.

Fig. 9: Shiba-inu, a Japanese native breed of dog designated as a natural monument.

Ryukyu-*ken (*Fig. 10) is a quite unique dog breed in Okinawa. It can be said that this dog breed is genetically closely related to Hokkaido-*inu* which is mainly kept in the northern part of Japan. Due to the migration of people, dogs are also moving together with them. Ryukyu-*ken* has a very special type of speckled hair like the tiger (Akishinonomya & Komiya, 2009).

Fig. 10: The Ryukyu-ken in Okinawa prefecture.

Japanese Chicken

The oldest bones of Japanese chicken were found in Japan at the Karakami ruins in Nagasaki prefecture. These bones date back to more than 2000 years ago. It was around that time that the Japanese started to keep chickens. Similar to the history of cattle, the consumption of chicken meat was prohibited in Japan. Therefore roosters were mainly serving as clocks for telling time, and sometimes for cockfighting, or for foretelling. Later, in the Edo period, Japanese people slowly started to breed chickens, not only to eat their meat or collect their eggs, but also to compete with their beauty, their long breath singing, and also to enjoy their appearances.

But even worldwide, the main breeding purpose was always the appearance of chickens, and not the quality of meat or the number of eggs. Only in the 20th century, economic aspects came to the fore in chicken breeding (Herre & Röhrs, 1990). It is rather difficult to define the correct number of chicken breeds because the breeding of varieties for improvements by humans is quite diverse. However, it is estimated that more than 200 different breeds are kept worldwide and 38 old, traditional breeds still exist in Japan (Tsudzuki, 2003a). 17 of these breeds are designated Natural Monuments (Figs 11-13) (Tsudzuki, 2003b). Shoda (2006) listed worldwide 177 remarkable chicken breeds, including 26 Japanese breeds.

Fig. 11: Chān, the long-crowing chicken, native to Okinawa prefecture.

Fig. 12: Toumaru, the long-crowing chicken native to Niigata prefecture, and designated as a natural monument of Japan by the Japanese government.

Fig. 13: Ukokkei, Japanese Silkie, designated as a natural monument.

Fig. 14: Onaga-*dori*, Japanese Long Tail Chicken, designated as a special natural monument.

Onaga-*dori*

Onaga-*dori* (Fig. 14) is the breed with "the longest tail feathers in the bird world". Originally, they were selected as a type that does not moult tail feathers. The way of breeding this chicken was well guarded secret in Tosa, now Kochi prefecture, until the end of the Edo era. The Lord of Tosa used these very long tail feathers as his symbol especially during the regular parade to Edo, now Tokyo. Anyone unfamiliar with this chicken would be quite amazed and amused by its beautiful feathers. In the 1830s, its longest tail was 3 meters long, and later on after World War II, its tail grew longer up to 13.5 meters, which is still the longest record to date. In 1923 this chicken breed was designated as a Special Natural Monument and since 1952 it is listed in the "Act on Protection of Cultural Properties", which passed as law number 214 in 1950.

Chabo

In Japan, this chicken breed was probably named after the Champa Kingdom. At the beginning of the Edo period around 1600, Chabo was possibly introduced from China. This breed was named in Japan after its place of origin, which is considered to be "Champa Kingdom" in the middle of South Vietnam. People in the Edo period were enthusiastic about this breed, and kept and improved it, resulting in several different plumage colors and sizes. Some Chabo were even exported from Japan in the Edo era from Nagasaki Port. That is the reason why some people still call this Chabo "Nagasaki" or a Japanese Bantam.

There are numerous fan clubs and societies all over the world in favor of this Japanese chicken breed. There are 25 different varieties of Chabo today (Fig. 15) (Akishinonomya & Komiya, 2009).

Fig. 15: The Uzurao, one of the Chabo breeds, designated as a natural monument.

Japanese domestic fishes

We could never overlook domestic fishes in Japan. Especially Koi, colored carp, are among the most expensive and valuable pets in the world, and also Kingyo, goldfish, are also quite popular among people. Originally Koi and also Kingyo (Fig. 16) were kept as companions in the middle of the Edo period. Koi were especially for the lord or higher classed people of respective region, while Kingyo was more for ordinary people (Roos, 2019). At the same time, Japanese Ricefish (*Oryzias latipes*) was fancied by the Japanese people as well.

Fig. 16: Kingyo, the goldfish is popular all over the world.

Koi, colored carp, and Kingyo, goldfish

Koi was created from carp (*Cyprinus carpio*) more than 200 years ago in Echigo, today's Niigata prefecture, just by mutation. People then began to breed them, so that today there are 80 different varieties. In 1914, the "Tokyo Taisho Exposition" was held in Tokyo and this EXPO made this fish very famous and popular.

During World War II, many varieties of Koi were lost, but the 'breeding of varieties' started again after World War II on the basis of a few parental fishes that survived and in the 1960s a big boom in breeding of Koi started. Nowadays, there are a lot of enthusiasts of this "swimming art". Only 0.5% from competing fishes have the quality to be used as future breeders. But under good conditions they could be kept for more than 30 years and a few could become even live to 100 years or longer. This is another reason why these fish are beloved by many people.

Kingyo was originally created in China from the Chinese crucian carp (*Carassius auratus*) which is its wild ancestor (Kijima et al., 2008; Wang et al., 2014; Wang et al., 2013). It is said that in 1502, Kingyo was introduced to Osaka from China. And then during the Edo period, a lot of different varieties were bred and now up to 200 of Kingyo varieties are known all over the world. This is probably because they are easier to keep than Koi.

The Role of Zoos in Japan

There are a few zoos in Japan which try to conserve such native domestic animal breeds. They focus more on the education of local citizens than on touristic visitors. Their collections of rare or old breeds are quite well maintained at this moment, but this engagement depends mainly on the director's or staff members' interest. There is a constant concern that such a concentration on the husbandry of domestic animal breeds will diminish or even cease, if there is a change in staff, the director or even the head of the municipality responsible for the zoos. Therefore, it is important to educate zoo staff as well as the officials working for the municipality, about the husbandry of old traditional livestock breeds as a cultural inheritance project and the role zoos can play in this. It can be said that zoos should furthermore add the husbandry and conservation of endangered domestic breeds to their goals and code of ethics to assure the survival of these breeds also for future generations.

In this context, in Germany the German Federal Ministry of Food and Agriculture financed a project to increase the overall contribution of zoos for the conservation of endangered livestock breeds (Kögler, 2021; Kögler et al., 2022).

Toyama municipal family park zoo

This zoo on Honshū island has a rich collection of native chickens, with more than 20 breeds. All of these breeds are well segregated in a different cage, and all with detailed information labels. Even though there are no real local domestic breeds in Toyama, the collection is remarkable. Besides the collection of chickens, there is a carriage inside the zoo which is pulled by Banba of Hokkaido, the heavy breed for sleigh races, bred from European cold blood horses in Japan (Fig. 17).

Fig. 17: Banba horserace on the racecourse in Obihiro, Hokkaido.

Okinawa Zoo

Okinawa Zoo in Okinawa prefecture is considered as a success in reviving the traditional Okinawa horseraces by the staff members of this zoo (Fig. 18). They are using horses that are kept at this zoo, in cooperation with many citizens who still know the original race, which had no longer been held since before World War II. Their cattle breed Kuchinoshima-*gyu* is used for rice planting, and the Yonaguni-*uma* is carrying food for the animals inside the zoo. The zoo's unique collections express the diversity and cultural background of these local breeds.

Fig. 18: Okinawa Zoo revives and organizes traditional Ryukyu (Okinawa) horseraces with Yonaguni-uma and in traditional costumes.

Asahiyama Zoo

Also, the Asahiyama Zoo in Hokkaido has a good exhibition of domestic animal breeds. Following their concept "what we tell is about lives", they try to explain and to demonstrate the origin and process of domestication from their wild ancestors. This zoo does not keep extraordinary breeds, but keeps more common imported breeds of chickens, ducks, pigs and goats. Their exhibition of domestic breeds, using several information boards (Fig. 19) handmade by their staff, is very educational and informative for visitors.

Fig. 19: Asahiyama Zoo: Simple, but informative labels about domestication.

The Society for Livestock Studies

The "Illustrated Encyclopedia of European Poultry" was published by Fumihito Akishinonomiya et al. 1994. Even before this publication, The Society for Livestock Studies has started their activity mainly with chickens (Mohri, 2019). Today, however, the Society's field of activity includes more livestock breeds and themes in general. It started with the surveys of actual sites as well as molecular phylogenetic studies, and today the Society is trying to elucidate the whole process of domestication (Fig. 20).

The Society is also researching the culture and history of living organisms based on the fact that domestic animals were created through interactions with humans. As genetic evidence disappears over time due to the needs for improvements, the Society focuses on natural history materials, such as taxidermies, skeletal specimens, video/photo materials and also on DNA preservation.

Conclusion

In general, there are not a larger number of breeds and varieties of old Japanese domestic breeds. Especially chickens represent an interesting diversity (Akishinonomiya & Komiya, 2009), and the numbers of Japanese breeds represent about 10% of all worldwide chicken breeds. A few of the breeds were introduced in Japan, and some of them are quite rare and extremely

Fig. 20: The Members of the Society for Livestock Studies have close contact to all breeders of old livestock breeds and visit often also their breeding facilities.

valuable cultural assets. Nevertheless, it is quite difficult to successfully keep even those characteristic, very precious breeds, because most of them are not so easy to breed and have definitely no economic or commercial value.

This is the reason why farmers do not want to keep such breeds.

Furthermore, the Japanese government definitely does not provide enough support for private efforts to conserve local breeds. A few breeds are kept in some local zoos or touristic farms, but the majority is threatened in their persistence by low numbers of individuals and holders. The Society for Livestock Studies is working well in some cases, but no one can tell how long this will last. And we must emphasize that it is not enough just to conserve or preserve them, but it is more important to appreciate their real value and hopefully to use them. From that point of view, the biggest issue of Japanese livestock is to find a way of to preserve them for the future as "Living Cultural Heritage".

The husbandry of domestic livestock in Japan is rather different to the European style. Originally, domestic animals in Japan are mainly used as gift to the god and also as working animals. Therefore Japanese never operated big farms for livestock animals. It was more a cottage industry, which had of course also less input on nature than any factory farming. Further-on, all the domestic animals were well incorporated into the life system of Japanese people. The breeds became resistant to a harsh environment and developed strong self-activities to survive, but by breeding management they should not become "wild animals" again. Such a system is of course difficult to maintain in a society that emphasizes economic values and efficiency.

On the other hand, with population growth, energy and food shortage and climate change diversity of livestock becomes more important than efficiency-oriented uniformity and identity. Livestock, created by selection pressure that matches the nature and the folk customs of a region, have the ability to breed and survive in harsh conditions which we could imagine for

the near future. For this reason, it is important to maintain the old traditional Japanese breeds as livestock that can be expected to have the ability to respond and adapt, when environmental changes occur.

Therefore it is high time and almost last minute to protect the diversity of these native domestic breeds in Japan. We should never underestimate their biological value and cultural worth. It is pity that other problems like diseases and climate changes have much higher priority for the government and that the conservation of these old traditional livestock breeds depends mainly on private initiatives.

Epilogue

Many Japanese art masters have painted and sculptured a variety of domestic animals. All these artworks tell us the shape and appearance of them even after several hundreds of years. In fact, those art pieces helped to revive some of the extinct breeds, and now such a re-breeding project is taking place in the Amami Islands in Kagoshima prefecture. In 2022, the Amami native domestic chickens as well as the rare Amami pigs were found on the islands. It is encouraging to see that projects have been started to keep, breed and multiply them with the cooperation of local people on Amami (Fig. 21). It will be interesting to see the outcome and result of this project in a few years.

Fig. 21: The Teirya-duri chicken on Amami Islands is one of the projects to revive this old, traditional breed and to preserve it for future generations.

Zusammenfassung

Es wird ein Überblick über die wichtigsten alten japanischen Haustierrassen gegeben, die bis auf die Japanische Wachtel und den Koi-Karpfen, die in Japan aus Wildtieren domestiziert wurden, ursprünglich alle nach Japan importiert und hier – isoliert auf den verschiedenen Inseln – zu typisch japanischen Haustierrassen weitergezüchtet wurden. Manche von ihnen sind heute selten und als wertvolle Kulturgüter hochgeschätzt.

Dennoch ist ihr Bestand gefährdet, da sie schwieriger als die modernen Haustierrassen zu züchten sind und momentan keinen großen wirtschaftlichen, kommerziellen Wert haben.

Einige wenige Rassen werden in Zoos oder auf touristischen Bauernhöfen gehalten, die meisten Rassen sind jedoch durch die geringe Anzahl an Individuen und privaten Besitzern in ihrem Fortbestand bedroht. Die japanische „Society for Livestock Studies" versucht deshalb, die alten Haustierrassen als „lebendiges Kulturerbe" für die Zukunft zu bewahren, zumal sich diese alten Rassen häufig besser an sich verändernde Umwelteinflüsse anpassen als die modernen Haustierrassen und deshalb in der Viehwirtschaft der Zukunft eine durchaus wichtige Rolle spielen können.

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Bemerkenswertes Lebensalter beim Dromedar

Remarkable Longevity in the Dromedary

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Obwohl Dromedare (*Camelus ferus* f. *dromedarius*) schon seit langer Zeit in zahlreichen tiergärtnerischen Einrichtungen gehalten werden, ist noch längst nicht alles über ihre Lebensweise geklärt. Dromedare sind domestizierte Kamele, deren Stammform nach wie vor unklar ist (Zscheile & Zscheile, 2018). Auch über das Lebensalter des Dromedars findet man nur wenige konkrete Angaben. So kann man bei Zscheile & Zscheile (2018) lesen, dass für diese Tierart ein maximales Lebensalter von fast 28 1/2 Jahre bekannt ist. Diese Angabe findet man auch bei Weigl (2005), welcher sich wiederum auf Jones (1993) bezieht. 28 Jahre werden auch von Schwartz & Dioli (1992) von ostafrikanischen Dromedaren als höchstes Lebensalter angegeben. Aristoteles, der das Dromedar „arabisches Kamel" nannte, berichtete seinerzeit, dass es mehr als 50 Jahre alt wird (Krumbiegel, 1952). Auch andere Autoren schreiben von einem hohen Lebensalter, welches Dromedare erreichen sollen. So gibt Köhler-Rollefson (1991) an, dass Dromedare 40 Jahre alt werden können, jedoch ohne dies konkret zu belegen. Nowak (1999) nimmt ebenfalls an, dass Dromedare ein Lebensalter von bis zu 50 Jahre erreichen.

Im Zoo Vivarium Darmstadt wurden Dromedare vom Januar 1972 bis zum Oktober 2010 gehalten. Während dieser Zeit wurden zahlreiche Jungtiere geboren. Am 27. 1. 1980 kam die Stute „Kati" zur Welt (Ackermann, 1980) und lebte zeitlebens im Zoo Vivarium. Aufgrund zunehmender Lebensschwäche und da sie festlag und nicht mehr aufstehen konnte, wurde das Tier am 19. 10. 2010 eingeschläfert. Es hat damit ein Lebensalter von 30 Jahren, 8 Monaten und 22 Tagen erreicht. Auch wenn mit hoher Wahrscheinlichkeit Dromedare noch älter werden können, war die Stute „Kati" das Dromedar mit der längsten genau bekannten Lebensdauer.

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Gotta Chop 'em All? Investigating the Impact of Food Presentation on Zoo-housed Azara's Agoutis

Muss man alles kleinschneiden? Untersuchung der Auswirkungen der Futterpräsentation auf im Zoo gehaltene Azaras Agoutis

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Abstract

The presentation of zoo animal diets can affect animal behaviour, nutrition, motivation and ultimately, welfare. While the science of zoo food presentation is advancing, there remains a tendency for food to be presented in ways that speed food deterioration and do not reflect the ecology of the species being fed. The current literature on zoo food presentation has tended to focus on specific taxonomic groups, especially Primates and Carnivora, with less research focus on taxa such as Rodentia. To fill a gap in the literature, a study was undertaken at Woburn Safari Park on a group of five Azara's agoutis (*Dasyprocta azarae*) to investigate the effects of chopped or whole diet presentation on behaviour. Animal behaviour was recorded using instantaneous focal sampling at 60 second intervals in one-hour sessions, with continuous sampling of events. Overall, stashing behaviour significantly increased, while feeding and food manipulation behaviour increased and foraging levels decreased during the whole food condition. There was no significant effect on aggression levels. Keeper preparation time significantly reduced during whole foods saving over two minutes of keeper time per meal, and no significant difference in the amount of food eaten was noted. Stashing and food manipulation are natural behaviours in wild agoutis, and as such whole food presentation may allow agoutis to express a wider range of natural behaviours. It should be noted, however, that a decrease in foraging

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behaviour was noted. Further studies into a wider range of zoo-housed species would help to identify taxa that would benefit from whole food, or alternative, food presentation.

Keywords: chopped food, *Dasyprocta azarae,* food preparation, zoo nutrition

Introduction

One of the aims of a zoo nutritionist is to ensure animals are given diets that are both nutritionally appropriate and that encourage species-specific behaviour (Plowman et al., 2006). While the field of zoo nutrition has advanced, the origins of many zoo diets stem from a time when advanced knowledge was not available and as such many diets were developed through trial-and-error or folklore knowledge (Brereton et al, 2021). While many older practices have now been scientifically examined, others, such as timing of foods and food preparation, have not been examined across the broad array of taxa housed in zoos and aquaria.

Food presentation styles vary throughout zoos and aquaria, but the chopping of foods into small, bitesize pieces is a common strategy (Shora et al., 2018). In the wild, animals would not receive their food carefully diced into pieces. Suggested reasons for chopping food into smaller pieces include the suggestion that chopped food could increase foraging (Waasdorp et al., 2021) and reduce aggression (Mathy & Isbell, 2001), though these suggestions have not been systematically investigated. Conversely, in some species, aggression has been shown to reduce when whole foods are provided (Smith et al., 1989; Sandri et al., 2017; Shora et al., 2018; Welsh et al., 2022). It is likely, therefore, that whole food diets may actually be better for some common zoo species.

The preparation of chopped food diets takes a significant amount of keeper time (Griffin & Brereton, 2021) and decreases the nutritional quality of the food provided (Hodges & Toivonen, 2008). For example, the water and vitamin content (e.g. vitamin C) of chopped food rapidly reduces, while ethylene content increases (Watada et al., 1996; Hodges & Toivonen, 2008). For smaller chop sizes and in higher ambient temperatures, this deterioration of food quality occurs more rapidly. The chopping of foods also increases the risk of microbial contamination as moist surfaces are opened to their environment (Brackett, 1987). The chopping of foods should therefore be considered from a cost-benefit standpoint, taking into account animal preference, keeper time (and its financial consequences), food nutritional value and microbial contamination.

While some animal orders, such as Primates, Carnivora and Elephantidae, have been well studied in a zoo environment, other orders have received limited attention (Melfi, 2009). The order Rodentia, for example, is exceptionally well-represented both in terms of species diversity (2,375 recognised species, IUCN, 2023) and in individuals in zoos (over 46,600 individuals: Species360, 2023). Welfare-oriented research in this taxonomic group therefore has the potential to improve the lives of thousands of animals.

Rodentia, with their constantly-growing incisors, have the ability to gnaw through tough materials and as such could be a good model for food presentation research (Whishaw & Tomie, 1989). Food presentation has been well studied in laboratory rodents and has identified some interesting trends associated with particle size (Whishaw & Dringenberg, 1991). In rats (*Rattus* spp.) and house mice (*Mus musculus)*, for example, smaller food items are typically eaten at the food bowl, whereas larger food items are associated with running with food and hoarding (Nakatsuyama & Fujita, 1995). It is possible that this trend, in which animals are more likely to transport large food items to safe places for eating, is conserved across a range of mammalian taxa.

The agouti (*Dasyprocta* spp.) is a genus of large, South American rodents (Henry, 1999). Agoutis possess a generalist feeding strategy and are able to eat a wide range of fruits, seeds

and nuts, though occasionally also meat and eggs (Dubost et al., 2005; Jones et al., 2019; Silva, 2013). The constantly-growing incisors of the agouti enable them to gnaw through the tough shells of even Brazil nuts (*Bertholletia excelsa)*. The 13 species of agouti are reasonably well-represented in zoos globally (693 individuals); of these, Azara's agouti (*Dasyprocta azarae)* makes up the majority of the world zoo population. There is no published research, to the authors' knowledge, on food presentation effects for any agouti. Research on the effects of food presentation on agouti behaviour may therefore have value in evidence-informed husbandry.

Material and methods

Study subjects and location

Data collection was undertaken between January and March 2023 at Woburn Safari Park in the United Kingdom. Prior to data collection, the study was approved through ethical review at University Centre Sparsholt. Behavioural research was undertaken on five female Azara's agoutis, that were housed together in a public exhibit with a large outdoor enclosure combined with a smaller, heated, indoor exhibit (Tab. 1). All individuals originated from Cotswold Wildlife Park, but parentage is uncertain. The agouti shared their exhibit with common marmosets (*Callithrix jacchus*) (Green et al., 2023) but did not share any food nor shelter with them, and all husbandry routines, bar feeding, continued with no changes during data collection. Before the main study began, a one-hour pilot study was completed in December 2022 while the agoutis were shut inside their house. The four researchers involved in data collection (AV, JD, MMH and MH) also completed an interobserver reliability test to ensure the accuracy of the behavioural observations, this was conducted by watching a video observing and recording the behaviour of a related species, the capybara (*Hydrochoerus hydrochaeris*). Approval for data collection was provided once all pairs achieved a Kappa Cohen coefficient above 0.9.

Tab. 1: Study subject details

House name	Studbook number/ID	Birth date	Birth location
Muriel	EAZA/403	23 Feb 2017	Cotswold Wildlife Park
Betsy	EAZA/410	13 Nov 2015	Cotswold Wildlife Park
Ethel	EAZA/418	20 Jul 2015	Cotswold Wildlife Park
Elsie	MM1931	4 Nov 2014	Cotswold Wildlife Park
Doris	EAZA/315	21 May 2014	Cotswold Wildlife Park

Study design

The researchers observed the agoutis from one viewpoint around the enclosure which provided best visibility. Behavioural observations were conducted using instantaneous focal sampling for state behaviours at 60 second intervals for one-hour timeslots, with continuous sampling of event behaviours (Bateson & Martin, 2021). A total of 24 hours of data were collected for each agouti in the study. An ethogram (Tab. 2) was adapted based on the pilot study to define the observed behaviours. Three hours of data were collected at set times; 10:45, 12:15, and 14:00 to coincide with the three feeds given in the day and to avoid issues associated with pseudoreplication. The forecast temperature, humidity, windspeed, current weather conditions and ultraviolet level were recorded at the start of each hour of observation, using World Weather Online (2023). The study was conducted during open and close days of the park, with visitor presence sporadic and unpredictable.

Tab. 2: Ethogram, authors own, adapted from Shora et al. (2018).

Behaviour type	Behaviour	Definition
	Autogrooming	Cleaning or picking at the animal's own fur.
	Feeding	Chewing and swallowing the food. Includes drinking water.
	Food manipulation	Tough or inedible parts of the food are removed using the mouth and teeth.
	Foraging	Using tactile means to look for food, using mouth and paws while looking around.
	Locomotion	Running and walking on land, without food.
	Resting	No locomotion, or sat down, or head down, or lying down, or no attentiveness to its surroundings.
	Stationary	No movement while standing or sitting, usually with the head upright.
	Vigilance	Observing other animals or humans.
Event	Aggression	Using any part of the body, animal jumps towards a conspecific in a vicious manner, usually includes a small vocalisation and results oftentimes with a flee.
	Dropping	The act of dropping food under no pressure from other individuals.
	Flee	A response to a stimulus with an aggressor. Involves moving away from the area.
	Food manipulation	Tough or inedible parts of the food are removed using the mouth and teeth.
	Stashing	Picking up multiple food items at one time without stopping to eat or stash the food.
	Inter-socialising	Interaction with individuals of a different species, not involving locomotion.
	Intra-socialising	Interaction with other individuals of the same species, not involving locomotion.
	Locomotion with food	Running and walking with food in paws or mouth.
	Scent marking	Marking territory by urinating or rubbing anal scent glands over stationary object.
	Sentry	Being alert to its surroundings and standing on the animals' hind legs, as if to look for danger.
	Sniffing	Nostril flaring, head up.
	Startle	A response to a stimulus without an aggressor. Involves moving away from the area.
	Stashing	Digging a small hole and placing food into hole, including retrieval of food.
	Stealing	Food being taken from one individual to another without dropping.
	Stomping	Using back legs to aggressively hit the floor.
	Vocalisations	Squeaks, grunts, and barks.

Food presentation

Food was presented in one of two formats: either chopped or whole. Chopped food items were prepared in approximately 3 cm^3 cubes by animal keepers, whereas whole food items were not chopped (except very large food items such as butternut squash (*Cucurbita moschata)* which were sometimes quartered). Each day, the agoutis had 675 g of fruit and vegetable diet given to them, with the diet not changing throughout the study to prevent variables like food motivation and preference skewing results. The diet consisted of butternut squash, chicory (*Cichorium intybus)*, and beetroot (*Beta vulgaris*), though occasional substitutions were used as part of normal husbandry. The food presentation alternated between chopped and whole each week, to prevent the acclimatisation of the agoutis to one presentation style and to mitigate the effects of extraneous variables such as the season, weather, and visitor presence. When the food was presented, it was scattered over a three metres space on the enclosure floor, to make it easier when collecting left over food and ensure visibility throughout. At the end of each data collection day, the left over food was collected and weighed in to ensure the agoutis were still consuming an appropriate amount of food (weight accurate to the nearest gram). Diet preparation time (including cleaning of equipment) was also timed at the beginning of the day to see if it was quicker to prepare whole foods. In addition to the study diet, a staple diet of guinea pig food was given ad lib in multiple bowls throughout the enclosure as per normal husbandry. Consumption of guinea pig feed was not assessed in this study.

Data analysis

Data were collated using Microsoft Excel™ 2016 and Minitab version 21. Figures were produced using Excel. For statistical analysis, comparisons were made to investigate the impact of food condition (chopped or whole) on selected agouti behaviours. The data for these selected behaviours were tested for normality, and where data were normal, a paired t-test was used. For non-normal data Wilcoxon tests were used. Similarly, comparisons of time taken for food preparation and for food consumption were conducted for chopped versus whole food using Wilcoxon's tests.

Results

State behaviour

An activity budget (Fig. 1) was generated to show the differences in behaviour between the chopped and whole food conditions. For state behaviours, six behaviours (autogroom, dig, locomotion, resting, stationary and vigilance) were not affected by food condition. For the whole condition, time spent feeding was significantly increased ($t_{(59)}$=3.51, P=0.026) and foraging was significantly reduced ($t_{(59)}$=4.67, P<0.001).

Event behaviour

Event behaviours were analysed by looking at the group of animals as a whole, with a focus on behaviours concerning feeding and aggression (Fig. 2). Food condition resulted in no significant difference in dropping food, aggression, fleeing, food manipulation, sniffing or startle. Stashing occurred significantly more often ($W_{(59)}$=6, P<0.001) in the whole food condition, as did locomotion with food ($W_{(59)}$=4, P=0.045).

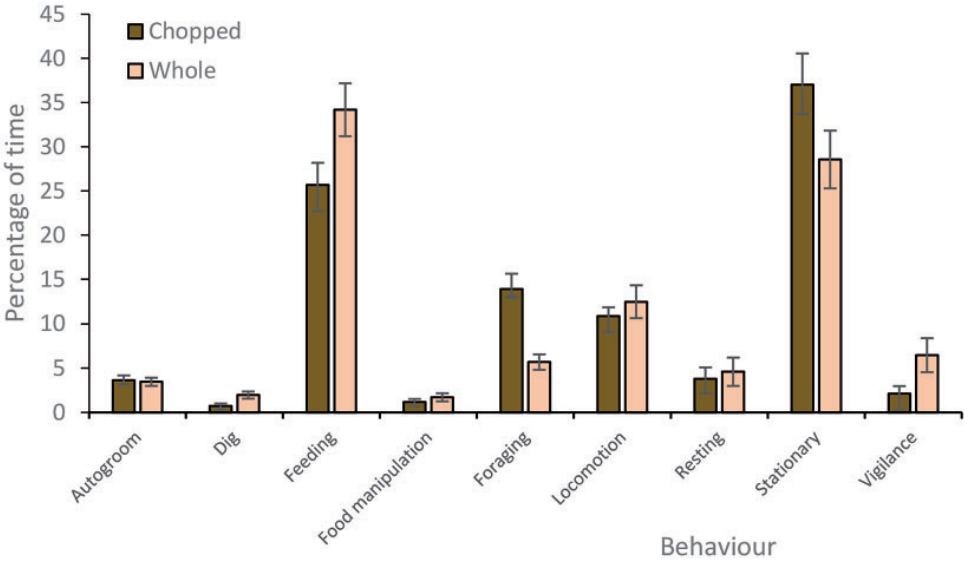

Fig. 1: Difference in state behaviour between chopped and whole conditions (+/- standard error).

Food consumption and keeper preparation time

There was a significant difference between the time it took keepers to prepare the diets for either chopped versus whole (P=0.05), with it taking an average of 395 seconds to prepare chopped food versus an average of 233 seconds for whole food preparation. There was no significant difference in amount of food eaten between conditions.

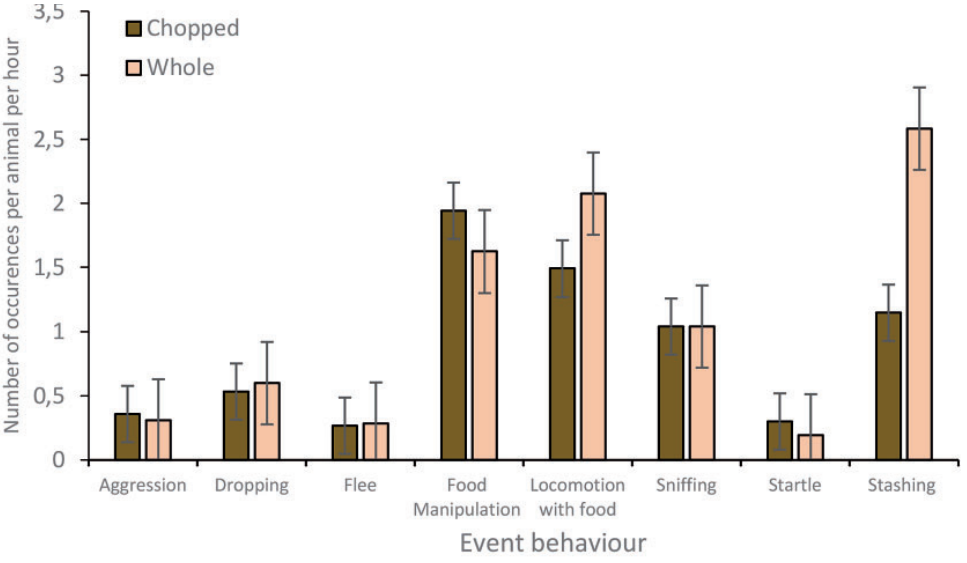

Fig. 2: Event behaviour during chopped and whole food conditions (+/- standard error).

Discussion

Overall, agouti activity budgets remained relatively stable irrespective of food condition. However, several notable changes occurred when whole foods were provided: time spent feeding and occurrences of moving with food and hoarding were increased, while time spent foraging decreased. Keepers saved an average of 162 seconds when preparing whole food diets as opposed to chopped meals. Given the limited changes in animal behaviour and the time saving benefits for keepers, provision of whole food may be a viable option for captive agoutis.

Effect on behaviour

When whole foods were provided, agoutis spent significantly more time engaged in feeding behaviour and considerably (but not significantly) less time spent inactive. This is a promising direction, as it therefore increases activity levels whilst providing the animals with more naturalistic activities (Young, 1997). The increase in time spent feeding, despite no significant difference in the amount of food eaten, is indicative that the food was more challenging to process or that food motivation was higher (meaning that the agoutis were eating the food sooner after it entered the exhibit). This direction is positive, as it demonstrates that agoutis spent longer engaged in naturalistic behaviours, rather than longer periods of stationary resting.

The whole food condition was also associated with a significant decrease in foraging behaviour. This reduction in foraging behaviour may be a direct result of whole food provision, as a) whole foods are easier to spot and therefore can be found rapidly and b) whole food items take longer to process, meaning that the agoutis had less time to search for food items. Foraging is commonly perceived as a beneficial activity for zoo animals (Young, 1997), so the reduction in this behaviour should be noted. The amount of foraging exhibited by wild agoutis has not been systematically studied (Jones et al., 2019), so further research in this field would be valuable.

Stashing or hoarding behaviour also significantly increased when whole foods were provided. Hoarding is a natural behaviour across rodents, carnivorans and birds and allows animals to safely store food for future use (Andersson & Krebs, 1978). Hoarding behaviour has useful application, especially in unstable environments where food may sometimes be scarce (Whishaw & Tomie, 1989). In the agouti, as in many rodent species, hoarding is believed to be a natural behaviour (Jones et al., 2019). While the trigger for hoarding is not known, it appears that in this case larger food items were more attractive for hoarding.

No other significant changes in behaviour occurred in this study. The limited effect on other aspects of agouti behaviour, such as welfare indicator behaviours or social behaviour, suggests that the whole food was not considered to be stressful by the animals. Rodents are often neophobic when introduced to novel environments or enrichment styles, yet the whole food condition did not elicit this response (Barnett, 2018). Given that the whole food item condition took less time for keepers to prepare and is potentially of higher nutrient value, with a lower risk of microbial contamination (Watada et al., 1996), this feeding style could help in moving forward the husbandry for agoutis in general. It should be mentioned that the study feed periods could be spaced out over a longer period of time to provide longer opportunities for feed-related behaviours.

Future directions

This study opens up several avenues for future research from both a pure and applied science standpoint; from a pure science perspective, the association between food particle size and hoarding and locomotion with food warrants further investigation. The results of this study demonstrate that hoarding behaviour increased when larger food items were provided, similar to

the findings in rats and mice (Charron & Cabanac, 2004; Mares & Williams, 1977; Whishaw & Dringenberg, 1991; Whishaw & Tomie, 1989). While it seems logical that animals should select larger food items for stashing, it should also be considered that an animal could also hoard smaller food items by gathering several items and transporting them simultaneously. Given that large food particle size has been identified as a trigger for hoarding in evolutionary different rodent species (rats, agouti), it is possible that food particle size may be motivated by particle size across a much wider range of rodents. Further pure research may aid in testing this hypothesis.

In a related vein, locomotion with food appears to be driven by food particle size (Whishaw & Tomie, 1989). This is a logical extension of the hoarding theory, as animals need to transport their food in order to hoard it. However, a much wider range of species have been seen to selectively transport larger food items: this has been observed in South American coatis (*Nasua nasua)*, whereby group aggression was reduced when whole food was provided, as individuals were more likely to transport large food items to secluded spots to eat (Shora et al., 2018). It is likely that this transporting of large food items has resulted in reduced aggression in other taxa when fed whole food (e.g. Sandri et al., 2017). Future investigations could identify what sizes of food (e.g. very small, medium, large) elicit locomotion with food and could explore the associated impact on group aggression.

From an applied standpoint, future studies could consider the complex relationships between food nutrient value and size and the motivation for feeding and hoarding. For example, Rozek & Millam (2011) demonstrated that orange-winged amazons (*Amazona amazonica)* were highly motivated to gain access to oversized pellets, even when a nutritionally identical small pellet was available in the exhibit. It was beyond the scope of this study to identify food preferences and motivation, though it is likely that higher-calorie items are preferentially eaten or hoarded. Research could be conducted that investigates whether certain items are likely to be eaten first and which items are normally hoarded. There should also be some consideration of the risk of pests in association with hoarded food, which may provide opportunities for pests. Comparative studies that allow the animal to select its preferred size of food would also have merit.

Finally, future studies should consider a wider range of species. Given the presence of a couple of positive changes in behaviour were noted, with only one possible negative change (foraging), it appears that whole foods may improve agouti husbandry regimes. It is likely that a much wider range of rodents, all of whom are equipped with tough teeth for gnawing, would benefit from whole food. Other taxonomic groups that have featured rarely in zoo and aquarium food presentation research include reptiles, passerine birds and fish (for a review, see Brereton, 2020).

Conclusion

The provision of whole food items resulted in increased time spent feeding, hoarding and moving with food and reduced foraging in a group of zoo-housed agoutis. Given that there was a limited change in behaviour as a result of food condition, and that providing food in the whole format saved minutes of keeper time, it is reasonable to suggest that food could be provided to agoutis in larger or in whole form, in zoos globally. The extra processing required for whole foods may be enriching for agoutis and therefore may potentially enrich the daily husbandry for these animals. Further studies across a wide range of species would help to provide an evidence-base for animal food presentation.

Acknowledgments

The authors would like to thank the team at Woburn Safari Park for their support throughout the study.

Zusammenfassung

Die Aufbereitung des Futters für Zootiere kann sich auf das Verhalten der Tiere, ihre Ernährung und Motivation auswirken und letztlich das Wohlergehen der Tiere beeinflussen. Obwohl die Wissenschaft der Präsentation von Zoofutter voranschreitet, besteht nach wie vor die Tendenz, das Futter so zu präsentieren, dass es den Verderb des Futters beschleunigt und nicht die Ökologie der Spezies widerspiegelt, die gefüttert wird. Die aktuelle Literatur über die Präsentation von Zoofutter hat sich tendenziell auf bestimmte taxonomische Gruppen konzentriert, insbesondere Primates und Carnivora, und weniger auf Taxa wie Rodentia. Um eine Lücke in der Literatur zu füllen, wurde im Woburn Safari Park eine Studie an einer Gruppe von fünf Azaras Agoutis (*Dasyprocta azarae*) durchgeführt, um die Auswirkungen von kleingeschnittener oder unzerteilter Nahrung auf das Verhalten zu untersuchen. Das Verhalten der Tiere wurde in 60-Sekunden-Intervallen in einstündigen Sitzungen mit kontinuierlicher Erfassung von Ereignissen aufgezeichnet. Insgesamt nahmen das Versteckverhalten, das Fressverhalten und die Futtermanipulation deutlich zu und die Futtersuche nahm unter dieser Bedingung ab. Es gab keine signifikanten Auswirkungen auf das Aggressionsniveau. Die Zubereitungszeit durch den Tierpfleger wurde aber signifikant reduziert. Während der Fütterung unzerteilter Nahrung sparte der Tierpfleger mehr als zwei Minuten pro Mahlzeit und es wurde kein signifikanter Unterschied in der Menge des gefressenen Futters festgestellt. Verstecken und Manipulation der Nahrung sind natürliche Verhaltensweisen wildlebender Agoutis, so dass die Agoutis ein breiteres Spektrum an natürlichen Verhaltensweisen zum Ausdruck bringen. Es ist jedoch anzumerken, dass ein Rückgang des Futtersuchverhaltens festgestellt wurde. Weitere Studien an einer größeren Anzahl von in Zoos untergebrachter Arten würden dazu beitragen, Taxa zu identifizieren, die von ganzer Nahrung oder alternativen Nahrungsangeboten profitieren würden.

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DER ZOOLOGISCHE GARTEN

THE ZOOLOGICAL GARDEN

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Gundis (*Ctenodactylus gundi* (Rothmann, 1776)) in European Zoos
Since when, how to keep, and why?

Gundis (*Ctenodactylus gundi* (Rothmann, 1776)) in europäischen Zoos
Seit wann, wie zu halten und warum?

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Summary

Gundis (*Ctenodactylus gundi*) are small herbivorous and philopatrous (females) rodents that live in colonies in arid and semiarid climates of North Africa. They are not endangered, but are rarely kept in zoos. In 1995 and later in 2007 a small "founder group" of gundis came from Tunisia to the "Aquazoo Löbbecke Museum" (Düsseldorf, Germany). The two groups originated from widely separated areas of Tunisia and formed the initial base of Gundis kept in European zoos. However, all gundis kept in European zoos as part of the studbook (ESB) to date are descendants of the animals from 2007. An over 20 years' experience in these animals as well as data from a studbook kept since the year 2000 by one of us (Sandra Honigs) allow describing husbandry and breeding guidelines, trends of the population currently kept in zoos and pay attention to some non or insufficiently explored matters concerning gundi biology. According to previous experience, gundis cannot be kept in human care in the long term without major effort. They are preferably kept in groups in enclosures with a floor space of at least 1.5 m x 1 m x 1.2 m (W x D x H) for one pair; per animal the area increases by half a square meter each. The substrate should consist of clay and a thin layer of sand. In addition, the enclosure must contain rock structures with hiding places, be well air-conditioned and have at least one place

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for “sunbathing”. Feeding is done with a mixture of various seeds and conventional rabbit food. The data so far from the Aquazoo and the studbook show that it is very difficult to form new breeding pairs or breeding groups with individuals from different populations because of the high aggression towards foreign conspecifics. Females are fertile for at least six years giving birth to one to four young per litter. The mortality of the young is relatively high and the number of births seems to be decreasing in some institutions probably due to inbreeding depression**.** However, some individuals lived almost ten years.

Key words: Gundis (*Ctenodactylus*), studbook, keeping and breeding

Introduction

Gundis (Ctenodactylidae) are small, approximately guinea pig-sized, territorial herbivorous rodents living in social groups. They are obligate rock-dwellers that live up to an elevation of about 2.300 m (*Ctenodactylus* sp.) in semi-desert and desert mountainous areas of north and east equatorial Africa (Fig. 1, left and right; summarized in Gouat, P., 2013 and López-Antoñanzas, 2016), with low precipitation (about 50 to 300 mm per year), mean temperatures of 2 to 7°C in the coldest month, and mean temperatures near their home range of 27 to 35°C (data from Tunisia, Séguignes, 1983).

Ctenodactylidae might be one of the oldest rodent families which are united in the suborder Ctenohystrica together with the Hystricognathi (porcupine-like rodents) (e.g., Huchon et al., 2000, 2002, 2007; Upham & Patterson, 2012), originated in East Asia during the Eocene and then spread to Africa (e. g., López-Antoñanzas, 2016; López-Antoñanzas et al., 2011). Currently, four genera with five species are known, i.e. *Pectinator spekei*, *Massoutiera mzabi*, *Felovia vae*, and two *Ctenodactylus* species (*C. gundi* and *C. vali*). The range of *C. gundi* extends from Morocco over Algeria and Tunisia to Libya, that of *C. vali,* is restricted to relatively small and isolated areas in Algeria, Morocco and Libya (see general maps in Cassola, 2022). In Algeria, the ranges of the two species are immediately adjacent but do not overlap (Gouat, P., 1988).

Name-giving for the whole family are ‘combs’ of strong hairs present on the 1st and 2nd toes (= 2nd and 3rd “finger”) of the hind feet, which serve for grooming (Fig. 2, left). The rest of the coat is very fine and dense and serves mainly the insulation for cold and perhaps also protects against UV radiation (Fig. 2, right; George, 1978a).

Fig. 1: Left: Detail from the habitat of *Ctenodactylus gundi* in Bou-Hedma National Park (Tunisia). Right: Gundi in its natural habitat. Photos: S. Honigs

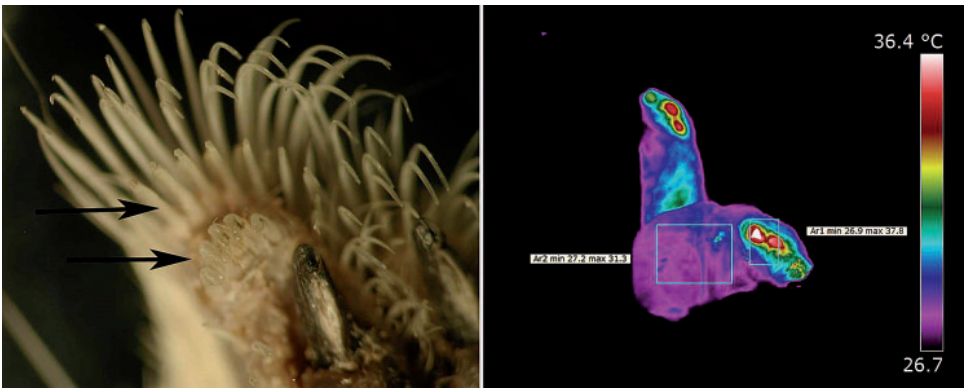

Fig. 2: Left: The typical combs over the claws of the first and second toe of the hind feet (see arrows). Right: Thermography of two gundis (ambient temperature about 25°C). Note the insulating effect of the fur (colour towards blue). Photos: S. Honigs

The two *Ctenodactylus* species are very similar. Diagnostic characters include a greater length of head and body, higher mean weight and more hairs per cm² of skin in *C. gundi,* different 'alert' calls, and the shape of the last molar (M3) in the maxilla, which is L-shaped in *C. gundi* and kidney-shaped in *C. vali* (see George, 1978a; 1982; summarized in Gouat, P., 2013 and López-Antoñanzas, 2016).

Probably the most common species of *Ctenodactylus* observed in the field and held in human care is *C. gundi*, to which we largely confine our discussion below. *C. vali* we consider only occasionally; many of the findings so far only on this species may also apply to *C. gundi*.

In the natural habitat, gundis have a large number of enemies, primarily snakes, but also dogs, jackals, hawks, and ravens; in addition, they are also hunted and eaten by humans (e. g., Gouat, P., 2013) and are still taken from the field in larger numbers as research animals, e. g. to study their potential role as reservoir host of *Leishmania tropica* (Bousslimi et al., 2012) or to explore the evolutionary history of paramyxoviruses (Ghawar et al., 2018). According to the IUCN Red List, both *Ctenodactylus* species are rather not threatened (Read List Category, *C. gundi*: "least concern", Cassola, 2022; *C. vali*: "data deficient", Gerrie et al., 2016).

The numerous publications on the biology of gundis, which appeared in rapid succession from about 1973 onwards, report on field observations, but also on studies of animals in human care (containing detailed information on reproduction and specific behaviour, the study of which is hardly possible in the field) and on museum material (Gouat, P., 2013; López-Antoñanzas, 2016).

In Germany gundis have been kept in human care already at the end of the 19th century – but not very successfully. Brehm (1880) was able to keep them alive for only 14 days. P. Matschie (1895), head of the mammal department of the Zoological Museum in Berlin, presented gundis in a popular magazine at that time and also illustrated them (Fig. 3).

The Austrian biologist Paul Kammerer (1880-1926) cared for and carefully observed a pair of gundis for a time as a student (Kammerer, 1902). At the beginning of the 20th century, the zoologist and explorer Paul Spatz (1865-1942) brought living gundis to the zoological gardens of Berlin and Frankfurt, where they did "quite well there for a while" (sie „…hielten sich da eine Zeitlang ganz gut…" Brehm, 1922, p. 204). After that, gundis found their way into various museums and research institutions from time to time. The Hubrecht Laboratory in Utrecht (Holland) possessed about 300 (!) preserved uteri of animals collected in 1912 and 1913 (de Lange, 1934). Roth (1956), Biological Station Wilhelminenberg, Vienna (Austria), kept a specimen

Fig. 3: Early drawing of *Ctenodactylus gundi* (from P. Matschie, 1895).

from Tunisia and Eisentraut (1977), Museum Alexander Koenig, Bonn (Germany), maintained some individuals that were a souvenir of a research trip to Tunisia (Africa). However, rearing of the young was not successful. Grenot (1973) reported on two successful breedings of *C. vali*, emphasizes the rapid weight gain and the different weight development of twins, but omits information on husbandry.

Occasionally, gundis from the pet trade or from some zoos end up with private individuals, from whom, however, little is learned about keeping and breeding successes. As far as we know, apart from the early attempts mentioned above, gundis were not kept in European zoos for a longer period of time until the end of the 20th century.

In the years 1995 and 2007 gundis (*Ctenodactylus gundi*) from Tunisia were brought to the Aquazoo Löbbecke Museum Düsseldorf (NRW, Germany) – hereafter referred to as Aquazoo – reproduced there and were distributed over numerous European zoos.

The Aquazoo still keeps gundis today and thus has many years of experience in handling these animals as well as in their care and breeding. This experience of more than 25 years as well as data from the studbook kept by the first author since 2000 allow us to formulate guidelines for the keeping and breeding of these animals, to draw attention to some not or only insufficiently investigated questions of their biology and to show trends in the populations maintained until today (see also Honigs et al., 2002; Honigs & Greven, 2003). Concerning the vast literature, we mainly consider in the following those studies, which are zoo-relevant and from which also guidelines for an adequate husbandry of these animals can be derived.

Origin of the gundis in European Zoos and the European Studbook

In 1995, five adult gundis (three males and two females; hereafter referred to as population A) arrived from the Bou-Hedma National Park (Tunisia) to the Aquazoo, where in cooperation with the “Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ)” a permanent

exhibition for the information center of this park was prepared. We assumed that the gundis belonged to a social group (see below), especially since the animals arrived almost unharmed in a single transport crate. For several years, all gundis kept in European zoos descended from these five "founder animals". The last individual from this population (from F4) was born on 12.06.2012 and died at the Aquazoo on 20.03.2017 at the age of almost five years.

On 20 April 2007, in cooperation with 'Erlebnis Zoo Hannover, Germany' 14 gundis (six males, eight females; hereafter referred to as population B) arrived at Aquazoo Löbbecke Museum from Parc Nationale de Dghoumès, Tunisia (approx. 170 km southwest of Bou-Hedma; national park since 1980). Of the 14 individuals, nine were adults (four males, five females), three were adolescents (one male, two females), and two (one male, one female) were only a few weeks old. The animals were housed in two transport crates. Again, we assumed that the animals were from a single social group and that the few fatalities recorded during and after transport were largely stress-related. Of the imported animals, five specimens died in Düsseldorf already in the same year, three further specimens died in 2008, leaving only a few animals for breeding.

The individuals of the two populations could be distinguished by their habitus (size, skull shape, ear shape, etc., Fig. 4). However, both were clearly *C. gundi* (Honigs et al., unpub.). The original idea to mate gundis from population B with gundis from population A for blood refreshment failed because of the aggressiveness of the animals against group strangers (see below) and the fact that after two successful matings the young were born dead, so that animals from the two populations (until the extinction of population A) were kept separately.

Fig. 4: Habitus of *C. gundi*. Left: Female from Bou-Hedma (Population A). Right: Female from Dghoumès (Population B). Note the differences concerning the head, the shape of the ear and the fur. Photos: S. Honigs

In 2000, a monitoring studbook (MSB) for gundis was initiated by Aquazoo Düsseldorf in the framework of the Small Mammal Taxon Advisory Group of the European Association of Zoos and Aquaria (EAZA), which was converted into an ESB (European Studbook) in 2009 and has been maintained by Sandra Honigs (Aquazoo Löbbecke Museum) since 2000. Animals from private keeping or from keeping for research purposes are not recorded in it. Because of the striking differences, the animals from populations A and B were kept separately from each other and also kept separately in the studbook, until the final extinction of group A.

The documentation of the development of population A in human care until 1999 is incomplete. The five founder animals from population A were all deceased by 2000. Which of the five individuals were actually involved in the production of offspring is unknown. Some of the offspring were subsequently assigned studbook numbers G00001 through G00090. The "founder animals" remained at the Aquazoo; the offspring were given to various zoos. The animals from Bou-Hedma always reproduced only moderately, so that only rarely more than 50 individuals

existed at the same time in the zoos participating in the breeding program. Until the extinction of the population in F 4, a total of 69 births were recorded.

All imported gundis from population B and their offspring received the studbook numbers consecutively starting with G00091. Due to failures during transport or shortly after arrival in Düsseldorf – caused by bite injuries, diarrhea, parasite infestation etc. – finally only five animals (two males, three females) with the numbers G00095, G00096, G00099, G00101 and G00102 were suitable for breeding. All animals were fitted with a transponder chip between the shoulder blades.

As part of the breeding program, a varying number of zoological gardens in Europe have kept gundis over the past 20 years. Currently, 16 zoological gardens in Europe hold a total of about 100 individuals (as of September 2023). A total of 363 transfers occurred between the participating keepers during this time; 157 of these were through the Aquazoo. This was due to the fact that individual animals were taken back from the Aquazoo and attempts were made here to socialize them with new partners (see below). If successful, these new groups were then transferred to other zoos. The gundis currently kept in European zoos under the breeding program are exclusively offspring of the founder animals from population B.

Husbandry

In the field gundis live territorially and in relatively stable social groups. Females in particular are philopatric, i.e. relatively site-related (e.g., George, 1974; Gouat, P., 1991 a, 2013; Gouat, J. & Gouat, P., 1984; Gouat, P. & Gouat, J., 1983; Nutt, 2005). The social structure of these groups (= distinct reproductive units) varies and can be characterised with the keywords ‘family groups’, ‘multiple females per male’, ‘multifamily groups’, ‘ cooperative breeding units’ (e. g., Nutt, 2007b). Accordingly, information on the group size of a colony varies (two to 11, possibly even up to 20 individuals). This is also true for the area of the common home range (= territory), which the individual groups colonise, actively mark and defend against conspecific intruders (e. g., George, 1974; Gouat, J. & Gouat, P., 1984; Nutt, 2005; summary in Gouat, P., 2013).

Group size and territory in the field are strongly influenced by food availability, climate and altitude, and fluctuate throughout the year and between different years (Gouat, J. & Gouat, P., 1984). In extreme cases, for example in desert habitats on the edge of the Sahara, social units are composed of only one breeding pair (Gouat, J. & Gouat, P., 1984; Seguignes & Vernet, 1996). These dependencies apparently also shape the different breeding patterns or social structures within a group ranging from facultative monogamy, unimale polygyny (the most common association) to multi-male polygyny (Nutt, 2005, 2007 a, b). From the information about the habitat and living in the field it can be deduced how a gundi enclosure should look like and that adult gundis can be kept in pairs with offspring or several (one or up to three males, several females and offspring), but not how large a gundi enclosure should be at least.

More precise information about the very early keeping of gundis, e.g. in the Frankfurt Zoo (see above), no longer exists (J. Köhler, in litt.). Later, gundis were kept in human care (see above) and then either in pairs in cages (e.g. Kammerer, 1902; floor space of the cage 50 cm x 50 cm) or individually (Roth, 1956; floor space 2 m x 2 m), but altogether not for a very long time. Eisentraut (1977) kept up to five specimens in a cage with a floor space of 2 m x 1 m, recorded three births, but could only keep his animals alive for a maximum of eight months. Studies, for which successful keeping and breeding of gundis over longer periods were preconditions, appeared from 1973 (see citations below) and contain more or less continuous observations often over several years (for all species of the Ctenodactylidae except *Felovia* and *Pectinator*) as well as data on enclosure size (cage area 150 cm x 150 cm with up to five individuals for *C. gundi*: George, 1978b; cage area 2 m x 2.25 m with four individuals: Gouat, J., 1985).

Housing

According to the expert opinion on the minimum requirements for keeping mammals of the German Federal Ministry of Food and Agriculture (2014), a pair of gundis should have a minimum area of 1.5 m² (minimum height 1.2 m) and for each additional animal 0.5 m² area more. This may be fine in principle, but we are of the opinion that also considering animal welfare, gundis should be kept in (family) groups in more spacious enclosures with near-natural equipment.

In the years from 1995 to the present day, groups of gundis of various sizes (from one pair to a maximum of eight males together with five females) have been kept and bred in the Aquazoo Löbbecke Museum in the large exhibition enclosure, as well as backstage in smal-

Fig. 5: Various enclosures for gundis at Aquazoo Löbbecke Museum. Top: Exhibition enclosure. Below left: Gundis at the cave entrance. Below right: Backstage housing. Photos: S. Honigs

Fig. 6: Enclosures for gundis in the exhibition at other zoos. Top left: Korkeasaari Zoo, Helsinki (photo: Korkesaan Zoo, Helsinki, Finland, 2012). Top right: Former gundi enclosure at Magdeburg Zoo. Photo: Magdeburg Zoo, K. Ruske, 2017.

ler enclosures. The enclosure in the exhibition provides a floor area of about 8 m^2; the floor consists of a clay layer with a thin overlay of fine-grained sand in which the gundis frequently bathe (dust baths), a behaviour that very likely reduces the fur lipids as e.g. in gerbils and chinchillas (see Thiessen & Pendergrass, 1985; Barber & Thompson, 1990). In the background are superstructures of natural stone, e.g., granite or sandstone (which is preferable because gundis often gnaw on stones), with niches and burrows of various sizes (Fig. 5, top), one of which is large enough to accommodate the entire group (Fig. 5, below left). This is important for group cohesion and also applies to the burrows visited by gundis in the field (see also Gouat, P., 1991).

The show enclosure is illuminated all year round with PC-controlled LED spotlights ("basic lighting"), which are switched on successively over a period of 1 h from 6:30 am and from 5:30 pm to 6:30 pm. In addition, there are heat radiators (SolarRaptor; 8:00 am to 5:00 pm; through these up to 40°C are reached on the stone surface) and UV radiators (Osram Ultra Vitalux 300W, 11:00-12:00 am) above the areas where the animals mainly stay. The enclosure receives additional daylight through a glass roof. The temperature above the floor is about 25°C during the day and drops to about 20°C at night; on the stone wall it varies between 21°C and a maximum of 31°C. This is also true for the sleeping caves, i.e. the large climatic fluctuations that gundis can be exposed to depending on their natural environment (see above) are not taken into account when keeping them. Humidity varies from 24.5 to 73.3% during the day. Two food bowls, a drinking water container and mineral stones ("Nagerstein". Fa. Dehner, Rain) complete the equipment. Feeding takes place daily between 8:00 and 10:00 am. The cleaning of the enclosure is mainly limited to the removal of sand too soaked with urine and fecal pellets, which can be found (also in the field) in the rocky area and especially in front of the burrows (George, 1974; Gouat, P., 1992).

Behind the scenes, individual animals or pairs (in the larger terrariums sometimes up to nine individuals for a short time were kept in containers with base areas ranging from 100 cm x 50 cm to 160 cm x 60 cm (the heights varied between 100 and 120 cm). Here, too, the substrate consisted of sand (Rhine sand and a corner with fine chinchilla sand); in addition, there were hiding places between stones. Temperature, light conditions and humidity largely corresponded to the conditions in the show enclosure (Fig. 5, below right). A survey of the zoos involved in the breeding programme revealed that the animals are mainly kept in relatively large exhibition enclosures under largely similar conditions (cf. Fig. 6).

Nutrition and feeding

In their natural habitat gundis forage over long distances eating leaves, stalks, flowers and seed of almost any plant, i.e. they are opportunistic and generalistic herbivores adapted to utilise a fibrous and low fat diet (e.g., George, 1974; Gouat, P. & Gouat, J., 1983; Gouat, P., 2013). Recent studies show that, depending on the seasons, the animals consume mainly the green parts of a wide range of perennial and annual plants and their fruits (Lasgaa et al., 2021). Gundis pick up food directly by mouth from the ground or from a food bowl, but they are also able to fix larger pieces of food with their forepaws on the substrate to eat from or even, contrary to earlier views (George, 1982), to hold these pieces with the forepaws and guide them to the mouth (Fig. 7).

Fig. 7: Gundi feeding directly from the food bowl (left) and with the help of the front paws (right). Photos: S. Honigs

The gundis at the Aquazoo Löbbecke Museum have been fed a well-established diet (8 to 10 g per adult animal per day; see Honigs et al., 2002) consisting of the following ingredients (given as approximate proportions): 6% wheats; 6% rye; 6% carob; 6% millet; 2% mung beans; 12% sesame; 6% oat flakes; 12% paddy rice; 12% dried lentils; 12% grass seeds plus 20% pellets for guinea pigs or rabbits. Occasionally, hay is offered. Fresh feed (including husk leaves of corn cobs, bark of blackberry bushes and willow) is also provided. Food with high fat content (peanuts, sunflower seeds) should be fed, if at all, only moderately, because gundis tend to put on fat quickly. Gundis also like to eat fresh herbs such as thyme and basil. In view of the analyses of Lasgaa et al. (2021), the diet of gundis should be adapted to even more natural conditions and increase the proportion of grasses and shrubs.

Food containing free sugars (such as fruits, raisins, breakfast cereal etc.) result in diarrhea. Although not studied in detail, we assume that the insulin of gundis, as in other hystricomorphic rodents, is much less physiologically active than the insulin of other mammals (e.g. Opazo et al., 2004, 2005).

Gundis meet their fluid requirements through food and probably through metabolic processes. However, the concentration ability of their kidneys does not seem to be sufficient to survive a prolonged period with little or no water (*Ctenodactylus vali*: Rouffignac et al., 1981; George, 1987). Perhaps the relatively long (expressed as a percentage of total length of the gut) large intestine compared to other desert rodents reabsorbs water, especially since the animals' feces are also very dry (Gouat, P., 1993, 2013). However, gundis in human care should definitely have access to a watering trough, which they use, even if only occasionally, on the diet given above.

Handling and Sexing

Gundis are extremely shy in the wild, but quickly become accustomed to human observation in the show enclosure. Only when you enter the enclosure they disappear into their hiding places. Sometimes (for physical examination or medical treatment) it is necessary to catch gundis. In larger enclosures this is possible when the animals have retreated into a crevice. These should be large enough to reach into with the hand. The gundis are carefully (the hairs come out easily) grabbed by the back, pulled out of the burrow and brought into a slightly inclined position (belly up). Held in this way, they are usually quiet and can be easily examined (Fig. 8, top right). When grabbed by the neck, the animals resist violently and usually lose hair at this point. Since they can be held easily and without resistance in other ways, the neck grip should be avoided. Despite the sharp claws, it is also not advisable to use gloves in which you either have too little feeling (thick leather gloves) or in which the animals get caught when kicking (cotton gloves). Nets are also not recommended because the claws get caught in any form of mesh.

Also for sex determination one must take the animals in the hand. Younger males and probably subdominant males do not have a well-developed scrotum. Testicles are located lateral to the penis that can be pushed out by pressure with two fingers on either side. The anogenital distance of the male is approximately twice the size of that of the female. The vagina of the female is open only during parturition and estrus. The females have four teats. One pair is located at the

Fig. 8: Top left: Gundi shortly after birth. Top right: Holding a gundi for closer inspection. Bottom left: Genital regions of a female. Bottom right: Genital region of a male. Photos: S. Honigs

level of the clavicles in front of the base of the forelegs, another pair is located laterally behind each arm (George, 1978b).

Notes on behaviour

Activity

The activity of gundis depends strongly on the ambient temperature. In the wild gundis appear to be diurnal with activity peaks early in the morning and afternoon (before sunset). They leave their shared hiding places at sunrise, forage, rest in the shade or in a hiding place during the hottest part of the day to avoid temperatures above 32°C (Gouat, P., 1991b), but also spend a considerable time of the day sunbathing (up to 50% of the day, cf. Gouat, P. & Gouat, J., 1987; Gouat, P., 1991b) and are active again in the afternoon (before sunset) (George, 1974; Gouat, P., 1991b, 2013; Gouat, P. & Gouat, J., 1983; Nutt, 2005). At temperatures below 10°C and above 35°C, gundis remain in their hiding places. They are most active at temperatures between 25°C and 30°C (George, 1974, 1977). In gundis in human care there is a clearer distinction between sunbathing periods and other resting periods (the animals then lie on stones etc. and no longer under the radiant heater). The corresponding values vary greatly (perhaps this also has something to do with the social position within the group, but individual animals spent almost 70% of the day with both rest periods (Honigs et al., 2002)). When relatively cool ambient temperatures (around 20°C) persist for several days, gundis feel visibly uncomfortable and erect their hairs (Fig. 12A). However, we could always observe nocturnal activities at such temperatures both in the exhibition enclosure and backstage (Honigs et al., in prep.).

Social behaviour

Gundis communicate with each other using a rich accoustic repertoire and drumming (George, 1981; Gouat, J. et al., 1985). In general, members of a gundi group appear to interact relatively peacefully in the field. In case of quarrels, they also have enough space to avoid each other or to leave the group permanently. The territory is defended against intruders and marked with feces (especially at the entrances to the hiding places), urine and probably also with secretions of the anal gland (Gouat, P., 1991). This can also be observed in human care. To our knowledge, nothing is known about hierarchies in wild family groups. Young sexually mature males are expelled from the family group at different times depending on the stocking density.

In human care, depending on enclosure, group size and composition, males may remain in the family. Housing multiple males in a family group does not necessarily result in increased aggression between males. Nevertheless, sometimes quarrels like barking, chasing, and banditing and even serious mutual injuries can be observed (females seem to be more aggressive than males). Quarrels between males, females, and females and males often start without apparent cause and end with biting attacks. As weaker individuals flee but are still pursued in some cases, bite wounds are increasingly found in the posterior body region. According to our observations, there seems to be a linear hierarchy in larger groups of males and females, which is apparently visible during allo-grooming (Fig. 9, top left) and during joint sunbathing (Fig. 9, top right) – here the animals often lie in close proximity next to each other or on top of each other. Dominant individuals are preened more or are preferred as neighbours during joint sunbathing. Males and females that have been classified as dominant often greeted each other very intensively when they met by sniffing each other and mutual grooming; the dominant male grooms the dominant female conspicuously often (Honigs et. al., 2002).

Fig. 9: Social behaviour of gundis in a group. Left: Allo-grooming. Right: Sun-bathing. Photos: S. Honigs

The importance of common sunbathing is also evident from the fact that the animals become restless and also quarrel more often if they cannot do this. Quarrels also occur when the group cannot find refuge together in a cave, or when the enclosure is cleaned too much and all droppings are removed. Finding a common sleeping cave is essential for the cohesion of the group. The size of the caves varies depending on the size of the group. It should be approximately 15 cm x 16 cm x 15 cm (D x W x H) for three specimens. Inside the cave, the animals huddle close together and remain in the typical resting position (cf. Fig. 9).

Quarrels can lead to individual animals being excluded from the group and even killed. Injured animals should be quickly removed from the group and, if possible, separated together with a less aggressive conspecific from the same group (the sex is not decisive in this case). It should be noted, however, that even a short-term separation (about two days) can lead to them no longer being accepted by the group. If integration does not succeed (see below), the animal in question must be separated from the group and may even have to be kept alone for the rest of its life. The place required for this should be planned for when keeping gundis.

Establishing new breeding groups

The high aggressiveness towards foreign or "alienated" individuals makes it difficult to maintain stable and thus perhaps long-term healthy breeding groups in human care. The incorporation of previously isolated animals or new individuals into existing groups or the creation of new pairs from different groups must be done slowly and intensively monitored.

In this regard, the literature (e.g., summary in Quesenberry & Carpenter, 2012) recommends various procedures for rodents (rats, mice, chinchillas), including placing the animals together in sufficiently large enclosures with numerous hiding places and distraction opportunities, exaggerating their own odour with strong-smelling substances (e.g. camphor), or even "coerced closeness," i.e. placing the animals together for a period of time in a cage so small that they cannot fight and then placing them in a larger container container with hiding places etc. For gundis, most of these procedures have not proven successful.

In the Aquazoo Löbbecke Museum we could successfully socialise single or several (up to four) gundis with other conspecifics in many cases: For this purpose, the future partners were each placed in one half of an established enclosure divided by a grid. After about two days they changed sites. This procedure was repeated about three times. During this time the enclosure should not be cleaned. After that, the animals were lightly rubbed with the sand from both halves of the enclosure, then placed together under supervision in one part of the enclosure, and then observed for another three days. Sometimes it is necessary to repeat this

procedure. The decisive factor is the age of the animals to be integrated and how long the individual animals had already lived alone.

It has not been possible to integrate young animals that were still dependent on (substitute) milk during hand rearing into a group, but has been successful in individual cases at a later date.

Reproductive behaviour and breeding

Seasonality

In the field, reproduction is seasonal but occurs in different months depending on climatic conditions. George (1978b) suggested that the young she found in Tunisia in March were born in January to March and that gundis may generally be opportunistic breeders that could reproduce at any time if environmental conditions permitted. J. Gouat (1985) recorded births in the field in February to March and in May (see also Meddour et al., 2019). Table 1 summarises the breeding success in twelve relatively regular breeding institutions (studbook data). A total of 374 births were recorded from 2007 to 2022. The preference of a certain season can not necessarily be deduced from this.

The apparently climate-dependent seasonality of reproduction described for the field does not seem to exist in captive gundis under the above-mentioned largely stable conditions, which are largely constant throughout the year, or at least cannot be read from these data. It is clear, however, that under these conditions gundis can give birth to young in any month. Repeatedly, females have also given birth several times (up to a maximum of three times) in one year.

Tab. 1: Number and distribution of births and number of newborns during the year from July 2007 to December 2022 (data from twelve institutions that more or less regularly breed gundis).

Jahr	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	**Total**
2007	0	0	0	0	0	0	0	0	0	0	1	1	2
2008	0	1	0	0	0	1	0	0	1	1	0	0	4
2009	0	1	0	0	3	0	1	0	2	0	1	0	8
2010	1	3	1	1	3	0	2	1	1	5	2	0	20
2011	2	3	3	4	4	4	3	5	5	1	6	2	42
2012	2	6	4	3	7	2	4	1	2	3	3	3	40
2013	0	6	3	2	6	1	3	2	4	3	3	1	34
2014	1	1	5	5	1	4	1	6	2	2	3	2	33
2015	4	5	7	4	4	4	1	1	2	4	3	1	40
2016	3	5	2	9	4	2	0	4	2	4	1	2	38
2017	4	3	6	9	4	1	6	3	1	5	2	1	45
2018	5	3	3	2	2	2	1	1	2	2	1	4	28
2019	0	1	7	1	1	2	2	1	0	1	0	1	17
2020	1	0	2	0	0	1	0	2	1	1	2	0	10
2021	0	0	0	0	0	1	0	0	1	0	2	0	4
2022	1	2	0	1	0	0	1	0	1	2	1	0	9
Total	24	40	43	41	39	25	25	27	27	34	31	18	**374**

Mating, gestation, and birth

In the field, reproduction begins with the exclusion of supernumerary young males by both the non-reproducing the reproducing females (Nutt, 2005; Gouat, P., 2013). The most detailed data on the reproduction of *C. gundi* comes from J. Gouat (1985) and P. Gouat & J. Gouat (1987), who observed gundis in human care, but also in the field. These authors describe how males approaching the female, specific sexual trills, mounting and copulation that involves multiple thrusting intromissions. We have also repeatedly observed brief copulation attempts with probably non-responsive females (which have not become pregnant afterwards). Even such females are not conspicuously aggressive against the males harassing them. The latter also do not show submissive postures while approaching the female. However, it often happens that males ready to mate try to hold the female by biting the posterior region of the body. At most, the female loses fur; these bites never lead to serious injuries.

The females have regular oestrous cycles. The known data on this and on the gestation period are from George (1978b) and J. Gouat (1985) – own data are not available – and differ in some respect (data by George are given in brackets): The vagina is open 7.4 (4.7) days and closed 24.7 (23.6) days per cycle. The entire oestrous cycle is about 26 to 35 days (mean 28.7), the seasonal anoestrous 103-367 days (George, 1978b). The gestation period lasts 69-79 days. The few own observations lie approximately in this range. The number of young is reported to be one to three; twin births are most common (Gouat, J., 1985).

The data on the number of newborns per birth can be largely confirmed on the basis of 473 births (total number of births from 2007 to 2022 recorded in the studbook). In the period from 2007 to 2022, a total of 165 single young were born, 198 times twins, 90 times triplets and 19 times even quadruplets. With a private owner a female gave birth even to five young, three of which died immediately after birth; the other two could be raised by the mother until sexual maturity (H. Künzel, pers. comm.). In the field, triplets are already exceedingly rare (Gouat, J., 1985). Quadruplets in the field have been reported only once to our knowledge (Kock & Schomber, 1960). The birth weights varied from 16 to 40 g and are of course also dependent on the number of young per litter (Gouat, J., 1985; see also Honigs et al., 2002).

Rearing

Gundi young are precocious, fully furred with teeth and open eyes. They are able to walk within one hour after birth. They are sunbathing already a few hours after their birth. Very careful studies are already available on the rearing of the young and their behaviour, for example on the typical vocalisations of the young, which can be heard especially in the first two weeks, e.g., when they approach the mother, on the behaviour during suckling as well as the motor development of the young (George, 1978b; Gouat, J., 1985; Gouat, J. & Gouat, P., 1987; Gouat, P. & Gouat, J., 1987; Gouat, J. et al., 1985).

The newborns are licked dry by the group members (both sexes) (Honigs et al., 2002) and in the first days of life are guarded by the mother and probably by the dominant male, but also warmed and protected by the other adults. When adults approach the young, the young raises its tail and makes chirping sounds. The adults then groom the young and lick its genital region.

The mother begins to suckle her young about 12 h after birth for the first time. In the first week, especially in the morning hours shortly after the light came out, they suckled in intervals of about 20 min. The process takes less than 4 min each time. From the age of one week the young move safely and climb nimbly in the rocks. The mother then suckles the young about once an hour. According to our observations, the young are suckled more often in the morning and afternoon hours. There is often a break over the midday period. Allonursing – rare in human

care according to J. Gouat & P. Gouat (1987), but never seen in the wild – was observed regularly. Young gundis like to lie across an adult for rest. The mother defends her offspring against co-inhabitants (the gundis were for a time associated with panther turtles and spiny tails) by hissing and biting. The young are grabbed by the nape of the neck and carried to safety; they typically stretch strongly and remain in this position until they are set down again (Fig. 10, top left).

Fig. 10: Top left: Typical neck bite of the mother. Top right: Suckling of a young gundi. Bottom left: Mouth to mouth contact of mother and infant. Bottom right: Mouth-to-mouth contact of two adults. Photos: S. Honigs

The young are suckled up to six weeks (Fig. 10, top right), but according to our observations often even longer, but start to eat solid food (dry food mix and vegetables) already three days after birth. According to Gouat, P. (2013), young animals already ingest vegetable material long before weaning at about two weeks of age.

The significance of the conspicuous and frequent mouth-to-mouth contact between young and adults is not clear (Fig. 10, bottom left). We observed that the young start mouth-to-mouth contact at an age of about two to three days and also "chirp". According to George (1978b) food should be given to the young during this process, but according to J. Gouat, & P. Gouat (1987) only water.

Such contacts also occur between adults (Fig. 10, bottom right). Mouth-to-mouth contacts between mother and youngster are also known from other rodent species as "mouthing" or "mouth licking" (see Ewer, 1968). In *Acomys* this is thought to transfer food preferences (McFadyen-Ketchum & Porter, 1989), in *Micromys minutus* food (regurgitation feeding: Ishikawa & Mori, 1998). In *Meriones unguiculatus*, this contact – saliva-related chemical communication – is not limited to mother and child, but affects different phases of social life (Block et al., 1981).

Gundis gain weight particularly rapidly in the first weeks after birth, the mean weight gain from birth (day 0) to day 28 was about 2 g per day. The adult weight (about 290 g) is reached after about 70 days. Weaning usually occurs after 6 to 8 weeks (George 1978b). Figure 11 shows the nearly linear weight development of three juveniles (two littermates raised within a group, one hand-raised specimen). The littermates were marked with animal colour spray immediately after birth and then captured and weighed at irregular intervals (see also Honigs et al., 2002).

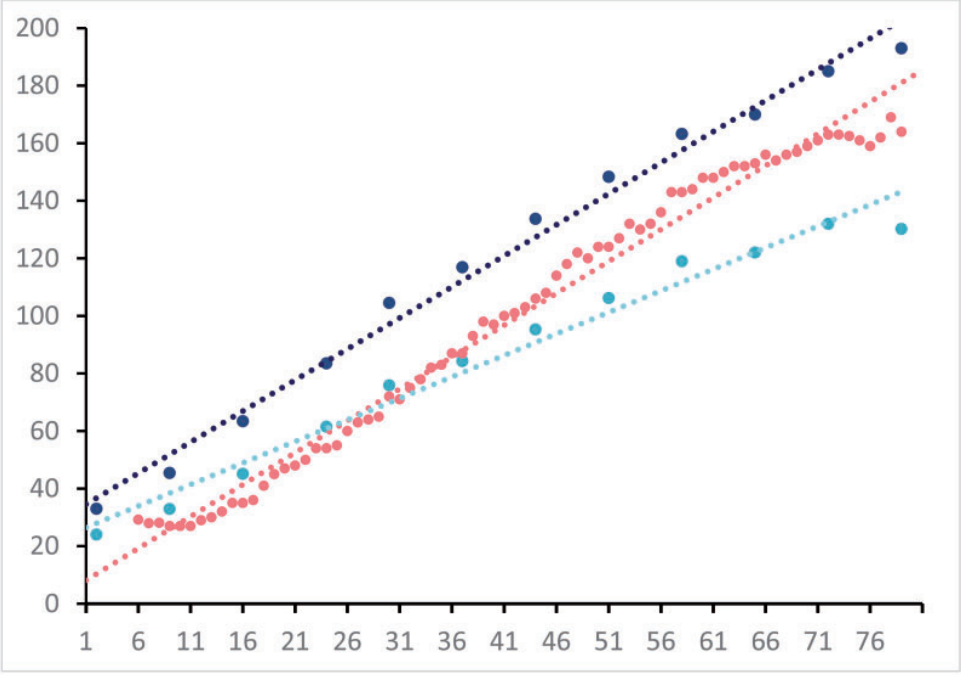

Fig. 11: Weight development of three gundis from birth to about days 79 and 104. Blue circles: Litter mates. Red circles: Hand-raised young.

Twins or triplets grow differently; often one of the newborns is heavier. Weaning is normally at six to eight weeks. *C. gundi* is fully grown and sexually mature in nine to twelve months George (1978b). These observations can be largely confirmed from our data (Fig. 11). However, we observed that some of the females were sexually mature at about six months. Young gundis have a lighter coat than adults until about six months of age.

Young that have lost their mother in an established group are often raised by other lactating females. Hand-rearing is possible, but very time-consuming. In the Aquazoo Löbbecke Museum, the young were given a hand-warm nutrient liquid consisting of 50 ml warm water, one teaspoon of Aptamil Pre (Milupa), one teaspoon each of cat milk powder (Fa. Gimpet) and baby fruit mash (e.g. apple, carrot, etc., from Fa. Hipp), a pinch of Mulgatol Junior (vitamin preparation, containing mainly vitamines B1, B2, B6, C and E, niacin, pantothenic acid and biotin) and Bene-Bac Gel (Albrecht GmbH) as well as half a teaspoon of herbicare plus (WDT) or Critical Care, Herbivore (Oxbow). The mixture is administered with a syringe (2 ml syringe with silicone teat, opening width 1 mm). During the first three weeks, the young must be fed every three hours during the day and every three to four hours at night; later it is enough to feed

every three hours during the day. Initially, about 1-2 ml were taken up per feeding. Hand-fed animals show a delayed weight development (Fig. 11; see also *C. vali*: George, 1978b, without further details).

In a total of seven trials, two newborns were successfully raised to sexual maturity. Even after 50 days, neither had reached the weight of naturally reared young. The two hand-reared young were successfully integrated into an existing group. One of these animals reached an age of 6.2 years, the other 7.4 years.

Life span

The life span of gundis in the wild is unknown. According to previous authors, gundis in human care either died relatively early (see above) or the authors only indicate over which periods they kept gundis without saying anything about the life span of single individuals (e. g., George, 1978a, b; Gouat, J., 1985). In the Aquazoo Löbbecke Museum, individual gundis have sometimes become almost 10 years old. However, to give a mean lifespan seems not very meaningful in view of the high mortality rate of the juveniles. Birth and death data (mostly without information about the cause of death) from the studbook of 102 gundis from population A show a mean age of 1.73 ± 2.2 years (range 0 to 8.96). If only the 46 individuals older than one year are taken into account, the corresponding values are: 3.62 ± 2.07 (range 0 to 7.96). The corresponding data of 692 gundis from population B reached an average age of 1.58 ± 2.2 years (range 0 to 9.69). Of these, 305 individuals become older than one year (3.42 ± 1.81; range 0 to 8.69). Of the 387 animals that died in the first year of life, 78 (approx. 20%) were stillborn or did not survive the first day. A total (including stillborns) of approx. 50% (341 animals) died before the first year of life. This high juvenile mortality is obviously not due to a possible inbreeding depression (see below), because it was already observed in the imported animals from the beginning.

Diseases

In the field, gundis are infested with various ectoparasites (fleas, mites, lice, and ticks), with a marked prevalence in males and old individuals; their abundance is closely related to climatic conditions (Meddour et al., 2022); wild-caught gundis also harbor tapeworms (e.g., Eisentraut, 1977). They are also reservoir hosts of *Leishmania* species (Bousslimi et al., 2012; Ghawar et al., 2018) and paramyxoviruses (Ghawar et al., 2017).

Gundis, like other rodents in human care, are at risk of numerous infections. The most common health problems are diseases of the respiratory system and the gastrointestinal tract. The routes of infection are mostly unknown and treatment of visibly ill animals has been largely limited to treatment of symptoms. Many of these may also have contributed to the high mortality of the young (see above).

Sick gundis often have a shaggy and dull coat and/or sunken flanks (Fig. 12, top right). In case of severe indisposition, the neck and back hairs are erected (Fig. 12, top left). In general, the animals should be carefully observed and frequently taken in hand to check e.g. eyes, nostrils and genital region and to be able to treat bite injuries, which occur mainly during the mating season or in rank fights. Wounds usually heal without complications, but large bite marks (Fig. 12, middle left) must be treated. In some males, inguinal hernias occurred especially in the third and fourth year of life (Fig. 12, bottom left), some of which could be successfully operated under anesthesia.

The operated gundis could be returned to their group without problems within the first two days. Sometimes purulent inflammations of the sole of the feet were observed (Fig. 12, middle right).

Diagnoses of diseases of gundis by veterinary diagnostic institutions are of varying informative value as exemplified by 110 deceased gundis (see Tab. 2). Of these, 47 gundis (52%) were affected by multiple diseases. In 19 animals (17%) the examination remained inconclusive.

Fig. 12: Symptoms of disease and injuries in gundis. Top left: Raised back hair. Top right: Shaggy hair and sunken flanks. Middle left: Bitten off ear. Middle right: Inflamed sole of feet. Bottom left: Inguinal hernia in a male. Bottom right: Tumor in the neck region. Photos: S. Honigs

In the Aquazoo Löbbecke Museum, the following pathogens with serious consequences for the gundi groups kept here have been detected post mortem (p. m) and/or in the living animal (liv.) and the feces (collective sample of droppings).

Salmonella (liv., droppings, p. m.). Symptoms: Acute chronic diarrhea, especially in young animals. Mortality was high, especially of new born and young animals. The animals were not medically treated, but the entire group was isolated until the death of all individuals.

Tab. 2: Disease problems of 110 gundis diagnosed post mortem by various veterinary diagnostic institutes.

Organ system	
digestive tract	enteritis (16), diarrhea (1), endoparasites (oxyurans, coccidians) (3), fatty liver (2), liver carcinoma (3), gastritis (1), malnutrition (12)
integument	purulent inflammation of feet (4), umbilicitis (2), leucosis (1), anasarca (1), tumor (1), dermatitis (1), mastitis (1)
reproductive	endometritis (2), inflammation of the vulva (2), abdominal pregnancy (1)
respiratory	(bacterial) pneumonia (25), peribronchitis (2), pulmonary edema (2), lung tumor, (1), pasteurellosis (1), tapeworm infestation of the lung (1), dust in the lung (2), undeveloped lung of fetuses at birth (3), amniotic fluid aspiration (fetus) (1)
urinary	nephropathy (3), glomerulosclerosis (1), fatty kidney (1), hepatitis (7), kidney disease (2), glomerulosclerosis (1), urethritis (1)
varia	lymphatic hypoplasia (1), cacheixa (due to oxyurans (1), chondrodysplasia (1), tuberculosis (23), tumors in various organs (4), cardiovascular failure (4), severe bite wounds (9), sepsis (4), heart defect (1), degenerative liver disease (1), abdominal bacterial infection (1), liver disease (1), middle ear infection (1), broken ribs (1)

Various *Mycobacterium* species, some of which occur together, including *M. avium, M. kansasii* (p. m.). Symptoms: Weight loss, coughing, sneezing, runny nose. Due to the risk of transmission (also to humans), the entire group has been euthanised in the event of positive detection.

Giardia (droppings, p. m.). Symptoms: Diarrhea (however, does not apply to all rodents; see Wasson, 2007). In general, gundis infected with *Giardia* (of different "strains" identified by ELISA -Tests plus PCR) are no longer kept in other zoos as a precaution. Since treatments (against diarrhoea) failed in the Aquazoo Löbbecke Museum, the sick animals were kept separated by sex until death.

Isolation from conspecifics that may be necessary for sick animals – if possible, treatment in the established group is to be preferred – should be as short as possible (see above), otherwise, if the disease permits, they should be socialised with a compatible social partner from their group.

It is remarkable that under the mentioned housing conditions neither in the Aquazoo Löbbecke Museum nor in other zoos serious dental diseases have ever occurred so far, which can be quite frequent in many rodents because of their continuously erupting teeth (see Quesenberry & Carpenter, 2012).

Why gundis in zoos?

Gundis are not an endangered species. So why should they be kept in zoological gardens? A first survey of zoological gardens keeping gundis has shown that these animals are main-

ly shown for "educational purposes". They look cute (Lorenz's child scheme), are apparently active during the day and at night, and are easily visible even when they are resting during the day, so overall they are attractive to a wide range of visitors. Gundis also represent inhabitants of deserts and semi-deserts, which can be used to demonstrate adaptations to these extreme biotopes. Less frequently, attention is drawn to the fact that this is a phylogenetically very old group of animals. In addition, observation of captive gundis can contribute significantly to knowledge of, for example, their behaviour, which is nearly impossible to observe in all details in the field.

Conclusions and prospects

Gundis can be kept in zoological gardens for long periods of time in an animal-friendly manner. Doing the same is attracting more and more interest. For example, in June 2019, the Aquazoo Löbbecke Museum shipped nine animals from European zoos to Japan (Saitama Children's Zoo, Higashimatsuyama, Saitama Prefecture). However, the current population is at risk, given the small number of founder animals and possible resulting inbreeding depression, and the fact that, at least in human care, it is extremely difficult and costly to acclimate animals that are not part of a group to each other. Even though gundis are not an endangered species and replenishment from the wild should be possible, their continued existence in zoos also depends on a sound breeding strategy and cooperation among participating zoos. In particular, there would be a need for optimisation with regard to the investigation and reporting of causes of death, the inclusion of more precise, probably then also more expensive, diagnostic possibilities, a regulated exchange of animals and compliance with a certain standard in the housing and nutrition of the animals. This would certainly also help to reduce the high mortality rate of young animals.

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Zusammenfassung

Gundis (*Ctenodactylus gundi*) sind kleine herbivore und philopatrische (Weibchen) Nager, die in kleinen Kolonien in ariden und semiariden Gebieten Nordafrikas leben. Sie sind nicht bedroht, werden aber dennoch nur selten in Zoos gehalten. In den Jahren 1995 und 2007 kam jeweils eine kleine „Gründergruppe" aus weit voneinander entfernten Gebieten Tunesiens in den „Aquazoo Löbbecke Museum", Düsseldorf, welche die Ausgangsbasis aller in europäischen Zoos gehaltenen Gundis bildeten. Alle heute in europäischen Zoos gehaltenen und im

Zuchtbuch geführten Gundis sind jedoch Nachkommen der Tiere aus 2007. Eine über 25-jährige Erfahrung mit diesen Tieren sowie Daten aus einem seit dem Jahr 2000 von Sandra Honigs geführten Zuchtbuch erlauben es, Haltungs- und Zuchtrichtlinien sowie Trends der derzeit in Zoos gehaltenen Population zu beschreiben und einige nicht oder nur unzureichend erforschte Aspekte der Gundi-Biologie zu berücksichtigen. Nach den bisherigen Erfahrungen sind Gundis in menschlicher Obhut langfristig nicht ohne größeren Aufwand zu halten. Sie werden möglichst in Gruppen in Gehegen ab einer Grundfläche von mindestens 1,5 m x 1 m x 1,2 m (B x T x H) für ein Paar gehalten; pro Tier erhöht sich die Fläche um je einen halben Quadratmeter. Der Bodengrund sollte aus Lehm und einer dünnen Schicht Sand bestehen. Außerdem muss das Gehege Felsaufbauten mit Verstecken enthalten, gut klimatisiert sein und mindestens einen Platz zum „Sonnenbaden" besitzen. Gefüttert wird mit einem Gemisch aus verschiedenen Sämereien und herkömmlichem Kaninchenfutter. Die bisherigen Daten aus dem Aquazoo Löbbecke Museum und dem Zuchtbuch zeigen, dass es wegen der hohen Aggression gegenüber fremden Artgenossen sehr schwierig ist, mit Individuen aus verschiedenen Populationen neue Zuchtpaare oder Zuchtgruppen zu bilden. Die Weibchen sind mindestens sechs Jahre fertil und bringen pro Geburt ein bis vier Junge zur Welt. Die Sterblichkeit der Jungen ist nach wie vor relativ hoch. Einzelne Individuen wurden jedoch fast zehn Jahre alt. Die Geburtenrate scheint in den letzten Jahren möglicherweise aufgrund von Inzuchtdepression abzunehmen.

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Case Report: COVID 19-Vaccination of two Captive Adult Bornean Orangutans (*Pongo pygmaeus*)

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Abstract

SARS-CoV-2 was and still is a severe global issue. Vaccination seems to be efficient to keep this pandemic virus under control. However, reports about this virus in other mammals than humans are sparse and little information is available regarding the protection of zoo-housed great apes. We report vaccination of two adult Bornean orangutans (*Pongo pygmaeus*) with Comirnaty from BioNTech/Pfizer. A 57-year-old intact female Bornean orangutan could be closely monitored due to well-adapted medical training. Multiple blood tests showed no changes in hematology or blood-chemistry. Antibodies were detectable one month after the second vaccination and highly increased three weeks after the third shot. Both animals showed, next to mildly increased body temperature for one day, no side effects.

Keywords: SARS-CoV-2, orangutan, vaccine, antibody

Introduction

Since 2020 corona virus has been a global issue of great severity (Shivalkar et al., 2021; Allender et al., 2022). Several vaccines were developed for humans to decrease mortality and the number of hospitalizations (Kashte et al., 2021; Bok et al., 2021; Fathizadeh et al., 2021). For the vaccine used in this study, pharmacologists recommend a booster after 4 weeks, as well as after 1 year (Polack et al., 2020). While experimental studies documented antibodies to increase after vaccination in humans (Bonura et al., 2022), little is known about building antibodies in non-human primates (Capone et al., 2021). To date, there are very few published clinical reports of vaccination against SARS-CoV-2 in great apes. In humans increased risk of pain at injection

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site, headache and venous sinus thrombosis have been observed as side-effects after regular vaccination (Polack et al., 2020; Finsterer, 2022).

All apes at Vienna Zoo are regularly trained for medical procedures and have positive relationships with their keepers. During data collection for this case report the group consisted of one adult male and four females. Keepers as well as visitors are potential carriers of different infectious diseases (Sherman et al., 2021; Delahay et al., 2021). Unfortunately, visitors sometimes feed the animals through the barrier of the outside enclosure, which might increase the risk of infection.

Due to the increasing number of SARS-CoV-2 infections and the availability of vaccines, the two oldest orangutans at Vienna Zoo got vaccinated with Comirnaty (BioNTech/Pfizer). Both orangutans (male "Vladimir", ca. 50 years old and female "Mota", 57 years old) are trained to voluntarily receive intramuscular injections by hand.

We report the vaccination of two adult orangutans, which we consider as high-risk patients due to their age and the daily contact to humans.

Case presentation

Ahead of the first vaccination they underwent a shortened physical examination as well as a screening for SARS-CoV-2 with a rapid antigen test (NEWGENE Bioengineering). For this test a throat swab was taken of both orangutans. Both are used to saliva collection during routine medical training (Fig. 1).

Due to a higher preparedness for training we could run a fully bloodwork as well as SARS-CoV-2 antibody analyses for the female. Furthermore, we took a saliva sample of the female for a SARS-CoV-2 PCR-test as well as for SARS-CoV-2 antigen test, with negative results. General bloodwork was within normal limits, the antibody neutralization test was lower than 0,1% which is interpreted as a negative result. We also took daily measurements of the body temperature in both animals before and for two weeks after vaccination. The measurement routinely took place every day before morning feeding. We used a tympanic thermometer to estimate inner body temperature and screen our animals for possible hyperthermia (Mogensen et al., 2018) (Tab.1, Fig. 2).

The first vaccination was scheduled for 29th November 2021. Both animals showed no signs of side effects on the following days. Another bloodwork was scheduled three weeks after the first vaccination. There were no changes in the differential bloodcell count. We also performed another throat swab for PCR examination which again remained negative. Antibody inhibition showed 4,99%, every level under 30% must be considered negative, according to the laboratory reference.

Ahead of the second vaccination we repeated the throat swab and the SARS-CoV-2 antigen test, which again had negative results. We maintained the booster 4 weeks after the first shot on 28th December 2021. Due to different circumstances the male did not cooperate during training on this day and the team decided to dart him with a blowpipe. Measurements taken on the following day by use of a tympanic thermometer showed mildly increased body temperature for both animals. Both received Paracetamol 500mg (Mexalen – ratiopharm) once (Tab. 2).

Apart from this, both animals showed normal behavior and good appetite. We repeated the blood test to look for antibody levels for the female three weeks after the second shot. The inhibition showed 6.97%, which is a non-significant increase and still negative.

The following month remained uneventful with regards to the vaccinations. The male orangutan struggled with orthopedic/neurologic issues which had been a known medical condition for years. In the summer of 2022, one of the younger females gave birth to a healthy offspring. No signs of behavioral changes or stress within the group were noticeable.

Fig. 1: Throat swab procedure during medical training session at Vienna Zoo. Photo: S. Keiblinger

Every now and then, keepers were sick and tested positive for SARS-CoV-2. If keepers felt sick, they did not enter the orangutan house. The old vaccinated female never showed signs of illness.

The next booster vaccination was scheduled one year after the first shot. At the end of September 2022, ahead of the vaccination, we repeated the full bloodwork. The routine bloodwork,

Tab. 1: Body temperature measurements for both animals around first vaccination.

Date	Temperature in °C (tympanic thermometer) 1,0; Vladimir	Temperature in °C (tympanic thermometer) 0,1; Mota	Notes
13.11.2021	36,1	35,0	
14.11.2021	36,0	35,2	
15.11.2021	35,9	35,8	
16.11.2021	-	35,6	
18.11.2021	35,8	35,6	
19.11.2021	36,1	36,0	
20.11.2021	35,8	35,9	
21.11.2021	36,1	35,6	
22.11.2021	36,3	35,4	blood
23.11.2021	36,1	35,2	
24.11.2021	35,8	35,6	
25.11.2021	36,0	35,4	
28.11.2021	36,0	35,2	antigene test
29.11.2021	35,9	35,8	**first shot**
30.11.2021	35,6	35,4	
01.12.2021	35,9	35,0	
02.12.2021	36,0	35,4	
03.12.2021	35,2	36,1	
04.12.2021	36,3	35,2	
05.12.2021	36,1	35,6	
06.12.2021	36,2	36,4	
07.12.2021	35,4	35,7	

including blood chemistry and differential bloodcell count, was again within normal limits. Contrary to the results from January 2022, the antibody inhibition showed 42,14%, which was higher than 30% and therefore must be considered positive.

Another vaccination was administered on 30th September 2022 again per hand injection during medical training. No side effects where noticeable at this time. The orangutans were alert and showed no increase in tympanic temperature. Eleven weeks after the third shot, the blood examination for antibodies in the female showed an inhibition of 599.40 %, which is the highest level measured so far (Fig. 3).

Fig. 2: Hand injection in cooperative care as a result of medical training at Vienna Zoo. Photo: S. Keiblinger

Tab. 2: Body temperature after second vaccination.

Date	Temperature in °C (tympanic thermometer) 1,0; Vladimir	Temperature in °C (tympanic thermometer) 0,1; Mota	Notes
07.12.2021	35,4	35,7	
08.12.2021	36,7	35,9	
09.12.2021	36,1	35,5	
10.12.2021	36,2	35,6	
15.12.2021	36,2	-	
16.12.2021	-	-	blood
21.12.2021	36,0	35,7	
23.12.2021	36,0	35,9	
25.12.2021	35,8	35,6	antigene tested
28.12.2021	36,7	36,3	**second shot**
29.12.2021	37,1	37,0	both 1 Mexalen
30.12.2021	36,1	35,5	both normal
02.01.2022	35,9	36,2	
03.01.2022	36,0	36,1	
04.01.2022	36,9	36,5	
05.01.2022	36,7	36,7	
06.01.2022	36,9	36,2	
07.01.2022	36,8	36,3	
08.01.2022	36,6	36,4	
09.01.2022	36,8	36,5	
18.01.2022	-	36,1	blood

The male orangutan “Vladimir” had a long period of conservative treatment of very bad orthopedic and neurologic conditions of his lumbar spine and hind limbs. In the following, he was euthanized on 14th February 2023. The blood we collected on this day was also used for SARS-CoV-2 antibody testing. Almost 20 weeks after the last vaccination, the inhibition in the male Bornean orangutan was at 9.10%, which must be considered negative.

SARS-CoV-2 antibodies / progression

Date	Value	Normal value
2021/11/22	< 0,1% IH	< 20
2021/12/16	4.99 % IH	< 20
2022/01/22	6.97 % IH	< 30
2022/09/23	42.14 % IH	< 30
2022/12/16	599.40 % IH	< 30

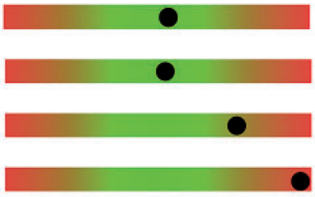

Fig. 3: Summary of SARS-CoV-2 antibody levels over the time span of this case report. There was a significant increase of antibodies in the female.

Discussion

This is a clinical case report of a vaccination against SARS-CoV-2 in captive Bornean orangutans. This topic should be considered as very important, due to the conservation status of Bornean orangutans (Ancrenaz et al. 2016; Molyneaux et al. 2022), as well as the possibility of transmission of disease between different mammals and humans (Sharun et al. 2021; Sherman et al. 2021; Delahay et al. 2021).

There were light clinical changes visible after the second vaccination (rise of body temperature). Otherwise the apes showed no abnormalities. The increase in antibody levels in one adult orangutan underpins the assumption, that non-human primates can build inhibiting units against SARS-CoV-2. No clinical signs were noticeable during the data collection for this case report. In the male orangutan we could not see antibody levels as high as in the female. This could be due to the different way of administration of the second vaccination (via blowpipe), although the male exhibited light hyperthermia one day after the second shot. We consider the general condition of the animal, as well as the daily treatment with different medications because of known orthopedic problems, to be possible reasons for the lower antibody level.

Due to the regular contact to keepers during daily routine an infection is not excluded. We consider the risk of a transmission as low, because of the lack of clinical signs. Besides, the keepers were regularly tested for SARS-CoV-2 and did not enter the orangutan enclosure when they felt sick. Furthermore, we cannot completely exclude the possibility, that these animals got contact to the coronavirus and built antibodies because of an acute infection, but did not show any clinical signs.

To date, there is still a lack of data about this topic, so further investigations are necessary. It certainly is beyond the scope of a single case report to give treatment recommendations. Still this case report should raise awareness for possibilities to protect Bornean orangutans, a critically endangered species (Ancrenaz et al. 2016), in human care. The use of vacccinations for humans in high-risk non-human primate individuals should however be considered on a case-by-case basis weighing possible risks and benefits.

Conclusion

A COVID-19 vaccination in two Bornean orangutans was safe and seems to be a safe and promising procedure to protect the zoo-housed population of a threatened species against this viral disease, which is the cause of a worldwide pandemic. There were no detectable severe side effects after the two orangutans were vaccinated. The results of a shortened clinical examination as well as appetite, body temperature and blood values were within normal limits. Measured blood antibody levels in the female orangutan enabled us to expect proper protection against SARS-CoV-2.

Zusammenfassung

SARS-CoV-2 war und ist ein schwerwiegendes globales Problem. Die Impfung scheint wirksam, um dieses pandemische Virus unter Kontrolle zu halten. Allerdings sind die Berichte über dieses Virus bei anderen Säugetieren als dem Menschen jedoch spärlich, und es gibt nur wenige Informationen über den Schutz von in Zoos untergebrachten Menschenaffen. Wir berichten über die Impfung von zwei erwachsenen Borneo-Orang-Utans (*Pongo pygmaeus*) mit Comirnaty von BioNTech/Pfizer. Ein 57-jähriges nicht infiziertes Borneo-Orang-Utan-Weibchen konnte aufgrund einer gut angepassten medizinischen Ausbildung genau überwacht werden. Mehrere Blutuntersuchungen zeigten keine Veränderungen in der Hämatologie oder Blutchemie. Antikörper waren einen Monat nach der zweiten Impfung nachweisbar und drei Wochen nach der dritten Impfung stark erhöht. Beide Tiere zeigten, abgesehen von einer geringfügig erhöhten Körpertemperatur für einen Tag, keine Nebenwirkungen.

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Breeding Station for the European Hamster (*Cricetus cricetus* Linnaeus, 1785) at Opel-Zoo Kronberg

Eine Zuchtstation für den Europäischen Hamster (*Cricetus cricetus* Linnaeus, 1785) im Opel-Zoo Kronberg

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Summary

Once abundant throughout Western Europe, the population size of the European hamster has decreased dramatically in the last 40 years. It is now listed as critically endangered and urgent action must be taken to enable the survival of the species. Therefore, the Hochtaunuskreis (Hesse, Germany) started to take conservation measures in 2012 and initiated a reintroduction programme for European hamsters which started in 2020. The Opel-Zoo supports this initiative by breeding hamsters for release. We here describe the husbandry system developed at Opel-Zoo in which every hamster can be housed according to German regulations ("Gutachten über Mindestanforderungen an die Haltung von Säugetieren vom 7. Mai 2014") in a relatively cost and space-effective way. Since 2018, over 165 hamsters have been born at Opel-Zoo of which 157 exceeded an age of 8 weeks. The medium litter size was 6. Until August 2023, 116 European hamsters were released in suitable habitats in cooperation with the federal agencies (Regierungspräsidium Darmstadt & Untere Naturschutzbehörde Hochtaunuskreis). It has been confirmed that some of them reproduced successfully.

Keywords: European hamster, *Cricetus cricetus*, breeding, conservation

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Background

The European or common hamster (*Cricetus cricetus*) is a characteristic species for fertile lowland steppes and grasslands in Europe and Asia. It has a high reproductive potential (Eibl-Eibesfeldt, 1953) and used to be common in anthropogenic habitats as meadows and croplands (Banaszek et al., 2020). Due to its habit to feed on and cache large amounts of crops, it was long regarded as pest and persecuted intensively. Common hamsters were also hunted for fur trade (see Nechay, G., 2000 for a detailed discussion of the historical and current situation of hamsters throughout Europe). Combined with the effects of intensified agriculture and habitat fragmentation, this led to a severe decline of population size in Western Europe (Kryštufek, B., Vohralík, V., Meinig, H. & Zagorodnyuk, I., 2016). After an updated assessment of the population status in 2020, the species is listed as critically endangered by the IUCN (Banaszek et al., 2020) because the population trend is decreasing over the whole range, including Eastern Europe, Russia, and Kazakhstan. The assessors project this to result in extinction between 2020-2050 if the situation does not change.

In the European union, the common hamster is listed in Annex IV (species in need of strict protection) of the "habitat directive" (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). In Germany, it is furthermore protected under federal law (BNatSchG) since 1980. The three most western populations of common hamsters occur in France, in the border region of the Netherlands, Belgium and Germany and in the German states of Rhineland-Palatinate and Hesse (Banaszek et al., 2020, Nationaler Bericht nach Art. 17 FFH Richtlinie in Deutschland 2019), where the von Opel Hessische Zoostiftung (Opel-Zoo) is located. Because of the responsibility for these populations on the edge of the range of the species, the state of Hesse intends to preserve and strengthen the last populations of common hamsters. In 2018, the state of Hesse, the Opel-Zoo, the regional nature conservation authority (Untere Naturschutzbehörde Hochtaunuskreis) and the registered association "Landschaftspflegeverband Hochtaunus e.V." signed a letter of intent concerning the protection of the European hamster which includes the establishment of reintroduction programmes. The goals of the reintroductions are to support and re-connect the remaining hamster populations in the region by establishing and populating suitable hamster habitats in geographically relevant areas. The Opel-Zoo supports the project with a breeding station, where European hamsters are housed, rehabilitated if necessary, and bred for reintroduction. To guarantee that hamsters are housed according to an official German expert report "Gutachten über Mindestanforderungen an die Haltung von Säugetieren vom 7. Mai 2014", we developed a new husbandry system for the species, that we describe in this article.

Hamsters at Opel-Zoo

In June 2018, 5.5 European hamsters arrived at Opel-Zoo. 1.1 hamsters were adult and wild-caught by federal agencies because of necessary translocations. 4.4 were sub-adult and bred in human custody; 1.2 and 3.2 belonged to the same litter, respectively. Due to a lack of space at other facilities, the hamsters were brought to the Opel-Zoo before the breeding station was completed. Therefore, they had to be held in small cages temporarily in accordance with the responsible authorities. Presumably, this resulted in one female developing stereotypic behaviour patterns (circling, later pacing). Stereotypies are invariant behaviour patterns without obvious goal or function that may be a result of distress and can be an indication of poor welfare (Mason, 1991 a, b). Once established, stereotypic behaviours can emancipate from their causing stimulus so that individuals go on performing the behaviours even when the original aversive

stimulus is no longer around (Mason, 1991 a, b). This female displayed stereotypic behaviours throughout her life and never raised her litters. No other hamster in the breeding station was observed to display stereotypic behaviours.

In July, the hamsters were moved into the breeding station located in the house for European rodents at Opel-Zoo. It was officially opened on 10th of October 2018. Visitors can see hamsters in two outside enclosures (total area: 20 m^2) that are equipped with sub-terrestrial windows (total size: 4.3 m^2), so it is possible to observe burrowing.

Breeding Station

The breeding area consists of a 32 m^2 room that can be heated and is lit by daylight (Fig. 1). It contains 14 commercial cages "SAVIC Suite Royal XL" that have been modified to fit the needs of hamsters and staff (Fig. 2). The furniture is accomplished by two "mating boxes", a washbasin, a retractable desk, a mobile rack, various shelves, and installations to store tools. We tried to keep all interior mobile to facilitate working and make most use of space at any time of the year.

Fig. 1: Breeding station for European hamsters at Opel-Zoo. Sides and back: SAVIC Suite Royal XL hamster cages. Middle: mating boxes (covered and used for storage outside of breeding season). Photo: Opel-Zoo archive.

Enclosures

As stated in an official German expert report ("Gutachten über Mindestanforderungen an die Haltung von Säugetieren vom 7. Mai 2014"), an adult European hamster has to have access to an enclosure with a base of 2 m^2. Therefore, we installed additional floor levels in every cage, so cages reach a base area of 4 m^2. Usually, one hamster has access to a whole cage. If necessary, cages can be divided into two compartments of 2 m^2 each, so that two adult hamsters can be housed. The "SAVIC Suite Royal XL" furthermore has the following advantages: a) it is placed on wheels, b) it allows sufficient ventilation at all cage levels, c) young cannot fall out thanks to the small gap between the bars, and d) the whole front consists of large doors, so all parts of the cages are easily accessible for the keepers.

Every enclosure is equipped with two or more sleeping boxes, a running wheel or "flying saucer", a food bowl, a water bottle (drinking feeder), tubes for hiding, wood for gnawing, a box filled with a sand-clay-mix for digging and ladders that allow the hamsters to switch cage levels. We place thin wooden plates between cages to prevent visual contact. For sleeping boxes, we mostly use residual cardboard boxes of suitable size (~ 30 cm L x 20 cm W x 25 cm H or larger) as they can easily be exchanged if hamsters urinate into the box. For nesting material, we offer hay and straw and use commercial wood shavings as ground cover. We started using running wheels but changed to "flying saucers" which are made of washable plastic. Also, the largest available running wheel has a diameter of 30 cm, which seems too small for adult European hamsters. Because the "flying saucers" are too light and turn over under the weight of an adult hamster, we stabilize them by gluing them onto a wooden board of approx. 30 x 30 cm.

Fig. 2: Furniture of European hamster enclosures at Opel-Zoo. Photo: Opel-Zoo archive.

Feeding

We use the following feeding plan (Tab. 1) to account for the varying energy requirements of hamsters in course of the year. To allow the hamsters to perform the natural behaviour of food caching, we provide more dry feed than required energy amounts. We check food caches on a regular basis and remove wet feed or the whole cache if it is moist or begins to go mouldy. Before hibernation, when the hamsters have already cached sufficient food, we reduce the daily amount of feed. During hibernation, amounts of dry food are changed once a week and vegetables are offered 2-3 times weekly. Because hamsters are mainly nocturnal, we use food consumption to check whether the animals are alive.

Tab. 1: Feeding plan of European hamsters at Opel-Zoo.

Frequency	Amount	Type of food
Daily (when not hibernating) When hibernating: - Dry food: changed once / week - Vegetables: 2-3 times / week	~ 100 g	Vegetables (beetroot, carrots, fennel, celery, parsnip…)
	1 branch	Foliage (hazel, beech, blackberry…) with wooden parts to allow gnawing
	If available	Herbs (dandelion, parsley, chive, chervil, salad burnet, sorrel, cress, borage…)
	Rarely	Fruit (berries, apple, dried rose hip, stone fruits without stone)
	~ 80 g	Dry feed Composition: - 55 % commercial parrot feed - 35 % whole grain oat flakes - 5 % commercial chicken feed - 5 % sweet corn
2x / week	½	boiled chicken egg
	25 g	commercial hedgehog feed (Claus Igelfutter Getreidefrei)
Daily for females when pregnant, lactating, or housed with young	Alternating ½ 25 g	 boiled chicken egg commercial hedgehog feed
Before hibernation	occasionally	Peanuts, glans, beechnuts, chestnuts (in shell)
		Hazelnuts, walnuts (in shell but slightly opened)
For medication	½ teaspoon	Apple sauce, mashed banana, baby food

Husbandry

As common hamsters are bred for reintroduction purposes in Opel-Zoo, it is vital that their natural annual and circadian rhythms are intact. Therefore, the breeding station is not heated until temperature drops below 10° C. Because the natural isolation effect under the soil surface is missing, heating is then implemented to prevent temperature from dropping too low, so that the hamsters are not killed by frost. The room is lit by daylight through ceiling windows which can be opened to allow airflow and prevent overheating of the room when necessary. Hamsters are not tamed (as this might negatively influence reintroduction process) but a good keeper animal relationship is hold up, especially with the breeding animals, to prevent chronic stress and increase breeding success.

We clean cages at least every 14 days. As some hamsters use one toilet spot very strictly and do not cache wet food items while others use their sleeping box for urinating and caching of all types of food, we vary cleaning depending on necessity. We clean toilet spots and remove wet food leftovers every day and exchange moist nesting boxes and food caches immediately. However, we try to minimize cleaning measures to reduce stress. If nesting boxes are clean, we do not remove them or the nesting material even if we clean the rest of the cage. To prevent disturbance during hibernation, we mainly stick to removal of moist spots and leftover food and only clean the whole cage if the hamster is awake. Usually,

hamsters wake up once per week. If no life signs (eaten food, urine, faeces) have been seen after 10-12 days, we check if the hamster is still alive. If we check, we are very careful as to not wake up the hamster. Hibernating hamsters are cold and breathe very slowly, a rose colour of the paws is a good indication of life. Hamsters might scream for several minutes while waking up.

Because of their sharp and protruding teeth, and to prevent stress and taming, we never take adult hamsters into hands. Instead, we use transparent tubes for moving and visual check-ups. Hamsters usually enter the tube voluntarily if it is placed in front of their snout (especially if the tube has been placed in the enclosure beforehand) and the handling person taps very gently on the tube with one finger. The tube can then be placed in a fauna box, so the hamster cannot escape (Fig. 3). Should the hamster try to leave the tube while not yet in the fauna box, a slight air blow on the snout will prevent it from climbing out on the front side while tilting the tube so the backside is lowered will prevent it from leaving there. This brilliant technique was introduced to us by Lisa Heimann and Marco Sander (Institute for Faunistic & breeding centre for European hamsters at Heidelberg Zoo). Subadult hamsters of up to about 140 g can be handled without the use of tools as they usually do not bite yet. We keep handling of young hamsters to a minimum as to prevent taming.

Fig. 3: Hamster secured in transparent tube and fauna box. Photos: Opel-Zoo archive.

Breeding at Opel-Zoo

The hamsters are paired between end of April to middle of July depending on end of hibernation, oestrus cycle of the females, and, for the second litter, weaning of the first litter. The cycle duration is 4 days, gestation period is 17 days.

Mating

Mating takes place in special “mating boxes” (Fig. 4) of approx. 1 m^2 which can be divided by a mesh and be easily accessed from above. The top can be closed so the animals can stay in the mating box overnight. Hamsters are introduced to each other as late in the day as possible to resemble their natural activity patterns, this is generally 4 p.m. or later, preferably after 6 p.m.

For introduction, we keep the mating box quite empty to have a better overview. First, the female is placed in one part of the box for approx. 5 min. Then the male is placed in the other part. After a brief orientation period, the male usually shows interest in the female at the mesh. If the female reacts very aggressively (jumping, eliciting grunts, attacking the male), the male is removed immediately. If the female reacts aggressively (grunting, short attacks), the animals stay separated for about 10 more minutes. As soon as there is only light aggression (grunting) or signs of interest (sniffing at the mesh), the separation mesh is remo-

ved. Should the female not show interest in the male, the male is exchanged. Some female hamsters are very picky and will only accept certain males (usually the heaviest). In case the female does not react to about 5 males, she is probably not in oestrus and the procedure is repeated the next day.

As soon as a pair is together, one keeper stays with the hamsters for at least 30 min to interfere if necessary (encounters can get very violent very quickly). If the male is interested in the female, he starts eliciting "pfffft" sounds that enhance in volume and duration. Normally, the female reacts to this with light signs of aggression and then starts to run away from the male. The male follows very narrowly while still eliciting "pfffft" sounds. Very often, the female turns every now and then to attack the male, who will continue to follow her afterwards. After a while, the male tries to mount the female. A successful copulation is indicated by both animals cleaning their genitals and resting for about 5 min. If the first copulation takes place within the first 30 min, the hamsters are left together overnight. If not, the pair is separated and let together the next night.

To prevent the hamster couples from fighting during the night, we offer several sleeping boxes, sufficient bedding, and sufficient food. We offer plenty vegetables but relatively small amounts of dry food, because some hamsters will try to carry it to their home cage and can get very stressed as they cannot leave the mating box. We separate the animals the next morning. To control whether mating was successful, the same pair is let together after four days. If the female is interested, the animals stay together overnight, again. If the female is not interested, the hamsters get separated and the control is repeated after another four days.

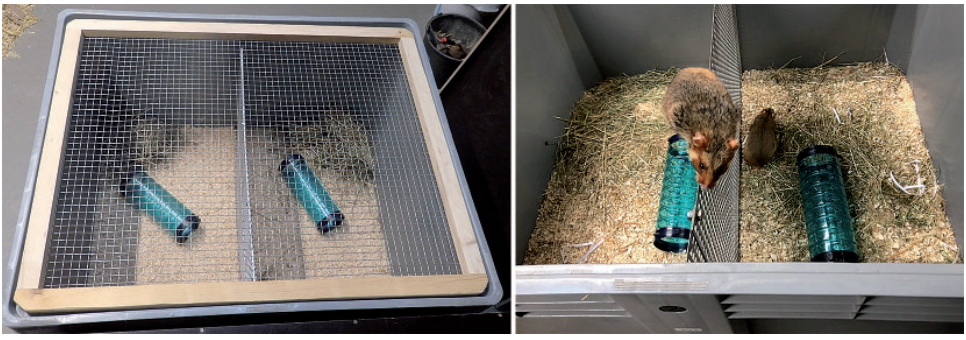

Fig. 4: Mating box. Mesh lids (left) will prevent hamsters from climbing over the fence (right; risk of falling and escape) while allowing close monitoring of the animals. Photos: Opel-Zoo archive.

Rearing

Young are born 17 days after a successful copulation. The first signs of young hamsters are soft squeaking sounds from the nesting box. We check (counting, weighting, visual check-up, Fig. 5, Fig. 6) the young after 7 days for the first time, as we try to avoid early disturbance. The control is repeated about weekly. During weaning, we try to reduce cleaning of the cage to an absolute minimum as young sometimes crawl around the substrate (probably because they are accidentally carried out by the mother while suckling). With eight to ten days, young hamsters start to actively leave the nest. After four weeks, we separate the young from the mother. In course of this, we check the sex and apply a transponder. If necessary, young can be kept together until 8 weeks old, but attention should be paid towards signs of aggression in the group.

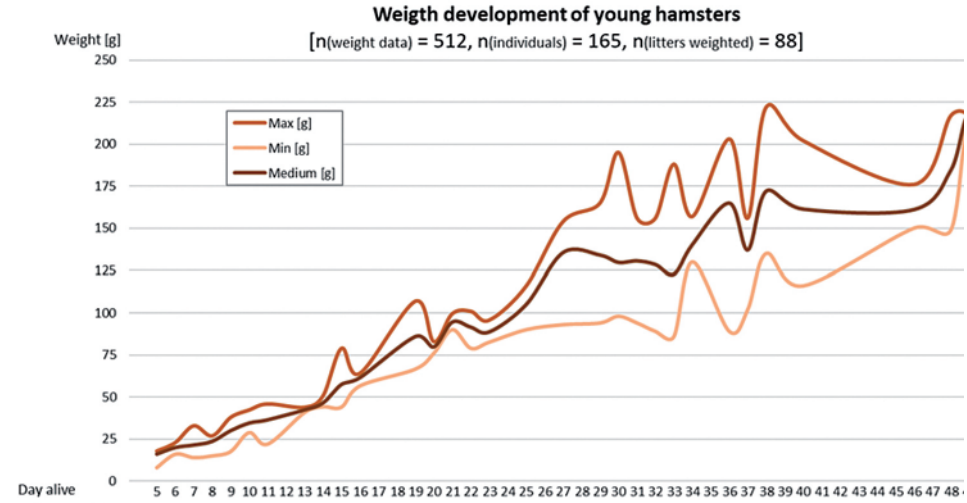

Fig. 5: Weight development of young European hamsters at Opel-Zoo. Litters may have been weighted several times on different days.

Fig. 6: Young hamsters of 5 (left above and below), 10 (middle above, at belly of mother), 16 (right above), 25 (middle below while receiving a transponder and right below during sex determination) days old. Photos: Opel-Zoo archive.

Breeding from 2018-2023

From 2018-2023, over 165 European hamsters were born in Opel-Zoo between the months of May and August (Tab. 2). The average number of young per litter was 6 ($n_{litters}$ = 27; litters excluded if no young were found at first check-up, as number of young remains unknown). Of the young that were present at first health check at approx. day seven, 95% (n_{young} = 165) reached an age of 8 weeks (56 days). On 6 occasions (18%, $n_{successful\ pairings}$ = 33), no young that reached an age of 7 days resulted from a successful copulation. In three of these cases, young were heard after birth but could not be found on first check-up. Because the mothers had successfully raised young before, we increased amounts of animal protein in the diet (changes already included in Table 1), as vitamin B3 deficiency deriving from nutrition has been shown to cause infanticide in European hamsters (Tissier, M.L., Handrich, Y., Dallongeville, O., Robin, J.P. & Habold, C., 2017). In the other three cases, which involved two females, no signs of young were seen or heard. One of the females did not show behaviour changes prior to birth, so that keepers assume she did not conceive (Table 2). The other female changed behaviour, so that keepers assume that young were born but consumed by the mother. This mother is the same individual that developed stereotypic behaviours during temporary holding in small cages. The female is the only one which never raised young and the only hamster that developed stereotypies in Opel-Zoo.

Tab. 2: Breeding of European hamsters in Opel-Zoo from 2018-2023. Sex m = male, f = female, ? = unknown, Aug. = August. Litters of which not all young survived are highlighted in italics. Pairings from which no young reached the age of 7 days are highlighted in grey.

Year	Number of pairing	Number of young at first counting (~ 7 days)	Number of young living up to day 56	Month of birth	Sex			Comments
					m	f	?	
2019	1	7	7	May	1	6	0	
2019	2	7	7	June	4	3	0	
2019	3	3	3	June	0	3	0	One young with missing leg
2019	4	1	1	June	0	1	0	
2019	*5*	*0*	*0*	*June*	*?*	*?*	*?*	*Mother = stereotypic female*
2019	*6*	*0*	*0*	*July*	*?*	*?*	*?*	
2020	7	7	7	June	3	4	0	
2020	8	5	5	June	3	2	0	
2020	9	3	3	June	2	1	0	
2020	10	6	6	June	2	4	0	
2020	11	2	2	June	1	1	0	
2021	*12*	*8*	*7*	*May*	*4*	*3*	*1*	
2021	13	6	6	May	4	2	0	
2021	*14*	*5*	*4*	*May*	*1*	*3*	*1*	
2021	15	*0*	*0*	*May*	*?*	*?*	*1*	*Young heard*
2021	16	7	7	May	5	2	0	
2021	*17*	*6*	*5*	*May*	*3*	*2*	*1*	
2021	18	5	5	June	2	3	0	

Tab. 2: Continued.

Year	Number of pairing	Number of young at first counting (~ 7 days)	Number of young living up to day 56	Month of birth	Sex			Comments
					m	f	?	
2021	19	7	7	July	3	4	0	
2021	20	5	5	July	3	2	0	
2021	21	6	6	July	3	3	0	
2022	22	9	8	May	2	6	1	
2022	*23*	*2*	*0*	*May*	*?*	*?*	*?*	*Mother had a tumor*
2022	24	7	7	May	3	4	0	
2022	*25*	*0*	*0*	*May*	*?*	*?*	*1*	*Young heard*
2022	*26*	*0*	*0*	*May*	*?*	*?*	*1*	*Young heard*
2023	27	9	9	May	4	5	0	
2023	*28*	*7*	*6*	*May*	*6*	*0*	*0*	
2023	29	9	9	May	2	7	0	
2023	30	9	9	May	5	4	0	
2023	31	9	9	May	6	3	0	
2023	32	0	0	-	?	?	?	Probably not conceived
2023	33	8	7	Aug.	4	3	1	
Total	**33**	**165**	**157**		**76**	**81**	**8**	

Reintroductions

Experience shows that, to improve reintroduction success, European hamsters should have a minimum weight of 150 g, better 200 g, when released (Lisa Heimann & Marco Sander, Institute for Faunistic & breeding centre for European hamsters at Heidelberg Zoo, pers. communication). Therefore, second litters of a female born in one season stay in care during winter to be reintroduced early in the next year. As females from the first litter of a year can give birth in the same year, young females can breed in Opel-Zoo once and then be released after winter.

With the help of Frankfurt Zoo and Zoo Osnabrueck, which kept young hamsters born in Opel-Zoo until they were heavy enough for release, a total of 116 European hamsters were reintroduced at two different sites in Hesse to date (24 in 2020, 27 in 2021, 31 in 2022, 34 in 2023). The numbers include two wild individuals that were caught by authorities for translocation and were released after they had bred successfully at Opel-Zoo as well as three individuals born at Zoo Osnabrueck.

The two reintroduction sites are situated in different districts and therefore executed and controlled by different authorities. At one site, situated in district Darmstadt-Dieburg, the hamster population failed to thrive due to unknown reasons so that reintroductions were stopped. The other reintroduction site is situated in the Hochtaunuskreis and is supposed to connect the remaining hamster populations in the districts Hochtaunuskreis and Wetteraukreis. Camera-trap monitoring by the regional nature conservation authority (Untere Naturschutzbehörde Hochtaunuskreis) confirms that the reintroduced hamsters have successfully reproduced in 2022 and 2023 (Figure 7). Regular mapping of hamster burrows suggests that the number of reintroduced

hamsters born in the breeding station at Opel-Zoo is sufficient to keep the population viable (Untere Naturschutzbehörde Hochtaunuskreis, unpublished data). Monitoring of the population and evaluation of the project is ongoing.

Fig. 7: Young European hamster leaving the burrow. Camera trap at one of the two reintroduction sites in June 2023. Photo: Untere Naturschutzbehörde Hochtaunuskreis.

Discussion and Conclusions

By intensive management, it is possible to breed up to 55 (and possibly more) European hamsters annually with only 7 breeding females and keep the hamsters in accordance with German regulations in a comparatively small breeding station (32 m^2 + outside enclosures for 2 individuals). While daily husbandry is relatively easy and quickly accomplished, mating is time consuming and requires experienced staff as well as detailed documentation. Keeping European hamsters in small mammal aviaries might have advantages for the animals as the ventilation is very good, and hamsters can have access to more space and options for vertical movement than in most traditional keeping systems. On the downside, this might reduce the numbers of animals that can be kept in a given space, potentially leading to a reduced number of individuals bred for reintroductions each year. Therefore, future studies should investigate if and how different husbandry systems influence the welfare of the animals, the number of births per litter, and the survival and growth rates of young in the stations and after reintroduction.

Survival rates of European hamsters in the weeks after release are low, but measures as electric fencing to prevent the predation by foxes can be taken to improve individual survival (La Haye et al., 2020; Villemey et al., 2013). The long-term survival of re-established populations is influenced by several factors related to habitat quality, as agricultural practices (La Haye et al., 2020; Ulbrich & Kayser, 2004; Villemey et al., 2013) and light pollution (Banaszek et al., 2020; Surov et al., 2016), as well as habitat size and connectivity (Ulbrich & Kayser, 2004). Therefore, detailed monitoring is vital to determine whether the number of individuals that are currently bred and reintroduced in Hesse is sufficient to establish self-sustaining populations.

This includes regular examination and possibly adjustment of habitat management and quality. In the project in Hesse, these complex tasks are implemented by the responsible federal agencies (Regierungspräsidium Darmstadt & Untere Naturschutzbehörde Hochtaunuskreis) and their partners. It will take several years until sufficient data is available to fully evaluate the project. Nevertheless, breeding success of reintroduced hamsters and numbers of active burrows at one reintroduction site indicate that with carefully chosen and well-prepared habitats as well as scientific monitoring, reproduction of European hamsters in breeding stations can play a vital role in the conservation of this species.

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We thank our colleagues of Heidelberg Zoo and the Institute for Faunistic, especially Lisa Heimann and Marco Sander for sharing their knowledge on European hamsters, and Lisa-Johanna Ebner for her vital input. Furthermore, we thank Zoo Osnabrueck and Frankfurt Zoo for their support in holding young hamsters until they have gained sufficient weight, which is important for reintroduction success.

Zusammenfassung

Einst in ganz Westeuropa verbreitet, ist die Populationsgröße des Europäischen Hamsters in den letzten 40 Jahren drastisch zurückgegangen. Er ist jetzt gelistet als vom Aussterben bedroht und es müssen dringend Maßnahmen ergriffen werden, um das Überleben der Art zu ermöglichen. Deshalb hat der Hochtaunuskreis (Hessen, Deutschland) 2012 damit begonnen Erhaltungsmaßnahmen ergriffen und ein Wiederansiedlungsprogramm für den Europäischen Hamster initiiert, das im Jahr 2020 begann. Der Opel-Zoo unterstützt diese Initiative, indem er Hamster für die Auswilderung züchtet. Wir beschreiben hier das Haltungssystem im Opel-Zoo entwickelte Haltungssystem, in dem jeder Hamster nach den in Deutschland geltenden Regeln (Gutachten über Mindestanforderungen an die Haltung von Säugetieren vom 7. Mai 2014) relativ kosten- und platzsparende Weise gehalten werden kann. Seit 2018 sind im Opel-Zoo über 165 Hamster geboren worden, von denen 157 ein Alter von acht Wochen überschritten haben. Die mittlere Wurfgröße betrug 6. Bis August 2023 wurden 116 europäische Hamster in geeigneten Lebensräumen in Zusammenarbeit mit den den Bundesbehörden (Regierungspräsidium Darmstadt & Untere Naturschutzbehörde Hochtaunuskreis) in geeigneten Habitat eingebracht. Es wurde bestätigt, dass einige von ihnen erfolgreich reproduziert haben.

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Killing Zoo Animals to Feed Carnivores in German-Speaking Zoos and its Acceptance by Staff, Visitors, and Media

Töten von Zootieren zum Verfüttern an Raubtiere in deutschsprachigen Zoos und die Akzeptanz bei Mitarbeitern, Besuchern und der Presse

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Abstract

Zoos keeping carnivores need to feed adequate animal material to these species. Several factors have contributed to the advocation of using zoo-raised animals (both domestic and non-domestic species) in a 'breed and feed'-approach for this purpose. These include the following: The welfare of the food animals (which is probably better in animals kept at zoos than at conventional or intensive livestock farms, animals of which are additionally transported and processed in slaughterhouses; allowing reproduction and the associated social behaviours rather than preventing reproduction in zoos), sustainability (by reducing transport), education (by not excluding 'death' from the cycle of life presented at the zoo), the sustainability of zoo animal

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populations (for which the production of a certain 'surplus' may be considered an important safety strategy). It has also been suggested that the feeding of whole carcasses, including large ones, has psychological and physiological benefits for the carnivores, as well as providing a didactic element. On the other hand, it has been felt that feeding whole carcasses and zoo-raised animals may not be socially acceptable and hence represents a risk for the reputation of zoos. Data on these aspects are sparse. We conducted a survey among German-speaking zoos on the practice of feeding zoo-raised animals, asking about the zoos' perceptions on which species should be excluded from this practice and about the zoos' experiences with staff, visitor and media reactions to such feeding events. 36 zoos participated, all of which had fed zoo-raised animals to their carnivores, in 223 feeding events (21% domestic and 79% non-domestic species, 87% mammal species). The animals fed were mostly mid-sized non-domestic ruminants in 25.6% of all events, followed by mid-sized domestic ruminants in 22.0%. The taxon most often mentioned as not suitable for feeding were the great apes. Four of the nine participating zoos keeping elephants did not exempt them from being fed, in principle (although no elephant feeding was reported). Most staff and visitor reactions were judged as 'accepting' of the feeding events, while the media and the local press mainly ignored them. When evaluating only those events that the media did report on, the zoo staff showed the highest acceptance, followed by visitors, whereas the reactions of the press were mainly neutral, with positive reactions ranging second and the negative ones ranging third (but notably less than no reaction at all). These results suggest that, at least among the zoos participating, reactions of the public need not be considered prohibitive to the practice of feeding zoo animals to zoo animals. Continuing education and public outreach efforts that stress the many sound reasons for this practice may further increase its acceptance. This should also be reflected in the operating concept of zoos that does not represent the killing and feeding of zoo animals to zoo animals as individual cases of 'surplus' specimens, but as a holistic animal husbandry, breeding, and welfare concept.

Keywords: carnivore feeding, slaughtering zoo animals, carnivores, whole carcasses

Introduction

In nature, carnivores prey on other animals. In zoos, they are also fed with animal material, either as whole prey/whole carcasses, carcass parts, or processed meat (Allen et al., 1996, Kleinlugtenbelt et al., 2023). Generally, this means that zoos buy these items from commercial providers. In the past, the source of these items may have appeared irrelevant, but in recent years sustainability, accountability and animal welfare, including that of animals raised for the sole reason of providing food for humans or other animals, have gained more relevance.

It would be a reasonable alternative to use the zoo itself as the source as part of a 'breed and feed' strategy. Prey insects, chicks, rodents and rabbits are commonly raised as food animals. The reasons for in-house animal food production may have been predominantly financial and logistical, as it may have been cheaper, or the only available option. However, increasing awareness of the relevance of animal welfare and sustainability issues (which also include the carbon footprint of any transport), adds the additional arguments of (i) no transport, and (ii) that zoos themselves, as animal husbandry experts, provide higher welfare-oriented animal husbandry than commercial animal production systems. Notably, animals in commercial production systems are typically not allowed to breed naturally, or raise their own offspring for periods that correspond to a natural situation.

In the debate about surplus animals in *ex situ* breeding programs (Bertelsen, 2018), the aspect of food animal production has mainly gone unnoticed. Rather, the argument of *ex situ* popula-

tion sustainability has been put forward, outlining that suppressed breeding (by separation, contraception, or sterilization) can have deleterious consequences for a population. The fact that the effect of contraceptives may not be easily reversible, in the sense of *"use it or lose it"* (Penfold et al., 2014), is part of this issue. The argument of animal welfare is, in our experience, somewhat less frequently mentioned, i.e., that the possibility to express courtship and mating behaviour, to breed, give birth to, and raise offspring, with all the biological and behavioural consequences, is usually denied without compensating mitigation if reproduction is not allowed. Note, for example, that a traditional veterinary medical education teaches castration and contraception methods, including potential medical side effects, but concepts on their effects on life-long welfare are not part of the curriculum. Importantly, the aspect has rarely been raised that preventing the breeding of surplus animals that could be used as food supports, by default, commercial food animal producers, whose animal welfare standards may be below those of zoos.

An important argument in this discussion is the actual or expected reaction of staff, visitors and the public to such a feeding regime. Many zoos operate in societies that endorse the killing of food production animals, yet shy away from killing zoo animals, whose welfare is most likely higher. The general invisibility of production animal killing in many societies may be a decisive factor in this reaction. While some zoos proactively address this paradox, possibly considering it part of their mission to educate the public about all implications of life (rather than presenting a selective picture that blends out unpleasant aspects), other zoos pre-emptively avoid the conflict. According to Carter & Kagan (2010), dealing with surplus animals is the *"most sensitive public relation issue"* that zoos could be confronted with nowadays.

However, it is difficult to gauge the degree to which the presumed objection of the public is real or not. The few studies on this aspect do not indicate that a majority of zoo visitors are opposed to a feeding method that makes visible the fact that an animal was killed for the carnivores. Several studies conducted in various countries revealed that zoo visitors are not generally opposed to carcass feeding, but rather see it as beneficial to the animals and believe that feeding whole carcasses has educational value and supports a more natural species-specific feeding behavior (Veninga & Lemon, 2001a; Gaengler & Clum, 2015; Roth et al., 2017 incl. several unpublished studies). Gaengler & Clum (2015), for example, found that the number of visitors disapproving of carcass feeding always remained at a low level, although it increased with carcass size and taxonomic proximity to humans. The minority who disapproved of public carcass feeding justified it mainly by an irritating effect on children or the participants themselves. Nevertheless, most visitors thought that carcass feeding would be more acceptable if visitors were educated about natural feeding behaviours by zoo staff (73%) or signs (68%). It has been suggested that zoos should assess the benefits of carcass feeding, which outweigh the small percentage of negative public perception (Veninga & Lemon, 2001b).

Some zoos feed their carnivores whole or partial carcasses of slaughtered surplus zoo animals of various species (Schäfer, 2015). To our knowledge, there is no quantitative overview of data on the feeding of zoo-raised animals to zoo animals. This study aims at documenting the frequency of this practice and the perceived reactions of various stakeholders to it, and putting these in the context of the animal species involved.

Methods

We collected and compiled data via an online survey (google forms) from zoos in Germany, Austria, and Switzerland. Of the 44 existing zoos that are members of the Association of Zoo Veterinarians ('Verband der Zootierärzte', VTZ), 36 responded. The survey was elaborated by

the VZT working group on 'Population Management'. The questions included whether zoos feed their own animals to their carnivores, what species they feed, who kills them, how they are presented and the perceived reactions of the zoo's staff members, visitors and the local media. Notably, this survey did not directly ask staff and visitors or surveyed media outlets, but relied on the impression noted by the zoo person judging these reactions. We also asked which species should be exempt from feeding to other animals.

Results

Thirty-six zoos participated in this study, all of which fed their own animals to their carnivores; one zoo provided photographic documentation (Fig. 1). In terms of the feeding event itself, 25 zoos (69%) permitted visitors to be present during the feeding of their own animals, six zoos (16%) did not allow visitor presence during the feeding, and five zoos (14%) carried out both public and non-public feedings.

Fig 1: A harpy eagle (*Harpia harpyja*) fed an agouti (*Dasyprocta leporina*) (left) and a snow leopard (*Panthera* uncia) fed a Barbary sheep (*Ammotragus lervia*). Photos by Helmut Mägdefrau

Two zoos (6%) decapitated their carcasses before feeding them, nine zoos (25%) divided their carcasses in such a way that the species of the carcass was unrecognizable, and 24 (67%) fed intact carcasses that allowed the species to be identified.

In total, 94 different species or animal groups were reported to have been fed in 223 individual feeding events (Tab. 1). These events used 21% domestic and 79% nondomestic species, comprising 87% mammals, 11% birds, two fish and one reptile species. The most frequently mentioned group of animals fed was by far that of non-domestic medium-sized ruminants, accounting for 37% of the 94 different species, 44% of the 82 mammal species and 26% of the 223 feeding events. Among domestic species, mid-sized ruminants (mainly sheep and goats, accounting for 22% of all feeding events) and small rodents (mainly guinea pigs, rats, and mice) were most frequently mentioned. Among nondomestic species, large ruminants (i.e. bison and yak) and mid-sized rodents (i.e. nutria) were most frequently used, although to a lesser degree than the mid-sized ruminants (Tab. 1).

Seventy-two percent of the responding zoos deemed the great apes to be unsuitable for feeding purposes (Tab. 2). Primates and carnivores were most frequently mentioned as species not suitable for feeding to other animals. For some taxa, we evaluated especially whether the respective zoo kept the taxa itself. In the case of great apes and dolphins, all participating zoos that

Tab. 1: Mammal species mentioned in 223 feeding events.

Taxon		domestic species (n)	% of the total 94 species	% of 82 mammal species	% of 223 feeding events	Non-domestic species (n)	% of the total 94 species	% of 82 mammal species	% of 223 feeding events
Ruminants	small[1]	-	-	-	-	3	3	4	1.8
	medium[2]	4	4	5	22.0	34	34	41	25.6
	large[3]	3	3	4	2.2	6	6	7	6.7
Equids		2	2	2	1.8	3	3	4	4.5
Camelids		2	2	2	1.3	1	1	1	0.4
Rodents/	small[1]	3	3	4	6.3	2	2	2	1.3
Rabbits	medium[2]	1	1	1	4.9	8	8	10	4.5
	large[3]	-	-	-	-	2	2	2	2.2
Macropods		-	-	-	-	2	2	2	0.9
Suiformes		2	2	2	2.2	2	2	2	2.2
Carnivores		-	-	-	-	2	2	2	0.9

[1]small ruminant: small gazelle-sized; small rodent: mouse or rat-sized
[2]medium ruminant: sheep-sized; medium rodent/rabbit: rabbit-sized
[3]large ruminant: cattle-sized; large rodent: mara or capybara-sized

Tab. 2: Species considered by the responding person to be unsuitable for feeding.

Which animals would you exempt from feeding?	n zoos	% of all 36 zoos	n zoos that kept the taxon	of which do not like to feed it
Great apes	26	72	17	17
Primates in general	16	44	-	-
Felids	13	36	-	-
Canids	12	33	-	-
Carnivores in general	11	31	-	-
Elephants	8	22	9	5
Rhinoceros	4	11	12	4
Anteaters	2	6	10	2
Dolphins	2	6	2	2
Tapirs	2	6	-	-
Bears	1	3	-	-
Xenarthrans in general	1	3	-	-
Marine mammals in general	1	3	-	-
Suiformes	1	3	-	-
No taxon	9	25	-	-

did not consider these taxa acceptable for feeding actually kept them. In contrast, not all zoos that kept elephants, rhinos or anteaters exempted these taxa from the list of potential candidates for feeding. A quarter of all zoos explicitly did not exempt any species from being fed; of these zoos, only one kept great apes and none kept dolphins.

In the majority of zoos responding, the keepers themselves did the slaughtering with a bolt gun and blood drainage, whereas most zoos used a licensed hunter or holder of a license for firearms when shooting the animals (Tab. 3).

Tab. 3: Persons responsible for killing/slaughtering.

Method	total n of zoos slaughtering their own animals by	n of zoos where keepers do the killing by	n of zoos where a veterinarian does the killing by	n of zoos where a hunter does the killing by	n of zoos where "others" do the killing by
shooting*	36	4	10	20	15
bolt gun*	36	27	14	4	8

*followed by blood draining

Reactions Reported

For all the zoos, reactions of the staff and visitors to individual feeding events were predominantly positive, whereas the majority of feeding events did not elicit any response from the press (Fig. 2).

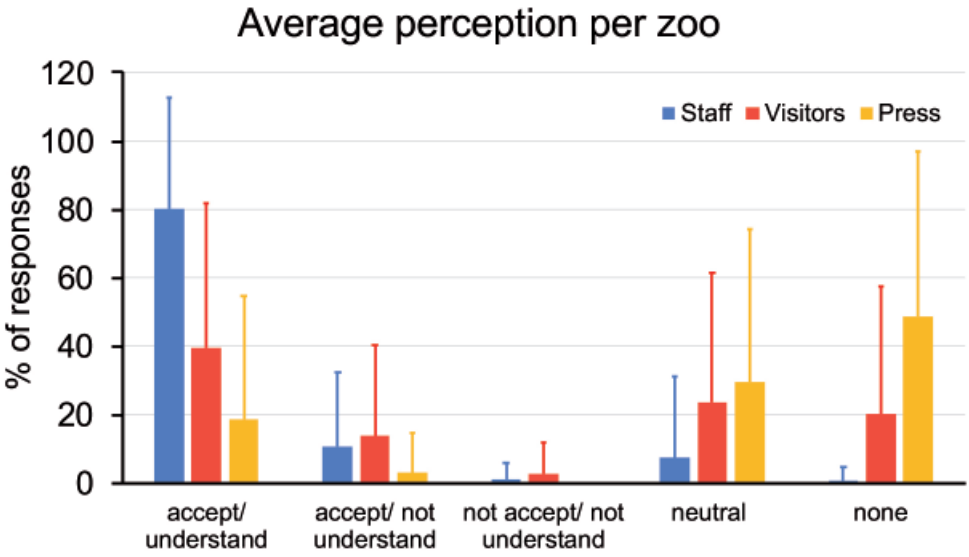

Fig. 2: Average perception per zoo for all feeding events.

Counting absent reactions as part of overall reactions makes a comparison between the groups difficult. Therefore, from here on, all reactions are given only as a percentage of the actual reactions. The resulting evaluation indicates that both visitors and press show a homogenous pattern: In the case of visitors, the majority of feeding events was accepted and understood, and neutral and more critical reactions decreased continuously. Press reactions ranged from accepting to critical, with the majority being neutral. In contrast, there was a dichotomy among zoo staff. Whereas most staff members accepted and understood the feeding events, they were actually more critical of them than neutral. In other words, the zoo staff appeared to be split into an accepting majority and a critical minority, with little neutral ground. This pattern persisted in all the subsequent evaluations.

While the data does not lend itself to easy statistical evaluation (due to the large imbalance among zoos in terms of numbers of feeding events), some general trends can be gleaned: Zoo

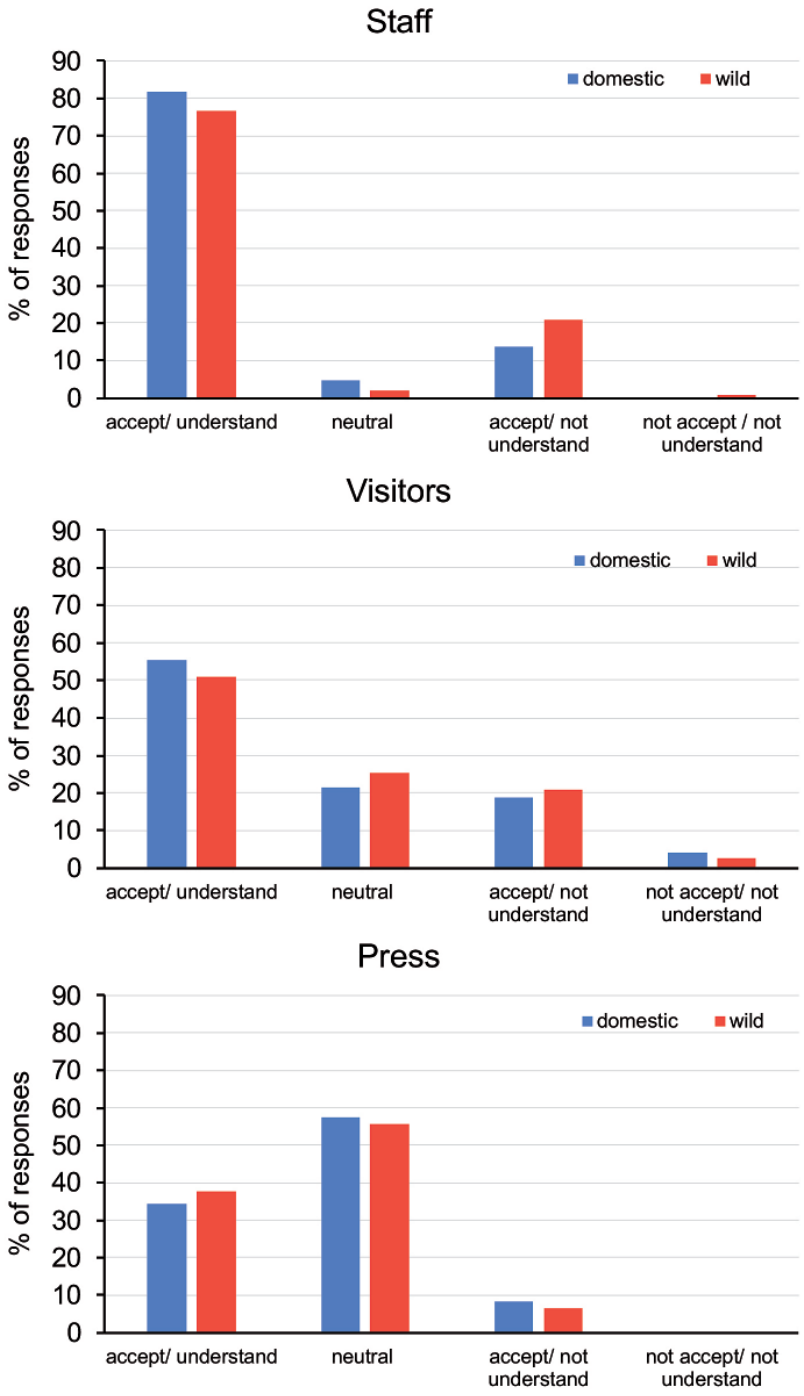

Fig 3: Reactions of staff members, visitors and the press to feeding domestic vs wild species.

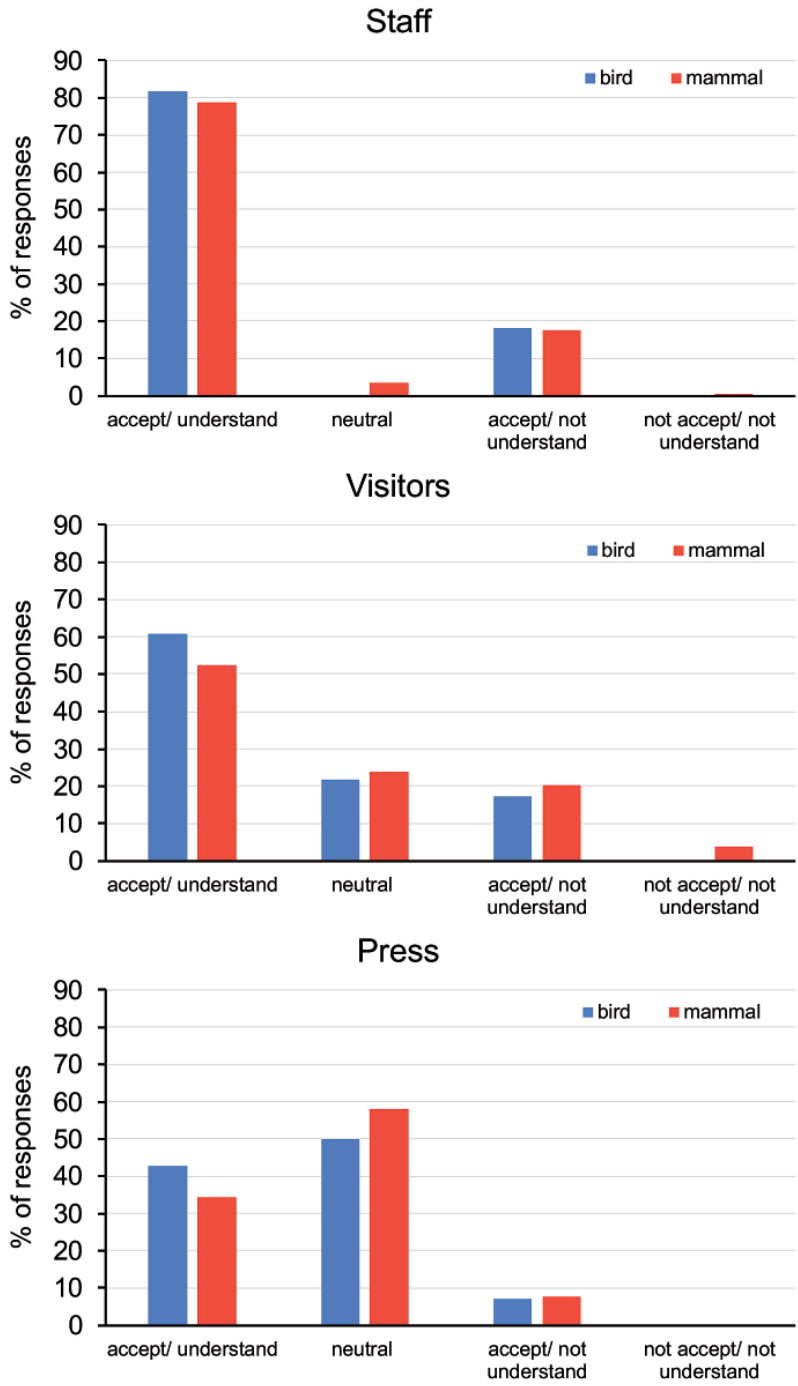

Fig. 4: Reactions of staff members visitors and the press to feeding bird vs mammal species.

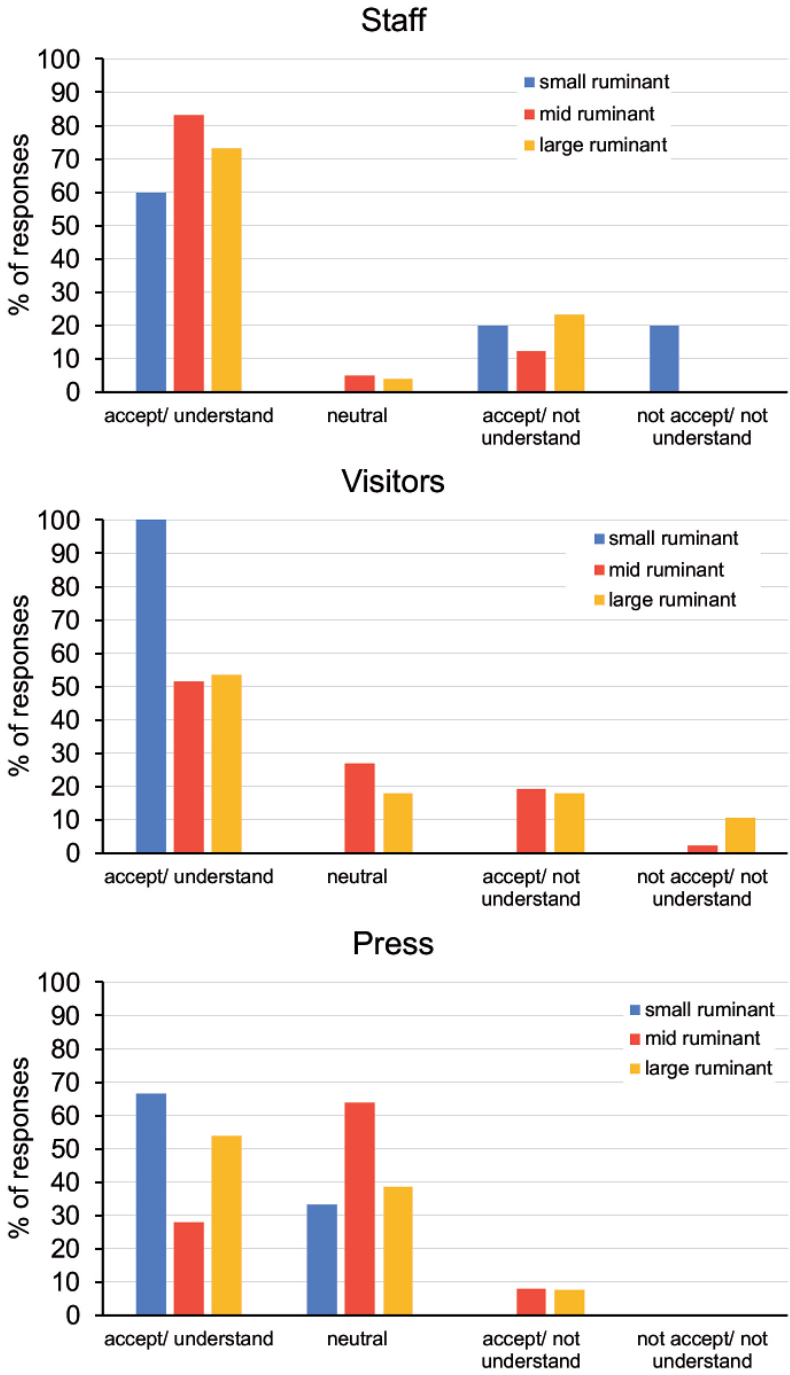

Fig. 5: Reactions of staff members, visitors, the press to feeding ruminant species of different sizes.

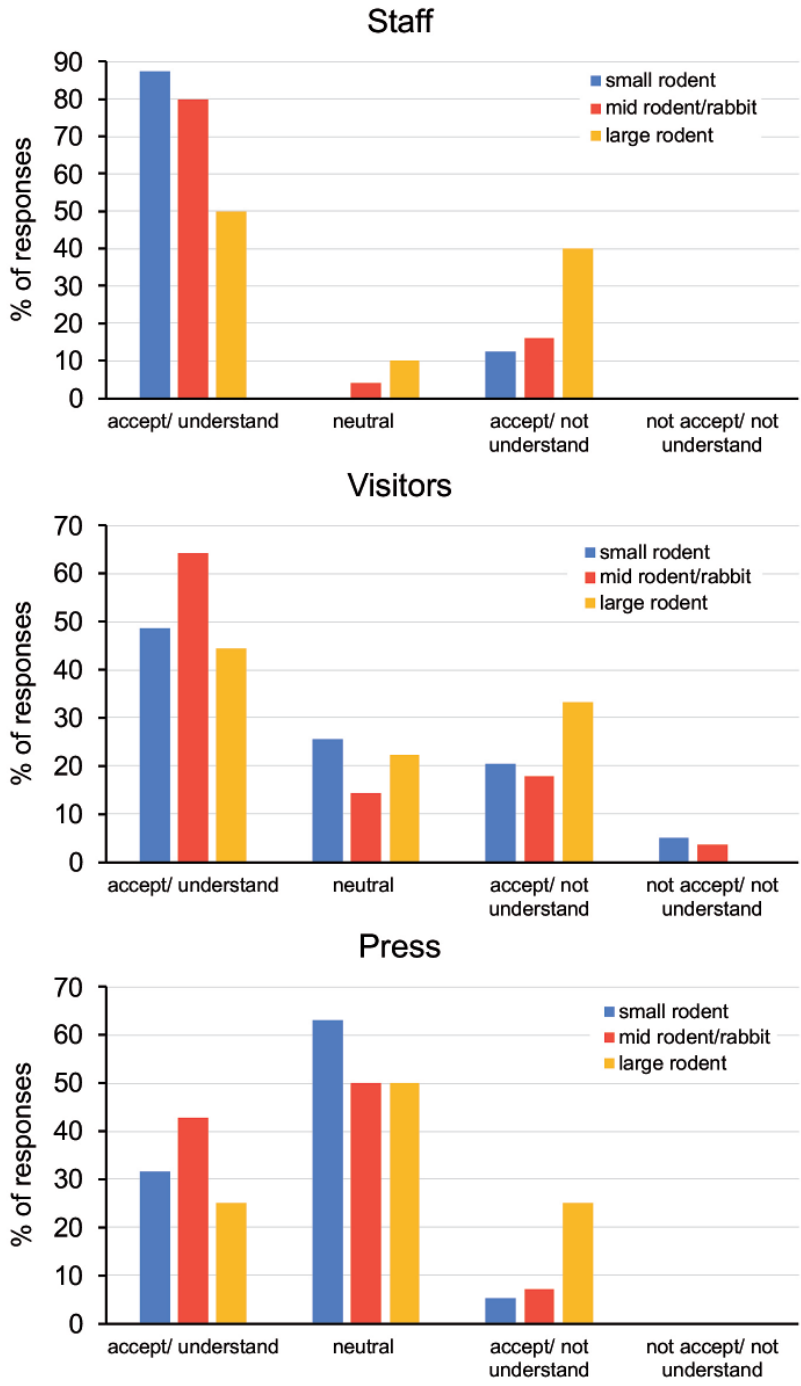

Fig. 6: Reactions of staff members, visitors and the press to feeding rabbits and rodent species of different sizes.

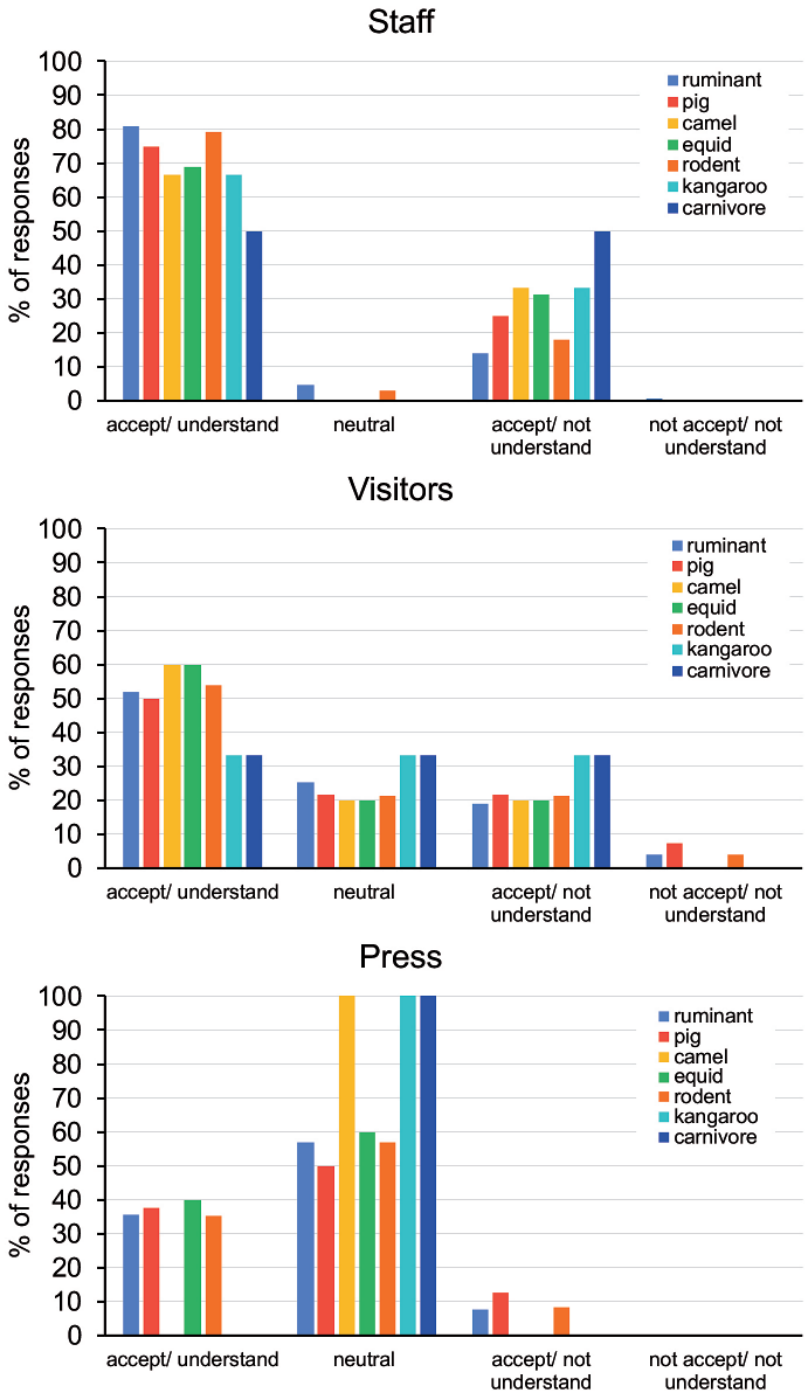

Fig. 7: Reactions of staff members, visitors and the press to feeding various mammal groups.

staffs are split (although the majority approves of feeding their own animals), the public generally approves of feeding killed zoo animals and the press is largely neutral, yet with more approving than critical reactions. Feeding domestic species appears to be slightly easier to accept than the feeding of non-domestic species (Fig. 3), and the same holds true for birds compared to mammals (Fig. 4). Among ruminants, no clear pattern was evident with respect to body size (Fig. 5), whereas in rodents, it seemed that feeding medium and especially large rodents was seen more critically than the feeding of small rodents (Fig. 6). When dividing the mammals by taxonomic group, the split within the zoo staff was particularly evident. It was the feeding of kangaroos to carnivores that elicited the most critical response (yet, it should be noted that these cases represent a minority of feeding events) (Fig. 7).

With respect to public education, 75% of the zoos provided no education to the public about feeding during most of these feeding events and 18 zoos never gave any kind of public education during a feeding event. 25% of the zoos had a responsible staff member standing close by for any upcoming questions, 19% did educational talks during the feeding events, 17% did some kind of education through social media and 11% used other educational options. Many zoos used more than one educational technique. There was no evident correlation between the visitor reactions reported and the public education efforts by the zoos.

Discussion

Over the past years, the use of zoo animals for feeding purposes has been questioned, but our findings suggest that the perception towards feeding a zoo's own animals to carnivores kept at the zoo is not as negative as previously assumed. However, the number of zoos surveyed in this study was small, geographically limited and constrained to membership in the Association of Zoo Veterinarians of German-speaking countries. Visitor reactions reflect the cultural attitudes of each area, so that broader surveys across the European zoo community would be welcome. Also, it must be noted that reactions asked for related to staff, visitors and media, and not – because this would have been impossible to judge – of the overall society. Evidently, detailed interviews with staff, zoo visitors and people who do not visit zoos would be interesting in the future, as well as linking feeding events and husbandry practices to the respective public and social media reactions in a quantitative manner.

Based on this survey, only a few taxa are still largely considered unsuitable or unacceptable to be fed to carnivores, such as great apes and elephants. This corresponds to the "cuteness index" depicted by Bertelsen (2018), wherein meat, insects, fish, small rodents and day-old chicks range lowest, domestic animals being in the middle range, non-domestic prey species (such as zebras, antelopes or giraffes) scoring higher, but being topped by charismatic species such as elephants and great apes. Thus, the reluctance to feed these latter groups to other animals can be expected to be highest. Domestic species that are also consumed by humans and those species featuring prominently as prey animals in predator-prey narratives (such as wild ruminants) are particularly well tolerated as food animals. This contrasts, for example, to anteaters or tapirs (Tab. 2), which are also preyed upon in their natural habitat, but whose peculiar physiognomy sets them apart. The comparatively high proportion of negative visitor reactions to feeding kangaroos to zoo carnivores, although they are even hunted for human consumption in their native habitat, may be explained by their distinctness from animals typically slaughtered in the region of the present study (Fig. 7). In this respect, it would be interesting to perform a similar survey across Australian zoos and assess whether the perception of feeding kangaroos is different on that continent.

The perceived reactions mirror this ranking, regardless of whether staff, visitors or the media are concerned. Our findings indicate that keepers have a tolerant and understanding attitude to-

ward feeding their own zoo animals to their carnivores, except for a small minority who neither approve nor understand this practice. The literature sheds no further light on this subject. In hindsight, both the high acceptance and the dichotomic split in this group is understandable. On the one hand, zoo keepers can be expected to better understand the 'cycle of nature' as well as the behavioural benefit of both (surplus) breeding for the breeding group and carcass feeding for the carnivores than the general public, since their choice of profession may well be connected to this knowledge. On the other hand, one does not become an animal keeper to kill animals, but rather because of an emotional connection that may also be more pronounced than that of society as a whole, and which may lead to a distinct aversion to the practice. The lack of 'neutral' reactions from zookeepers is thus understandable. Here, we propose that a positive emotional bond to a specific animal, and to animals in general, need not preclude the acceptance of the unavoidability of death in general, and the respectful, humane killing of a specific individual that was provided with high quality husbandry conditions.

The zoo visitors asked about in our study appeared to tolerate and generally comprehend this feeding practice. As previously mentioned, naturalistic feeding practices are seen as a potential issue for zoo visitors, but a closer look makes clear that the number of visitors who disapprove of this practice remains very low (Gaengler & Clum, 2015). More detailed studies on the perception of the killing of animals would be welcome, as would be even more efforts to educate the public in this regard.

The press seemed in general more neutral and uninvolved in the feeding events in our study, but when involved, the majority was understanding and accepted this feeding practice. As evidenced in this survey, and as easily understandable, the press does not report on all feeding events in their local zoo. This may be an indication that more naturalistic feeding of carnivores with zoo-bred animals is not considered to be as spectacular as one might have deduced from notorious public outcries, in particular that related to the killing of the surplus giraffe 'Marius' at Copenhagen Zoo (Bertelsen, 2014). Concerns by zoo managers that the public, and in particular media will have negative reactions to the feeding of zoo animals to zoo animals are intuitively understandable, but based on the judgement voiced in our survey, are not based on the experience of the majority of participating zoos. In that same line of thought, it should be remembered that even in the notorious 'Marius' case, the large majority (79 %) of public media reactions were considered 'neutral' (with 4% 'positive' and 17% 'negative') (Zimmerman et al., 2014), and that the scientific director of Copenhagen Zoo was elected "citizen of the year" in the aftermath of the related public media activity (Vesterberg, 2014).

Given the combined effects of nutritional value, behavioural management, and public education, it is surprising that European zoos do not generally feed large carcasses, irrespective of whether they derive from animals raised at the zoo or elsewhere (Kleinlugtenbelt et al., 2023). It has been reported, for example, that feeding large whole carcasses enhanced cooperation among zoo-managed bush dogs (*Speothos venaticus*) (Macdonald, 1996) and painted hunting dogs (*Lycaon pictus*) (Veninga & Lemon, 2001a) and helped zoo-managed lions resolve social tensions during the feeding event (Höttges et al. 2019). Whole-prey feeding is linked to reduced plaque formation and focal palatine erosion (Lindburg, 1988). In particular, the less digestible or indigestible components of whole carcasses, including bones, tendons, cartilage, skin, hair or feathers, have been termed 'animal fibre' and may benefit the health of the carnivores by modulating their intestinal fermentation (Depauw et al., 2013). A carnivore consuming a carcass is also a truer representation of natural circumstances than a carnivore consuming skinned meat on the bone, and will be more helpful in fulfilling the educational aims of a zoo.

As stated by Bertelsen (2018): *"The vast majority of human beings and every zoo known to the author have made the fundamental choice that it is acceptable to kill animals."* This has implications – for the actual individual act of killing, and for the general judgement of the societal setup.

If done without glee or displays of bravado or humour, but with respect, the killing itself need not detract from the dignity of the animal; if done in a professional way with adequate methods and at an adequate time in the animal's life (e.g., at dispersal age), it need not detract from the welfare of the animal or its social group. Taking the responsibility for this – respectful, welfare-compatible – killing may be an important didactic hallmark of modern zoos. Notably, this includes managing the animal's death in a part of its used surroundings during what it perceives as usual daily routine.

In current interpretations of the legislation in Germany, the focus is mainly on the individual animal, and less on the overall food production concept of both the society and the zoo, or on the societal goal of nature and species conservation. For example, a recent commentary explicitly denies a relationship between using zoo animals for food and the reduced demand this would have on commercially produced animals (Hirth et al., 2023) (section 58b, p. 806). However, in our view, the interrelatedness of feeding concepts (of zoos, of humans, of farm and pet animals) with enterprises that provide food for these demands cannot be ignored, as any individual consumer decision will affect the overall outcome, even if not immediately; and if animal welfare is considered a relevant societal issue (as it is for zoos), then the corresponding implications cannot be ignored, either. As another example, Hirth et al. (2023) claim that no act of killing can ever be necessary to prevent a species from going extinct (section 58b, p. 805); again, while sounding intuitive on an individual case basis, this statement seems to ignore constraints population managers have to operate under in real life, and the effect individual case decisions have on an overall outcome, even if not immediately.

Thus, a typical dilemma arises when decisions about killing an individual animal are made on a case-by-case basis: if the main aim of allowing this animal to be procreated is proclaimed to be species conservation, then an *ad hoc* decision to kill (and feed) it as a 'surplus animal' might be perceived as in conflict with that aim. For example, Hirth et al. (2023) repeatedly state that such a case may represent a 'contradictory conduct', where killing is justified by circumstances that make the animal 'surplus', whereas that situation would have been predictable and the procreation of the individual could have been prevented. As long as zoos proclaim species conservation as the main goal, and the killing of individuals as peculiar 'surplus' cases, this standpoint may appear valid. Such an approach cannot be considered holistic, as it excludes an integrated view of how zoos are managed (including food provisioning and their carbon footprint), of the restricted resources under which nature and species conservation necessarily operate, and important aspects of animal welfare (both for commercially raised food animals and for zoo animals) that zoos, as centers of animal husbandry expertise, stand for.

Therefore, it might be beneficial for general media outreach and the education of visitors, as well as for the acceptance of local and national executive agencies, to have a written, overarching concept that outlines the principles of feeding animal products in a specific zoo, as well as the source of the animal products. In other words, the breeding of zoo animals should, from the outset, have a dual aim: species conservation and welfare-oriented high quality food provision. This should include aspects of sustainability, accountability, animal dignity and welfare, as well as alternative sources of food animals, in addition to considerations of population sustainability. When the breeding of zoo animals is planned, from the outset, to include killing and feeding as well as ensuring thriving *ex situ* populations, then the indictment of contradictory conduct does not apply (Hirth et al. 2023) (section 58d, p. 807).

Acknowledgement

We thank all those zoos who chose to remain anonymous in our study for taking the time to participate.

Zusammenfassung

Zoos, die Fleischfresser halten, müssen diese Arten mit tierischem Material füttern. Mehrere Faktoren haben dazu beigetragen, dass die Verwendung von in Zoos aufgezogenen Tieren – sowohl Haustieren als auch Wildtieren – im Rahmen einer ‚Breed and Feed'-Strategie zu diesem Zweck befürwortet wird, darunter das Wohlergehen der Futtertiere (das bei in Zoos gehaltenen Tieren möglicherweise am höchsten ist, verglichen mit Tieren aus konventioneller oder intensiver Tierhaltung, die nach Transport in einem Schlachthof getötet werden; Ermöglichen von Fortpflanzung und damit verbundener Verhaltensweisen statt Unterdrückung der Fortpflanzung in Zoos), die Nachhaltigkeit (durch Verringerung der Transporte), die Bildung (indem „Tod" nicht aus dem im Zoo dargestellten Lebenszyklus ausgeschlossen wird), die Nachhaltigkeit der Zootierpopulationen (für welche die Produktion eines gewissen „Überschusses" als wichtige Sicherheitsstrategie angesehen werden kann). Darüber hinaus wird angenommen, dass die Fütterung ganzer Tierkörper, einschließlich großer Kadaver, psychologische und physiologische Vorteile für die Fleischfresser mit sich bringt und auch ein didaktisches Element enthält. Im Gegensatz dazu wurde behauptet, dass die Fütterung ganzer Tierkörper und von Tieren, die in Zoos aufgezogen wurden, gesellschaftlich nicht akzeptabel sein könnte und daher ein Reputationsrisiko für Zoos darstellt. Es gibt wenig Daten über diese Fütterungspraxis. Die Autoren haben eine Umfrage unter deutschsprachigen Zoos zur Praxis der Fütterung von Zootieren durchgeführt und die Meinung der Zoos darüber erfragt, welche Tierarten von dieser Praxis ausgeschlossen werden sollten, sowie die Erfahrungen der Zoos hinsichtlich der Reaktion von Mitarbeiterinnen und Mitarbeitern, Besucherinnen und Besuchern sowie der Presse auf solche Fütterungen. Insgesamt nahmen 36 Zoos an der Umfrage teil, die bei insgesamt 223 Fütterungen (21 % Haustierarten und 79 % Wildtierarten; 87 % Säugetierarten) Tiere aus der eigenen Zoohaltung an ihre Fleischfresser verfüttert hatten. Die am häufigsten verfütterte Gruppe war die der mittelgroßen nicht domestizierten Wiederkäuer mit 25,6 % aller Fütterungen, gefolgt von mittelgroßen domestizierten Wiederkäuern mit 22,0 %. Das am häufigsten genannte Taxon, das als nicht zur Verfütterung geeignet betrachtet wird, sind die Menschenaffen; im Gegensatz dazu haben vier der neun teilnehmenden Zoos, die Elefanten halten, diese nicht grundsätzlich von der Fütterung ausgenommen (es wurde aber keine Verfütterung eines Elefanten gemeldet). Die Reaktionen des Personals und der Besucher wurden mehrheitlich als „akzeptierend" eingestuft, während die Presse die Fütterungen überwiegend ignorierte. Bei der Bewertung nur der nicht ignorierten Ereignisse hatte das Zoopersonal die höchste Akzeptanzrate, gefolgt von den Besuchern, während die Reaktionen der Presse hauptsächlich neutral waren, gefolgt von positiven Reaktionen, während negative Reaktionen an dritter Stelle standen (alle drei aber deutlich weniger als gar keine Reaktion). Diese Ergebnisse deuten darauf hin, dass – zumindest in den teilnehmenden Zoos – die Reaktionen der Öffentlichkeit auf die Praxis der Fütterung von Zootieren an Zootiere nicht als prohibitiv angesehen werden müssen. Kontinuierliche Aufklärungs- und Öffentlichkeitsarbeit, die die vielen guten Gründe für diese Praxis hervorhebt, könnte ihre Akzeptanz weiter erhöhen. Dies sollte sich auch in den Management-Konzepten von Zoos widerspiegeln, die das Töten und Verfüttern von Zootieren an Zootiere nicht als Einzelfall-Lösungen für *Surplus*-Individuen beschreibt, sondern als Teil eines holistischen Konzeptes von Tierhaltung, Zucht und Wohlergehen.

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