Conservation of *Pan troglodytes verus* in West Africa: Local Perceptions and Physiological and Behavioural Responses of Chimpanzees in the Wild

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Conservation of *Pan troglodytes verus* in West Africa: Local Perceptions and Physiological and Behavioural Responses of Chimpanzees in the Wild.

Memoria presentada por **Mónica Arias Brocal**

Bajo la dirección del **Dr. Xavier Manteca Vilanova** y del **Dr. Manel Lopez-Bejar**

Para la obtención del grado de doctora dentro del programa de doctorado de Producción Animal del Departamento de Ciencia Animal y de los Alimentos de la Universidad Autónoma de Barcelona

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FACULTAT DE VETERINÀRIA

El Dr. Xavier Manteca Vilanova, catedrático del departamento de Ciencia Animal y de los Alimentos de la Universidad Autónoma de Barcelona, y el Dr. Manel Lopez-Bejar, profesor titular de universidad del Departamento de Sanidad y Anatomía Animales de la Universidad Autónoma de Barcelona,

Certifican:

Que la memoria titulada "Conservation of *Pan troglodytes verus* in West Africa: Local Perceptions and Physiological and Behavioural Responses of Chimpanzees in the Wild", presentada por Mónica Arias Brocal con el fin de optar al grado de doctora, ha sido realizada bajo su dirección y, considerándola terminada, autorizan su presentación para que sea juzgada por la comisión correspondiente.

Y para que conste a los efectos oportunos, firman la presente en Bellaterra el 14 de septiembre de 2018.

Dr. Xavier Manteca Vilanova Dr. Manel Lopez-Bejar

A los chimpancés.

Por permitirme estar a vuestro lado.

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INDICE

RESUMEN

El objetivo general de esta tesis fue estudiar y valorar el bienestar de los chimpancés *(Pan troglodytes verus)* en libertad mediante indicadores fisiológicos y conductuales, así como conocer las percepciones de los habitantes en una Reserva al sureste de Senegal.

La mayoría de habitantes en la Réserve Naturelle Communautaire de Dindéfélo son de etnia Peul con una economía de subsistencia que les lleva a buscar recursos básicos en el bosque para poder sobrevivir. Humanos y chimpancés compiten por recursos básicos como el agua y árboles. Se realizaron 338 entrevistas a los locales para conocer sus percepciones sobre la conservación de chimpancés. Las percepciones locales sobre conservación de chimpancés se vieron influidas por el nivel educativo, la formación en un proyecto medioambiental en la zona y las creencias tradicionales de la etnia. Estas percepciones locales nos permitieron diseñar líneas de acción para mejorar la conservación de primates y la coexistencia sostenible entre humanos y chimpancés.

Además realizamos un estudio para valorar las respuestas fisiológicas de los chimpancés ante actividades antropogénicas en la Reserva. Se recogieron 155 muestras fecales frescas en 4 áreas de la Reserva con diferentes características: presión humana, fuegos forestales, campos de cultivo y grupo control. Se encontraron aumentos de concentraciones de cortisol fecal asociados a actividades antropogénicas pero también a dinámicas de la propia especie como temporada de apareamiento, interacciones agonísticas o competición por el alimento entre grupos. Por otra parte, la concentración de hormona tiroidea estuvo relacionada con la disponibilidad de alimentos. Las concentraciones de hormonas son herramientas útiles para valorar el bienestar de especies en extinción.

Finalmente, se estudiaron las respuestas comportamentales de los chimpancés en un sitio dominado por los humanos. La zonificación de Dindéfélo coincide con diferentes tipos de presión humana y se añadió otra zona control, donde estaba restringido el paso a humanos. La alimentación de los chimpancés disminuyó de forma significativa al aumentar el número de personas presentes, como grandes grupos de turistas. La huida de los primates fue mayor el año que estuvieron en la zona de mayor actividad antropogénica pero también sufrieron persecuciones y enfrentamientos de 4 machos adultos extranjeros. Se encontraron aumentos en metabolitos de cortisol fecal relacionados con actividades antropogénicas y dinámicas de la especie. No se encontraron relaciones significativas entre los metabolitos de cortisol fecal y las conductas de huida. Una vez más, confluyen múltiples factores para poder mejorar la conservación de chimpancés en libertad y mejorar una coexistencia sostenible.

ABSTRACT

The general objective of this thesis was the study and evaluation of the wild chimpanzee´s welfare *(Pan troglodytes verus)* by means of physiological and behavioural indicators and to know the local perceptions in a Reserve in the southeast of Senegal.

The majority of inhabitants in the Réserve Naturelle Communautaire of Dindéfélo belong to Peul ethnicity with a subsistence economy that leads them to look for basic resources in the forest in order to survive. Humans and chimpanzees compete for basic resources such as water and trees. Three hundred thirty eight interviews were carried out among the locals inn order to know their perceptions about the conservation of chimpanzees. Local perceptions of chimpanzee conservation were influenced by educational level, environmental project training in the area and traditional beliefs of the ethnic group. These local perceptions allowed us to design an action plan to improve primate conservation and sustainable coexistence between humans and chimpanzees.

We also conducted a study to assess the physiological responses of chimpanzees to anthropogenic activities in the Reserve. One hundred fifty five fresh faecal samples were collected in 4 sites of the Reserve with different characteristics: human pressure, forest fires, crops and control group. There were increases in faecal cortisol concentrations associated with anthropogenic activities but also dynamics of the species themselves such as mating season, agonistic interactions or food competition between groups. Concentration of thyroid hormone was related to the availability of food. Hormone concentrations are useful tools for assessing the welfare of endangered species.

Finally, behavioural responses of chimpanzees in a human-dominated site were studied. Dindéfélo's zoning coincides with different types of human pressure and another control zone was added, where the access to humans was restricted. The feeding of chimpanzees decreased significantly as the number of people present increases, such as large groups of tourists. The flight of apes was greater the year they were in the zone of high anthropogenic activity but they also suffered persecutions and confrontations of 4 foreign adult males. Increases were found in faecal cortisol metabolites related to anthropogenic activities and dynamics of the species. No significant relationships were found between faecal cortisol metabolites and flight behaviours. Once again, multiple factors converge to improve the conservation of wild chimpanzees and improve sustainable coexistence.

INTRODUCCIÓN GENERAL

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1. Conservación y crisis de la biodiversidad

1.1. Actividades antropogénicas

Una de las definiciones de la Conservación de Biodiversidad, según la Unión Internacional para la Conservación de la Naturaleza (IUCN), es el conjunto de acciones para mantener poblaciones de especies y áreas de ecosistemas. El término Biodiversidad fue acuñado por Wilson en 1988 y se refiere a "toda la vida que hay en la tierra. Abarca las plantas y animales que podemos ver, pero también los organismos microscópicos que viven en el suelo, las bacterias en nuestro sistema digestivo y la miríada de procesos biológicos que sustentan la vida en la tierra". La diversidad biológica es "un concepto fundamental, complejo y general, que abarca todo el espectro de organización biológica, desde genes hasta comunidades y sus componentes estructurales, funcionales y de composición, así como las escalas de espacio y tiempo" [Núñez et al., 2003]. Sin embargo, esta diversidad biológica se está perdiendo actualmente. Cálculos recientes de extinción de especies indican que se está produciendo entre 1.000 y 10.000 veces más rápido que las tasas básicas a lo largo de la época geológica, es decir, parece que nos acercamos a un período de "extinciones masivas" inducidas por los humanos [Lawton y May, 1994]. Esta advertencia la sustenta el hecho de que más del 12% de las plantas que florecen, por lo menos el 10% de todos los árboles y el 24% de los mamíferos están actualmente amenazados de extinción. Hay un fortalecimiento de la hipótesis de que el mundo natural está experimentando la sexta mayor extinción en la historia [Thomas et al., 2004].

Las cuatro primeras extinciones fueron causadas por meteoritos, grandes volcanes o la explosión de una supernova y resultaron ser muy mortíferas. La última de las cinco grandes extinciones de la Tierra ocurrió hace 65 millones de años, en el Cretácico, cuando un meteorito impactó contra la superficie del planeta y sus consecuencias fueron la pérdida del 75% de las especies, entre ellas los dinosaurios. Lo relevante es que en esta posible sexta gran extinción la causa sería la acción del hombre. Además esta causa humana no está remitiendo sino que aumenta cada vez más.

Actualmente estamos experimentando una crisis de biodiversidad debido al aumento de la población humana en todo el mundo, incremento de las demandas del mercado, el crecimiento de desigualdades económicas, la expansión de la agricultura, la fragmentación de hábitats, la deforestación, la extinción global de especies, el cambio

climático y la contaminación. El incremento total en riqueza de especies es a medida que la latitud disminuye hacia el ecuador: Neotrópicos, África y Asia. La mayor pérdida de biodiversidad se encuentra en estas zonas tropicales debido a que son las zonas más ricas en recursos naturales y por tanto de mayor explotación (Figura 1). A su vez en estas zonas es donde viven las poblaciones humanas más pobres y la desigualdad económica se incrementa aún más. Hay un aumento estimado de la población mundial de 7 mil millones en 2012 a 9 mil millones en 2050, donde el crecimiento más alto es en las naciones tropicales. Hoy en día, 2 mil millones de personas viven en regiones donde viven especies de primates y se caracterizan por altos niveles de pobreza [Estrada et al, 2017].

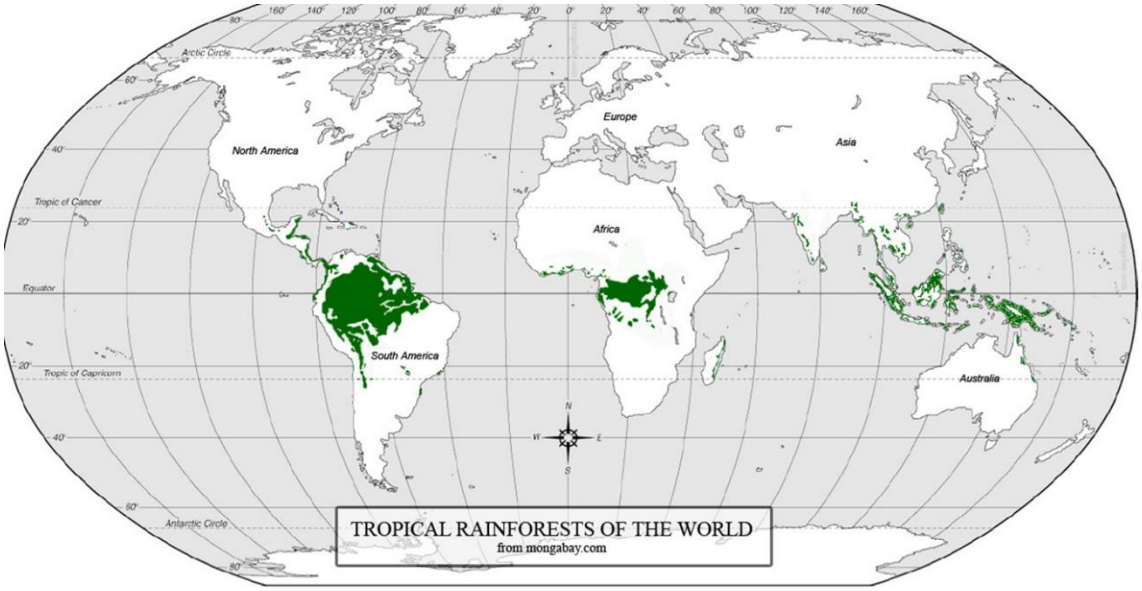

Figura 1. Bosques tropicales del mundo [Estrada et al., 2017].

Gibson estudió la degradación en biodiversidad en bosques tropicales. Entendió por bosques primarios aquellos que no tienen o han tenido poca perturbación humana. Sus resultados demostraron que la conversión y degradación forestal reduce en gran medida la biodiversidad tropical. Concluyó que los bosques, sobre todo en bosques primarios, son insustituibles para sostener la biodiversidad tropical. Por tanto, instó a la protección a través de áreas protegidas, ampliar la red de reservas y frenar la demanda internacional de productos forestales de bosques primarios. El apoyo social, financiero y técnico necesario para lograr tales objetivos sigue presentando uno de los mayores

desafíos de la conservación de la biodiversidad tropical en el siglo XXI [Gibson et al., 2011].

1.2. Chimpancés *(Pan troglodytes verus)*

En las zonas cercanas al ecuador, la población de grandes primates está disminuyendo de manera alarmante. Como postula Estrada: “Los primates no humanos, nuestros parientes biológicos más cercanos, son un componente esencial de la biodiversidad tropical, que contribuyen a la regeneración del bosque y la salud de los ecosistemas. Hay 504 especies en 79 géneros distribuidos en el Neo trópico, África continental, Madagascar y Asia. De manera alarmante, el 60% de las especies de primates están en peligro de extinción y el 75% ha visto reducida su población. Esta situación es el resultado del incremento de las presiones antropogénicas sobre los primates y sus hábitats, principalmente las demandas del mercado local y mundial, que conducen a la pérdida de hábitat a través de la expansión de la agricultura industrial, ganadería a gran escala, tala, extracción de petróleo y gas, minería, construcción de presas y nuevas redes de carreteras en regiones de primates. Otros impulsores importantes son el aumento de la caza, consumo de carne de primates y el comercio ilegal como mascotas, el cambio climático y la transmisión de enfermedades. A menudo, estas presiones actúan en sinergia, lo que agrava la disminución de la población de primates. Las regiones de grandes simios coinciden con zonas de alto crecimiento de la población humana y elevados niveles de pobreza. Es necesaria atención internacional inmediata para revertir el riesgo inminente de extinción de primates y para atender a las necesidades de los locales de manera sostenible. Aumentar la conciencia científica y pública mundial sobre la difícil situación de los primates del mundo y los costos de su pérdida para la salud del ecosistema y la sociedad humana son imperativos” [Estrada et al., 2017].

Uno de los grandes simios es el chimpancé *(Pan troglodytes),* especie en peligro de extinción según la Lista Roja de la IUCN. Esta especie ha sufrido una reducción significativa de la población en los últimos 20-30 años debido a altos niveles de caza furtiva, enfermedades infecciosas y pérdida de hábitat por la expansión de las actividades humanas. A pesar del reciente incremento de los esfuerzos de conservación dirigidos a los chimpancés y otros animales salvajes, la población de *P. troglodytes* continuaría disminuyendo debido a: un rápido crecimiento de población humana en el África subsahariana, caza furtiva de animales silvestres, comercio ilegal de carne de animales salvajes, llegada de la agricultura industrial, deforestación, corrupción y falta

de aplicación de la ley, falta de capacidad y recursos, inestabilidad política en algunos Estados del área de distribución y transmisión de enfermedades como el Ébola [Humle et al., 2016].

En Senegal, habita la subespecie *Pan troglodytes verus* que está en peligro crítico de extinción. La última estimación del tamaño total de la población de esta subespecie es de 18.000 a 65.000 en África occidental. En Senegal, esta especie está cerca de la extinción. *P. t. verus* es una de las subespecies más amenazadas y se estima una población de 200-400 chimpancés en Senegal [Humle et al., 2016; Pruetz and Bertolani, 2009]. En un censo realizado en la Réserve Naturelle Communautaire de Dindéfélo (RNCD), se han estimado entre 36 y 91 chimpancés en 2014 [IJGE sin publicar; Waller and Pruetz, 2016].

1.3. Réserve Naturelle Communautaire de Dindéfélo

La Reserva cubre un área de 14.050 hectáreas en la región de Kedougou, en el extremo sureste de Senegal (Figura 2). Limita al norte con las vertientes montañosas del Fouta Djallon, al este con el río Gambia y al suroeste con Guinea-Conakry. La sabana sudanesa y el bosque guineano conforman un mosaico de parches de bosques, cultivos y pastos como resultado de las actividades humanas [Pacheco 2012, 2013; Pruetz and Bertolani, 2009]. Es una zona con temperaturas extremas de calor y escasa lluvia. En la estación seca las temperaturas superan los 40 grados. El promedio de precipitaciones anuales es menor de 1.000 mm [Pruetz and Bertolani, 2009]. Por tanto, los recursos naturales son escasos.

Figura 2. Mapa de la RNCD en Senegal.

La RNCD fue creada en 2010 por el Consejo Rural de Dindéfélo. Este Consejo es el organismo gestor de la Comunidad Rural de Dindéfélo constituida por 12 poblaciones y 7.000 habitantes. La Reserva está dentro de la Comunidad Rural de Dindéfélo (16.000 hectáreas). La Comunidad Rural de Dindéfélo fue creada en el 2008 por decisión de la población. En el 2009 se celebraron las primeras elecciones democráticas para elegir presidente quien toma las decisiones como relevo de los antiguos jefes del pueblo. El presidente dirige varias comisiones, entre ellas, la de medio ambiente. En dicha comisión hay un Comité de gestión de la RNCD para la conservación de la biodiversidad con especial interés en el chimpancé al estar en peligro crítico de extinción y conseguir una coexistencia sostenible. El Instituto Jane Goodall España (IJGE) en Senegal ayuda en la gestión del Comité de la RNCD con diversos proyectos. Los lugares de estudio en la Reserva fueron: Dindéfélo, Segou, Nandoumary (Diogoma II) y Sabe (República de Guinea) porque son las áreas de investigación y gestión de conservación del IJGE (Figura 3).

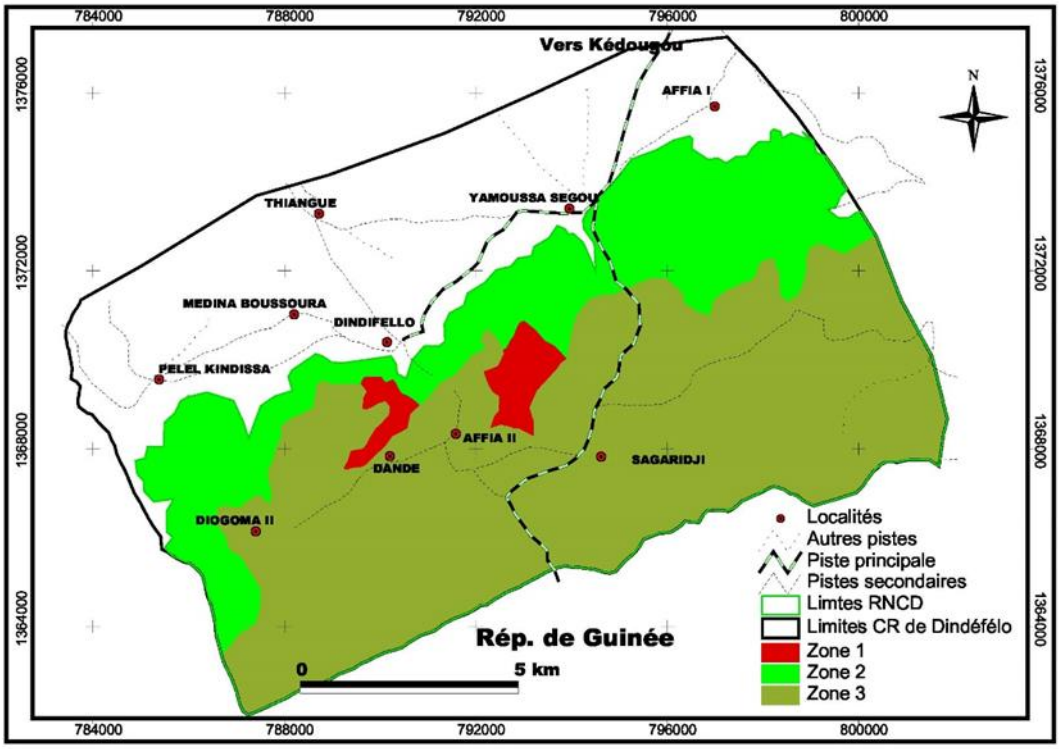

Figura 3. Mapa de la RNCD en la Comunidad Rural de Dindéfélo.

En Senegal, hay actividades antropogénicas tales como la expansión de la agricultura, las minas de oro, la competencia por los frutos del bosque, la transmisión de enfermedades, construcción de presas, la caza furtiva y el comercio ilegal de chimpancés. Como resultado, el conflicto humano-vida silvestre está en aumento [Boyer-Ontl et al., 2014; Humle et al., 2016; Howells et al., 2011]. La RNCD sería un ejemplo de problema de conservación de la biodiversidad, y especialmente de los chimpancés. La población humana en la Reserva ha aumentado en los últimos cinco años: 1.236 habitantes debido principalmente a una alta tasa de natalidad (4,6 hijos de media por mujer) y a un descenso de la mortalidad epidémica y materno-infantil. La familia extendida es un modelo económico de subsistencia. La economía local apenas excede el límite de subsistencia y se basa en la agricultura, la tala y el ganado [Kormos et al., 2003]. En una de las zonas más pobres de Senegal, los locales necesitan los recursos del bosque para sobrevivir [Kormos et al., 2003; Michalski et al., 2005; McLennan, 2008; Pruetz y Bertolani, 2009; Pacheco et al., 2012]. A su vez, los chimpancés están perdiendo su hábitat debido a la acción humana. Cada año grandes extensiones de bosque son incendiadas para abrir campos de cultivo en una tierra pobre. Durante 2010-2011, 42 incendios fueron registrados con un área quemada de

2.552 hectáreas en toda la región de Kédougou. Los incendios son un factor importante de degradación del ecosistema. Esto se debe principalmente a la falta de seguridad y control [Muñoz et al., 2014 *sin publicar*].

De manera que los encuentros entre humanos y chimpancés son muy frecuentes. Hay una competición por recursos naturales. Agua, árboles, frutos hacen coincidir al mismo tiempo y espacio, humanos y chimpancés [Wood et al., 2004; Hockings and Humle, 2009; Hockings and Sousa, 2013; Pacheco et al., 2012]. Estudios previos del IJGE muestran que la población local en 6 de las 10 aldeas de la Reserva parecen tener constantes conflictos con los chimpancés en puntos de agua [Pacheco et al., 2012]. Además, los frutos que comen los chimpancés de marzo a junio solo se encuentran en los bosques de galería. Los chimpancés se ven obligados a estar muy cerca de los humanos, a menos de 30 metros. Esto se ve agravado por un gran aumento del turismo descontrolado para refrescarse en ríos y cascadas. En mayo del año 2015, por ejemplo, 300 turistas llegaron en solo 30 minutos en la Cascada de Dindéfélo *(observación personal).* Otro ejemplo de competencia de recursos naturales es en junio cuando la dieta de los chimpancés es básicamente el fruto del lare *(Saba senegalensis)*. Sin embargo, la población local recolecta toneladas ilegalmente para comerciar en los mercados locales y nacionales [Duvall, 2008; Norconk and Boinski, 2011; Pacheco et al., 2012; Hockings and Sousa, 2013; Pruetz, 2013; Ramón et al, 2017; Waller and Pruetz, 2016]. En 2014, se recolectaron legalmente 25 toneladas de *S. senegalensis* [Muñoz et al., 2014 *sin publicar*]. En definitiva los chimpancés encuentran su hábitat dominado por el hombre y los locales se ven forzados a acudir al bosque por recursos a pesar de tener miedo de encontrarse con los chimpancés.

2. Conservación y percepciones locales

2.1. Introducción

En los últimos años, ha crecido la investigación de las percepciones y actitudes de las poblaciones locales dentro de la conservación de la biodiversidad. En concreto, en la conservación de primates le han denominado etnoprimatología, ciencia que combina la primatología y antropología, el punto de vista de seres humanos y otros primates al convivir en espacios ecológicos, sociales, integrados y compartidos. Este enfoque permite evaluar y comprender con mayor eficacia las ecologías complejas y el potencial para la sostenibilidad en las comunidades de primates humanos y otros [Fuentes, 2012; Hockings et al., 2015].

La investigación y la gestión de la conservación de la biodiversidad necesita estudios sobre las percepciones de la población local para diseñar líneas que potencien la coexistencia sostenible entre los seres humanos y las especies en libertad [Conforti et al., 2003; Campbell-Smith et al., 2010; McLennan and Hill, 2012; Pacheco et al., 2012; Costa et al., 2013; Hockings and Sousa, 2013; Fernández-Llamazares et al., 2016]. Trabajar con la población local es esencial porque tienen un conocimiento específico del área y administran los recursos naturales.

Además, si se conociesen las variables psicológicas podrían facilitar la forma de generar cambios en el comportamiento y hábitos en las personas locales según la teoría de Ellis. Ellis postuló conocer los pensamientos, emociones y comportamientos de las personas para generar cambios de comportamiento y hábitos [Pérez-Acosta, 2008; Costa, 2010; Costa et al., 2013]. El modelo básico de encuadre psicológico clínico se sirve del modelo A-B-C. Tras un acontecimiento o situación (A), se da lugar el desarrollo de creencias (B), a partir de las cuales la persona desarrolla emociones, pensamientos y acciones (C). Las perturbaciones emocionales pueden ser causadas por creencias, valoraciones y demandas inflexibles (exigencias absolutistas) llamadas creencias irracionales que derivarán en emociones y conductas disfuncionales o desadaptativas [Ellis and Abrahms, 2005]. El énfasis de esta teoría está en el cambio profundo en la filosofía de vida de la persona, y no meramente en una remisión de los síntomas. Esto se logra llegando, dentro del modelo A-B-C, al punto D: el debate racional emotivo o diálogo socrático modificado (que es la búsqueda de evidencias y refutación de ideas) enfocado a conseguir un nuevo efecto (punto E) más sano y adaptativo [Caballo, 2008]. De manera que ante una situación como es la conservación de chimpancés (A), si los locales tienen la creencia de respetarlos por miedo a la muerte (B), entonces los locales huirán (C) cuando vean a los chimpancés. El problema es que este miedo a los primates en otra situación como que los chimpancés entren al poblado para comer frutos puede hacer que les disparen (C2). En cambio, al conocer las creencias de los locales se puede proporcionar información y sensibilización hacia los chimpancés (D) para alcanzar una coexistencia pacífica y sostenible (E).

La conservación de la biodiversidad es compleja y requiere un trabajo multidisciplinar donde las ciencias sociales desempeñan un papel importante en la gestión efectiva [Hill et al., 2010; Costa et al., 2013; Hill, 2015; 2017; Webber and Hill, 2014; McLennan, et al., 2017]. Las actividades humanas son una de las principales causas de extinción de los primates en nuestro planeta como se ha comentado anteriormente. Hay un aumento de los conflictos entre humanos y chimpancés. El trabajo de campo etnoprimatológico es eficaz para identificar problemas específicos y encontrar soluciones in situ viables

para la conservación de primates [Torres et al., 2010; Hockings and Sousa, 2013; Hockings et al., 2015; Estrada et al., 2017; Sousa et al., 2017]. Un enfoque biosocial permite comprender las interacciones entre los humanos y la vida silvestre que se traduce en resultados más efectivos para una coexistencia sostenible [Setchell et al., 2017]. En el estudio de percepciones locales en esta tesis hemos seleccionado tres variables (educación, formación medioambiental y creencias tradicionales) que estarían relacionadas con las percepciones locales sobre conservación de chimpancés debido a la gran cantidad de datos recogidos.

2.2. Educación

Algunas investigaciones han encontraron correlaciones positivas entre la educación y las actitudes locales positivas hacia la conservación de especies protegidas [Gadd, 2003; Harcourt et al., 1986] pero otras no [Gadd, 2005] por lo que es necesario realizar más investigaciones. En Senegal la educación es pública. La escuela primaria es de los 6 a 12 años, la siguiente etapa (collègue) de los 13 a los 17 años y la educación secundaria (Lycée) de los 17 a los 19 años. La asistencia a la enseñanza primaria en toda la región de Kedougou fue del 54% en 2009-2010. En un estudio del IJGE en 2014 se contabilizó un total de 4 cases de touts petits, 8 écoles primaires, 2 collèges y 1 Lycée en la Comunidad Rural de Dindéfélo. Dindéfélo tiene todas las infraestructuras educativas, en Segou no hay Lycée y en Nandoumary solo hay ecole primaire. El 16% de la Comunidad Rural eran alumnos. La asistencia a la escuela primaria en Dindéfélo fue del 19,8%, en Segou el 14,5% y en Nandoumary el 17%.

Existen dos collèges para toda la Comunidad Rural. Éstos se encuentran en los pueblos de Dindéfélo y Segou. El 7% del total estaba escolarizado en este nivel de enseñanza. Del total escolarizado, el 35% eran chicas y el 63% chicos. El collègue de Dindéfélo presta servicio a 6 pueblos más.

Existe una mayor tasa de abandono femenina debido a que las mujeres suelen dejar su formación académica al contraer matrimonio o al tener el primer hijo. El número total de profesores es de 17 de los cuales dos son mujeres. La formación de los profesores es la enseñanza superior. Las necesidades manifestadas por el director del collège de Dindéfélo son: falta de agua en abril y mayo y escasez de material didáctico.

El collége de Sègou presta servicio a otras 7 aldeas. La infraestructura no ha sido construida aún, utilizan las aulas del école primaire. El número total de alumnos es de 90 de los cuales el 44,5% son chicas.

Existe solamente un Lycée en todo el territorio de la Comunidad Rural situado en Dindéfélo. Las clases del Lycée se imparten en el edificio del collége. El número de alumnos es de 14 de los cuales 6 son mujeres y 8 son hombres. El número de profesores es de 8, todos ellos hombres, con la enseñanza superior finalizada [Muñoz et al., 2014, *sin publicar*].

En la Reserva es frecuente que los niños no asistan a la escuela debido a que tienen que ayudar en casa con las tareas domésticas o trabajar en los campos de cultivo. En el caso de las aldeas que no tienen escuela, los niños tienen que caminar a pie varios kilómetros para ir a la aldea más cercana con colegio. Varias investigaciones en etnoprimatología han estudiado las relaciones entre variables como el género, la edad, la educación y el nivel económico, entre otros, con la percepción local sobre la conservación [Gadd, 2003, 2005; Harcourt et al., 1986].

2.3. Proyecto de formación medioambiental

La Reserva es una de las zonas más pobres de Senegal y varias ONGs ayudan en sanidad, educación y medio ambiente, entre otros [Kormos et al., 2003]. *Trees for the future* es un proyecto para revitalizar tierras dañadas por la deforestación y lleva unos años trabajando en Segou. Proporcionan semillas de árboles a los agricultores, formación técnica y asistencia de planificación en el sitio. Se han plantado más de 115 millones de árboles en docenas de países del mundo y se han revitalizado cientos de miles de hectáreas de tierra mientras se mejora la vida de las personas locales. En la RNCD, Nandoumary se incorporó al proyecto en 2015, con la ayuda del IJGE, y Dindéfélo aún no participaba. Los locales también aprendían a plantar árboles y los utilizarían como vallas para sus hogares y cultivos. De esta manera disminuiría la tala anual para reparar sus vallados. También se les proporcionaba herramientas y asesoramiento para abrir huertos y cultivos de forma sostenible. En Costa de Marfil han encontrado una correlación positiva entre su formación medioambiental infantil y actitudes locales positivas hacia la conservación de chimpancés [Borchers et al., 2009, 2014]. En esta investigación se estudió si la participación y formación en *Trees for the Future* tendría algún efecto en las percepciones o actitudes locales sobre la conservación de chimpancés en la Reserva.

2.4. Creencias tradicionales

El Islam es, hoy en día, la religión mayoritaria entre la etnia estudiada Peul/Fulbe/Fula/Fulani. África Occidental se islamizó mayoritariamente en el siglo XIX a través de las llamadas Revoluciones Islámicas. La adopción del Islam tuvo éxito porque se adoptó como estrategia y forma de rechazo a la presencia europea. El Islam comenzó a asimilarse por las clases dirigentes, la aristocracia militar y los comerciantes. A través de los comerciantes se propagó la religión. La porosidad característica de las sociedades africanas permitió que el Islam entrara con fuerza y que se asimilara rápido, ya que la conversión aportaba prestigio y no obligaba a romper con la tradición de manera brusca. Se produjeron numerosos sincretismos entre la religión islámica y el animismo originario de los Peul, que en la actualidad se mantienen. La forma de Islam adoptada en Senegal es sunnita con caracteres espirituales sufís [Muñoz et al., 2014, *sin publicar*].

Se entiende como animismo las creencias tradicionales sobre la existencia de espíritus en el bosque, zonas habitadas por el diablo, supersticiones relacionadas con la enfermedad, entre otros. Donde los chimpancés están relacionados con algo malo, mala suerte o incluso la muerte. El grupo étnico local realiza rituales de iniciación para adolescentes o utiliza amuletos de protección. En los hogares también pueden encontrarse objetos de protección de la mala suerte y malos espíritus. Asimismo hacen sacrificios para pedir algo a los espíritus. El marabú es un local experimentado con conocimientos en medicina natural, fabrica amuletos de protección o aconseja ciertos rituales para curar enfermedades o mala suerte. Muchos locales tienen más confianza en el marabú que en los médicos.

En la Reserva, los locales conocen historias sobre el diablo, poderes espirituales y chimpancés. Una de estas historias cuenta que hace mucho tiempo una mujer del pueblo fue al bosque con su bebé y se sentó cerca de la orilla del río. Entonces un chimpancé se acercó y se sentó junto a la mujer. Le cogió el bebé, lo mató, se lo devolvió y se marchó. Otra historia narrada por los Peul es que si caminas por el bosque y encuentras un chimpancé con gesto de amenaza o ataque, cuando llegues a casa, encontrarás a alguien de tu familia muerto. Son creencias sobre la muerte relacionadas con los chimpancés que coinciden con otros países y afectan a la conservación. Cuando las ONGs explican sus programas para ayudar a los chimpancés, muchos lugareños no lo entienden por esta razón [Sousa, 2017]. Recientes estudios han encontrado relaciones entre la religión o las creencias tradicionales con la conservación de biodiversidad. En algunos países africanos consideran ciertas especies como tótem y

los protegen pero en otros lugares los asocian con brujería y los matan [Costa, 2010; Costa et al., 2013; Casanova et al., 2014]. De manera que en esta investigación se consideró interesante tener en cuenta y conocer las creencias tradicionales de los Peul para estudiar si tenía algún efecto sobre la percepción local de la conservación de chimpancés en la Reserva.

2.5. Etnia Peul

Las etnias mayoritarias de la región de Kédougou son los Peul y los Malinké. La etnia Peul es el grupo cultural con mayor presencia en la región de Kédougou [Pruetz y Bertolani, 2009; Pacheco et al., 2012] y el segundo grupo mayoritario en Senegal después de los Wolof. Los Peul son el grupo cultural dominante en toda la Comunidad Rural de Dindéfélo.

Peul, en el idioma pulaar, significa dispersos, esparcidos y en la lengua de los wolof significa de color marrón claro o rojo en oposición a la palabra wolof que significa negro. Parece ser que, como la mayor parte de pueblos del Sahel, los Peul provienen del norte del continente africano. Debido a su gran historia nómada, los Peul han mantenido una lengua, un fondo cultural, tradiciones compartidas y un sentimiento importante de sí mismos.

La sociedad Peul se organiza en linajes o unidades de parentesco por las cuales se transmiten apellidos, herencias u otras formas de propiedad y se establecen alianzas y matrimonios. Los Peul son una sociedad semi-patrilineal, patrilocal, poligínica y endogámica. Son pautas de organización centradas en el varón. El hombre puede casarse con más de una mujer, reconocido por la Constitución senegalesa, con un máximo de cuatro mujeres por hombre. Entre los Peul, la dote consiste en una vaca.

Los peul han sido el pueblo nómada más grande de todo el continente africano. Tradicionalmente se han dedicado a la ganadería trashumante. Es a partir del siglo XIX cuando comienza su sedentarización. La gran mayoría se ha asentado por lo cual la ganadería ha perdido gran parte de su importancia económica pero no su eficacia simbólica. Esta reciente sedenterización explica que muchos de los pueblos de la Reserva tengan solo 100 años de existencia.

Muchos locales en esta zona desconocen las leyes oficiales y se rigen por la tradición local. La economía local apenas excede el límite de subsistencia y se basa en la agricultura, la tala, extracción forestal y el ganado [Kormos et al., 2003; Muñoz et al., 2014, *sin publicar*]. Los Peul son muy hospitalarios y te ofrecen lo poco que tienen. Sin

embargo, su economía de subsistencia les obliga a vivir de los recursos del bosque lo que supone una competición con la vida salvaje [Pruetz and Bertolani, 2009; Pacheco et al., 2012].

3. Conservación e indicadores fisiológicos

Cada vez se están utilizando más indicadores fisiológicos, como el cortisol, para valorar la respuesta de estrés del animal y su bienestar [Manteca et al., 2016]. Algunos estudios de primates han encontrado un aumento en los niveles de estrés ante actividades antropogénicas [Behie et al., 2010; Jaimez et al., 2012; Maréchal et al., 2014; Martínez-Mota et al, 2007; Muehlenbein et al., 2014; Rangel-Negrín et al., 2014; Shutt et al., 2014; Vanlangendonck et al., 2015] pero otras investigaciones no [Aronsen et al., 2015; Hvenegaard et al., 2014; Rimbach et al., 2013; Vanlangendonck et al., 2015]. De manera que es importante realizar investigaciones para averiguar el efecto de las actividades humanas en primates en libertad. Es interesante estudiar el estrés cuando se diseña un programa de conservación porque nos va a permitir conocer el nivel de bienestar de los chimpancés y así poder diseñar líneas específicas para la gestión de la biodiversidad.

3.1. La respuesta de estrés

Hay un debate en el mundo científico sobre la definición de estrés debido a su amplio uso. Cannon podría haber sido el primero en reconocer la función de la adrenalina, la noradrenalina y el sistema nervioso simpático. Él acuñó la frase “respuesta de lucha o huida” que es una forma de concebir la respuesta de estrés como una preparación del organismo para un súbito aumento de la demanda energética [Levine, 2005]. Seyle podría haber sido el primero en descubrir el papel de los glucocorticoides [Clark et al., 1997; Mason, 1975]. En esta tesis nos basamos en la definición de Talló [2016]: *“el estrés podría considerarse una variedad heterogénea de fenómenos que aparecen cuando el animal percibe (siendo real o no) una posible alteración negativa de sus expectativas de vida (genética y adquirida, incluida la supervivencia y el ciclo de vida) y responder a ella cambiando su estado en uno apropiado para enfrentar la amenaza y alcanzar las expectativas nuevamente”*.

Una variable importante en el concepto de estrés es la percepción de cada individuo independientemente de si el estímulo es una amenaza o no realmente [Levine, 2005; Moberg, 2000; Talló, 2016]. En función de estas características específicas del individuo

y el estresor se activan unas respuestas neuroendocrinas pero el más reconocido es el eje hipotálamo-pituitaria-adrenal (HPA) [Carlstead et al., 1993].

El sistema de estrés se encuentra en órganos periféricos y sistema nervioso central (SNC) [Chrousos, 2009; Habib et al., 2001]. En el SNC el eje HPA segrega dos tipos de hormonas: catecolaminas y glucocorticoides. Las catecolaminas a su vez se dividen en epinefrina o adrenalina y norepinefrina o noradrenalina. Los glucocorticoides son el cortisol y la corticosterona. Las catecolaminas están regidas por el SNC y los glucocorticoides por el eje HPA [Charmandari et al., 2005; Romero y Butler, 2007] (Figura 4).

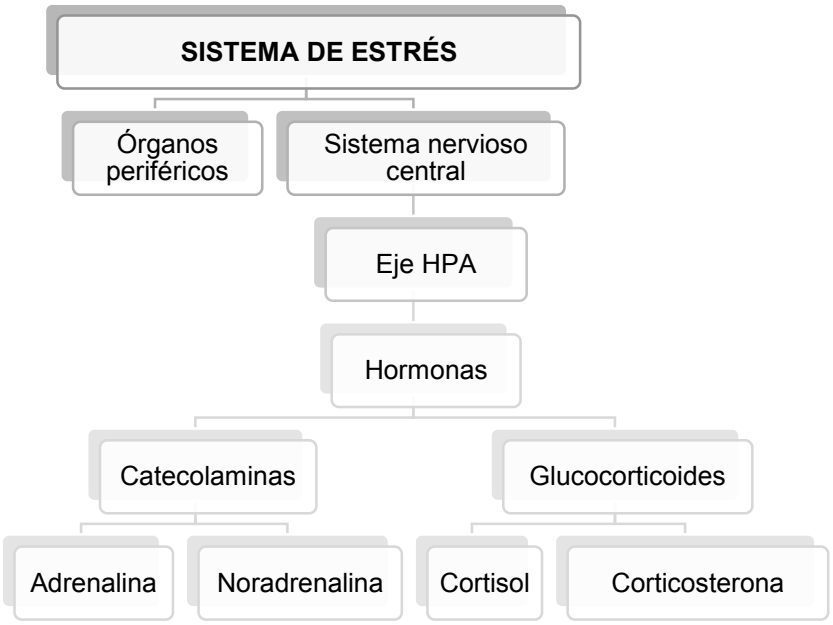

Figura 4. Esquema del sistema de estrés.

Ante un estímulo que pueda provocar estrés en un individuo éste puede luchar o huir de manera que en pocos segundos se activa una cascada neuroendocrinológica y se segrega catecolaminas por la glándula suprarrenal y el sistema nervioso simpático. Esta activación permite al animal reaccionar ante una amenaza aguda pero si persiste la respuesta de estrés, en unos 3 o 5 minutos (en vertebrados) [Sapolsky et al., 2000; Sheriff et al., 2011; Talló, 2016], el eje HPA se activa y se segrega glucocorticoides por la corteza suprarrenal. Este último sistema permite al sujeto recuperarse de la amenaza (Figura 5).

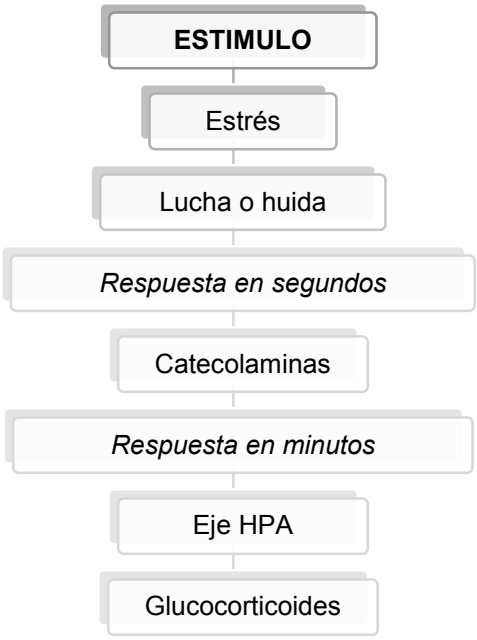

Figura 5. Esquema de respuesta de estrés a corto y largo plazo.

Cuando un animal percibe un estresor, el núcleo paraventricular hipotalámico aumenta los niveles de la hormona liberadora de corticotropina (CRH) y arginina vasopresina (AVP). Estas hormonas estimulan la glándula pituitaria anterior que segrega la hormona adrenocorticotrópica (ACTH) hacia la sangre [Sheriff et al., 2011]. La ACTH estimula la corteza suprarrenal para producir y regular los glucocorticoides [Habib et al., 2001] (Figura 6). Los glucocorticoides podrían ayudar al animal a recuperarse de un estresor y además inhiben las funciones que no son prioritarias [Romero y Butler, 2007].

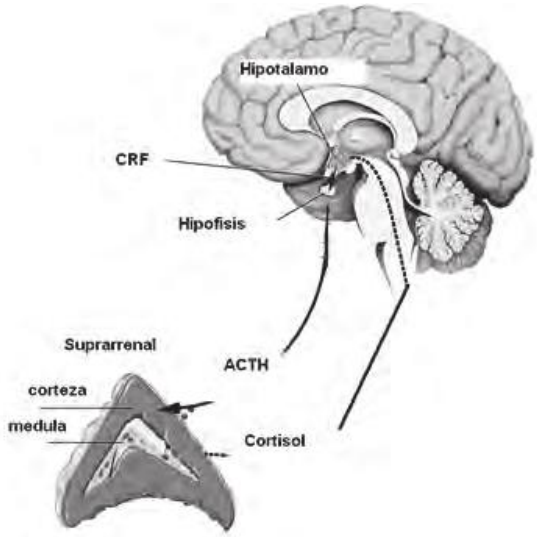

Figura 6. Eje hipotálamo-pituitaria-adrenal [Vales, 2011].

A corto plazo, las secreciones de glucocorticoides han sido relacionadas con respuestas adaptativas de animales a estresores y son consideradas beneficiosas para el organismo (caza, comportamientos sexuales o juego). Sin embargo, a largo plazo, la secreción de glucocorticoides podría llevar a patologías (como, por ejemplo, disrupción reproductiva o endocrina, supresión del sistema inmunológico y úlceras gastrointestinales) [Lane, 2006; Lay, 2010; Keeling and Jensen, 2009] que podrían reducir significativamente la salud, afectando a la supervivencia y éxito reproductivo [Sapolsky, 1992; Möstl and Palme, 2002]. Consecuentemente, los glucocorticoides han sido utilizados como indicadores de estrés en varias especies [Möstl and Palme, 2002].

3.2. Cortisol

En los primates, el cortisol, de la hormona glucocorticoide, se segrega en respuesta a varios factores estresantes para abordarlos a corto plazo. La secreción elevada de cortisol durante períodos prolongados de tiempo disminuye severamente la salud individual debido a una disminución de la respuesta inmune, disfunción multiorgánica, aumento de la infertilidad, reducción del crecimiento y aparición de comportamientos anormales [Rangel-Negrín et al., 2014; Carlitz et al., 2016; Chrousos, 1992, 2009; Arck et al., 2001; Cocks L, 2007; Santos et al., 2000; Möstl and Palme, 2002; Sheriff et al., 2010; Romero et al., 2001]. La cuantificación del cortisol puede llevarse a cabo en diferentes muestras, incluyendo plasma, saliva, orina y heces [Cocks, 2007]. En esta

tesis hemos utilizado el cortisol fecal debido a sus ventajas como método no invasivo, fácil recolección, respuesta de estrés de los animales en pocas horas y más de un día.

3.3. Cortisol fecal

En algunas investigaciones, los metabolitos de cortisol fecal (MCF) se han estudiado como un biomarcador no invasivo de la gravedad de los impactos antropogénicos en los primates [Carlitz et al., 2016; Maréchal et al., 2011; Rimbach et al., 2013; Shutt et al., 2014]. Las heces son fáciles de recolectar y no se molesta a los animales. Las MCF reflejan fielmente los niveles de cortisol libre en la sangre [Sheriff et al., 2010]. Las concentraciones de metabolitos de cortisol que se encuentran en las heces presentan una duración de unas pocas horas y más de un día [Palme et al. 1999; Möstl y Palme 2002]. La concentración de glucocorticoides en las heces podría ser una mejor estimación de la producción de glucocorticoides que el plasma, donde las concentraciones de cortisol cambian rápidamente [Möstl and Palme 2002].

Hay estudios que han encontrado un aumento en los niveles de estrés frente a la exposición al turismo [Romero and Wikelski, 2001; Behie et al., 2010]. Los altos niveles de estrés debido al turismo pueden afectar negativamente a la salud animal, el éxito reproductivo, la supervivencia [Romero y Wikelski, 2001; French et al., 2010], e incluso disminución de la población [Charbonnel et al., 2008]. Investigaciones recientes han encontrado cambios en los niveles de cortisol frente a perturbaciones antropogénicas como contaminación, exposición a humanos, falta de protección de áreas naturales y fragmentación de hábitats [Carlitz et al., 2016; Rangel-Negrín et al., 2014].

3.4. Hormona tiroidea T3.

Cuando se estudia estrés se pueden utilizar otras hormonas a parte del cortisol como la hormona tiroidea (T3). Los metabolitos de cortisol fecal (MCF) y T3 se utilizan para valorar el estrés de perturbaciones y nutrición. Estos dos sistemas endocrinos trabajan en colaboración para regular la disponibilidad y utilización de energía para satisfacer las demandas nutricionales, de crecimiento y termorreguladoras [Wunderink et al., 2012]. Los MCF aumentan rápidamente en respuesta a la mala nutrición, la temperatura fría y perturbaciones, se moviliza la glucosa para proporcionar energía para hacer frente a la emergencia inmediata [Sapolsky et al., 2000; Stetz et al., 2013]. Los MCF de estrés nutricional disminuirían cuando hay una alta disponibilidad de alimento mientras que

aumentarían cuando las actividades antropogénicas alcanzan sus cuotas máximas [Wasser et al., 2017].

La hormona tiroidea (*triyodotironina*, T3), por otro lado, produce una respuesta más conservadora al estrés nutricional y térmico, funciona ajustando el metabolismo. Cuando la escasez de alimentos se encuentra por primera vez, los niveles de T3 cambian lentamente lo que permite que el cuerpo utilice todo el combustible disponible para buscar alimentos. Si persisten las malas condiciones alimentarias, T3 declina bruscamente, disminuyendo el metabolismo para evitar que el cuerpo agote sus reservas de combustible restantes [Douyon and Schteingart, 2002; du Dot et al., 2009; Lee et al., 2014; Wasser et al., 2010]. T3 también puede ser almacenada ante una buena disponibilidad de alimentos cuando se necesita un metabolismo bajo para aumentar el crecimiento (por ejemplo, para acumular reservas de grasa en otoño) [Bianco and Kim, 2006]. T3 es relativamente insensible a la perturbación del estrés [Geris et al., 1999; Kitaysky et al., 2005; Schew et al., 1996; Walpita et al., 2007].

Las medidas de la hormona tiroidea también pueden proporcionar un índice valioso de los impactos del cambio climático entre la vida silvestre. La hormona tiroidea ajusta el equilibrio térmico para mantener una temperatura corporal constante cuando está fuera de su zona termal neutral. Las hormonas tiroideas disminuyen cuando las temperaturas suben por encima la zona termal neutral de la especie y aumenta cuando las temperaturas caen debajo de ésta [Silva, 2003, 2006].

Las hormonas tiroideas regulan la energía y proporcionan un índice de la tasa de metabolismo basal [Chastel et al., 2003; Hulbert and Else, 2013]. Los estudios muestran que la variación en la tasa de metabolismo basal debido al clima [Silva, 2006], la nutrición [Eales, 1988] y la reproducción [Chastel et al., 2003] están asociadas a la variación de niveles plasmáticos de T3. Métodos no invasivos recientemente desarrollados para evaluar T3 de muestras fecales proporcionan una herramienta poderosa para explorar la flexibilidad metabólica entre animales en su entorno natural [Wasser et al., 2010], lo que permite mediciones repetidas de las mismos individuos, sin la necesidad de captura [Cristóbal-Azkarate et al., 2016].

4. Conservación e indicadores conductuales

4.1. Presupuesto de actividad

Los indicadores conductuales son importantes para conocer el bienestar de los animales. La observación de cambios de comportamiento incluyen la aparición de

conductas anormales y alteraciones en la frecuencia, duración o intensidad de las conductas normales [Manteca et al., 2016]. Cambios en la alimentación, juego, maternidad, vigilancia, agresividad o afiliación pueden ser indicadores de un bienestar pobre. Algunos comportamientos de agresividad surgen cuando los recursos son limitados (comida, agua, espacio) [Nelson, 1995]. Con las conductas afiliativas se libera oxitocina [Neumann, 2008] y se reduce el estrés [Amico et al., 2004; Neumann et al., 2000]. Estos comportamientos sociales son indicadores positivos de bienestar [Boissy et al., 2007] porque también contribuyen a la cohesión social y reducen la tensión en grupos de animales [Wittig et al., 2016].

Nosotros hemos seleccionado en esta tesis el presupuesto de actividad y respuestas de huida como algunos de los indicadores conductuales de bienestar de los chimpancés en la Reserva. Los primeros son indicadores conductuales de necesidades básicas como la alimentación, desplazamiento, descanso, acicalamiento, juego y cuidado parental. Las respuestas de huida están relacionadas con el estrés como se ha explicado anteriormente y nos hemos basado en las categorías de McLennan y Hill [2012]: ignorar, monitorear, retirada, amenaza, huida y esconderse. También consideramos interesante estudiar la relación dichas conductas y metabolitos de cortisol fecal.

Para investigar de forma más concreta el impacto de las actividades antropogénicas en la conservación de primates en libertad se han realizado estudios sobre el presupuesto de actividad [Carlitz, 2016; Martínez-Mota et al., 2007; Rangel-Negrín, 2014]. Estos presupuestos de actividad son un indicador de si los animales se pueden adaptar a condiciones adversas porque actividades como el desplazamiento puede aumentar en bosques fragmentados asociado a una falta de recursos (alimentos) [Carlitz et al., 2016; Martínez-Mota et al., 2007]. Al sur de Senegal, los chimpancés muestran un conjunto de conductas características y adaptadas a ciertos estresores de calor, falta de agua y entornos abiertos de sabana. De manera que en Fongoli se ha encontrado que los chimpancés minimizan el gasto de energía en los meses más calurosos. Asimismo en los momentos más calurosos del día estos primates descansan más, viajan menos y seleccionan los bosques de galería. Se mueven más en horas tempranas del día que son más frescas hacia los puntos con limitada disponibilidad de recursos (agua y alimento). En la estación seca los chimpancés se relacionan en grupos más pequeños comparado con la época de lluvias [Pruetz and Bertolani, 2009]. El presupuesto de actividad que encontró Pruetz fue de: descanso-63%, alimentación-25%, desplazamiento-12%. De manera que es interesante tener en cuenta el presupuesto de actividad de los chimpancés (descanso, desplazamiento, alimentación, conductas

sociales y tamaño de grupo) para comparar los diferentes impactos antropogénicos en las zonas de estudio de la Reserva.

Otros autores han encontrado que aumenta la conducta de viajar en primates ante la falta de disponibilidad de alimento por fragmentación de hábitat y que a su vez tiene relaciones con incrementos de glucocorticoides fecales [Martínez-Mota et al., 2007]. Sin embargo, Kulp and Heinmann con similar presupuesto de actividad concluyeron que los bosques secundarios no eran el problema [Kulp and Heinmann, 2015]. Carlitz encontró un elevado porcentaje de alimentación del resto del presupuesto de actividad (alimentación—47%, descanso—34%, desplazamientos—11%, acicalamiento de uno a otro—3% o acicalamiento a sí mismo—2%, beber—1%, jugar—1%, agresión dentro del grupo~0.4%) en chimpancés donde la alimentación era en cultivos de azúcar y había conflictos entre humanos y chimpancés por la alimentación en campos de cultivo. Esto también estaba asociado con incrementos de niveles de cortisol [Carlitz et al., 2016].

4.2. Huida

Otra medida conductual para estudiar estrés en chimpancés en libertad es la huida [McLennan and Hill, 2012]. El cortisol predispone al animal a la huida o la agresividad. La huida es la respuesta predominante en poblaciones de primates que han vivido la caza [Bertolani and Boesch, 2008] o viven en bosques tropicales de baja visibilidad [Tutin and Fernández, 1991]. Cuando los chimpancés no tienen experiencia previa con humanos, hay estudios que han encontrado respuestas de curiosidad ante la presencia humana [Morgan and Sanz, 2003]. En cambio, en lugares con un aumento de la población humana, los chimpancés están habituados y normalmente los ignoran o a veces pueden mostrar cargas de agresividad hacia humanos [Grieser, 1996]. La habituación de grandes simios en África es definida como la aceptación por parte de animales salvajes a observadores humanos como elemento neutral en su entorno [Tutin and Fernández, 1991] a lo largo de varios años sin utilizar comida [Bertolani and Boesch, 2008].

5. Referencias

Amico JA, Mantella RC, Vollmer RR and Li X. Anxiety and Stress Responses in Female Oxytocin Deficient Mice. Journal of Neuroendocrinology. 2004. 16: 319–324.

Arck PC, Rose M, Hertwig K, Hagen E, Hildebrandt M, Klapp BF. Stress and immune mediators in miscarriage. Hum Reprod. 2001; Jan 7; 16(7):1505–11. PMID: 11425839.

Aronsen GP, Beuerlein MM, Watts DP, Bribiescas RG. Redtail and red colobus monkeys show intersite urinary cortisol concentration variation in Kibale National Park, Uganda. Conserv Physiol. 2015; 3(1): cov006.

Behie AM, Pavelka MS, Chapman CA. Sources of variation in fecal cortisol levels in howler monkeys in Belize. Am J Primatol. 2010; 72(7):600–6. doi: 10.1002/ajp.20813 PMID: 20166191.

Bertolani P, Boesch C. Habituation of wild chimpanzees *(Pan troglodytes)* of the South Group at Taı¨ Forest, Côte d'Ivoire: empirical measure of progress. Folia Primatologica. 2008; 79:162–171.

Bianco AC, Kim BW. Deiodinases: implications of the local control of thyroid hormone action. J. Clin. Invest. 2006; 116: 2571±2579. https://doi.org/10.1172/JCI29812 PMID: 17016550.

Bishop N, Hrdy SB, Teas J, Moore J. Measures of human influence in habitats of South Asian monkeys. International Journal of Primatology. 1981; 2:153-167. doi:10.1007/BF02693446.

Boissy A, Manteuffel G, Jensen MB, Moe RO, Spruijt B, Keeling LJ, Winckler C, Forkman B, Dimitrov I, Langbein J, Bakken M, Veissier I and Aubert A. Assessment of positive emotions in animals to improve their welfare. Physiology and Behavior. 2007. 92: 375-397

Boyer-Ontl KM & Pruetz JD. Giving the Forest Eyes: The Benefits of Using Camera Traps to Study Unhabituated Chimpanzees (*Pan troglodytes verus)* in Southeastern Senegal. Int J Primatol. 2014; 35:881–894. DOI 10.1007/s10764-014-9783-3.

Borchers C, Boesch C, Riedel J, Guilahoux H, Ouattara D, Randler C. Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows

Positive Impact on Environmental Knowledge and Attitudes. Int. J. Sci. Educ. 2014; Part B 4: 240–259. DOI:10.1080/21548455.2013.803632.

Borchers C, Riedel J, Boesch C and Breuer T. Deux programmes d'éducation environnementale pour la conservation des grands singes africains: Club Ebobo et Club P.A.N. », Revue de primatologie [En ligne], 1 | 2009, document 8, mis en ligne le 09 octobre 2009. URL: http://primatologie.revues.org/397.

Caballo VE. Manual de técnicas de terapia y modificación de conducta. Madrid: Siglo XXI. 2008.

Campbell-Smith G, Simanjorang HVP, Leader-Williams N, Linkie M. Local attitudes and perceptions toward crop-raiding by orangutans *(Pongo abelii)* and other nonhuman primates in Northern Sumatra, Indonesia. Am. J. Primatol. 2010; 72: 866–876. DOI:10.1002/ajp.20822.

Carlitz EHD, Miller R, Kirschbaum C, Gao W, Hänni DC, van Schaik CP. Measuring Hair Cortisol Concentrations to Assess the Effect of Anthropogenic Impacts on Wild Chimpanzees *(Pan troglodytes).* PLoS ONE. 2016; 11(4): e0151870. doi:10.1371/journal.pone.0151870.

Carlstead K, Brown J.L, Strawn W. Behavioral and physiological correlates of stress in laboratory cats. Appl. Anim. Behav. Sci. 1993; 38, 143–158. Doi:10.1016/0168-1591(93)90062-T.

Chastel O, Lacroix A, Kersten M. Prebreeding energy requirements: thyroid hormone, metabolism and the timing of reproduction in house sparrows Passer domesticus. J. Avian Biol. 2003; 34, 298–306. doi:10.1034/j.1600-048X.2003.02528.x.

Charbonnel N, Chaval Y, Berthier K. Stress and demographic decline: a potential effect mediated by impairment of reproduction and immune function in fluctuating vole populations. Physiol. Biochem Zool. 2008; 81, 63–73.

Charmandari E, Tsigos C, Chrousos G. Endocrinology of the stress response. Annu. Rev. Physiol. 2005; 67, 259–84. doi:10.1146/annurev.physiol.67.040403.120816.

Chrousos GP. Stress and disorders of the stress system. Nat Rev Endocrinol. 2009 Jul; 5(7):374–81.doi: 10.1038/nrendo.2009.106 PMID: 19488073.

Chrousos GP, Gold P. The concepts of stress and stress system disorders: Overview of physical and behavioral homeostasis. JAMA. 1992 Mar 4; 267(9):1244–52. PMID: 1538563.

Casanova C, Sousa C and Costa S. Are animals and forests forever? Perceptions of wildlife at Cantanhez Forest National Park, Guinea-Bissau Republic, Memórias Environmental Anthropology. 2014; 16:69-104.

Clark JD, Rager DR, Calpin JP. Special Topic Overview Animal Well-Being II. Stress and Distress. Lab. Anim. Sci. 1997; 47, 571–579.

Cocks L. Factors Affecting Mortality, Fertility, and Well-being in Relation to Species Differences in Captive Orangutans. Int J Primatol. 2007 Apr 1; 28(2):421–8.

Cooke SJ, Blumstein DT, Buchholz R, Caro T, Fernández-Juricic E, Franklin CE, Metcalfe J, O'Connor CM, St. Clair CC, Sutherland WJ, Wikelski M. Physiology, Behavior, and Conservation. Physiol. Biochem. Zool. 2014; 87, 1–14. doi:10.1086/671165.

Conforti VA, Azevedo FC. Local perceptions of jaguars *(Panthera onca)* and pumas *(Puma concolor)* in the Iguacu National Park area, south Brazil. Biological Conservation 2003; 111: 215–221. DOI:10.1016/S0006-3207(02)00277-X.

Costa S. Social perceptions of Nonhumans in Tombali (Guinea-Bissau, West Africa): a contribution to chimpazee *(Pan troglodytes verus)* conservation. Thesis. 2010. University of Stirling.

Costa S, Casanova C, Sousa C, Lee P. The Good, The Bad and The Ugly: Perceptions of Wildlife In Tombali (Guinea-Bissau, West Africa). J. Primatol. 2013; 2:1. DOI:http://dx.doi.org/10.4172/2167-6801.1000110.

Creel S. Social dominance and stress hormones. Trends in Ecology and Evolution. 2001; 16:491–497.

Creel S. Dominance, aggression, and glucocorticoid levels in social carnivores. Journal of Mammalogy. 2005; 86 (2): 255-264.

Douyon L, Schteingart DE. Effect of obesity and starvation on thyroid hormone, growth hormone, and cortisol secretion. Endocrinol. Metab. Clin. 2002; 31, 173-89.

du Dot TJ, Rosen DAS, Trites AW. Energy reallocation during and after nutritional stress in Steller sea lions: low quality diet reduces capacity for physiological adjustments. Physiol. Biochem. Zool. 2009; 82: 516-530. https://doi.org/10.1086/603637 PMID: 19637969.

Duvall CS. Human settlement ecology and chimpanzee habitat selection in Mali. Landsc. Ecol. 2008; 23: 699–716. DOI:10.1007/s10980-008-9231-x.

Eales J. The influence of nutritional state on thyroid function in various vertebrates. Am. Zool. 1988; 28, 351–362. doi:10.1093/icb/28.2.351.

Ellis Albert, Abrahms, Eliot. Terapia racional emotiva. 2005. México: Editorial Pax.

Estrada A. Human Population Growth, Poverty. In The International Encyclopedia of Primatology. 2017; 1–6. ISBN.

Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E, Di Fiore A, Nekaris K, Nijman V, Heymann EW, Lambert JE, Rovero F, Barelli C, Setchell JM, Gillespie TR, Mittermeier RA, Arregoitia LV, de Guinea M, Dobrovolski SR, Shanee S, Shanee N, Boyle SA, Fuentes A, MacKinnon KC, Amato KR, Meyer ALS, Wich S, Sussman RW, Pan R, Kone I, Li B. Impending extinction crisis of the world's primates: Why primates matter. Sci. Adv. 2017; 3.

Fernández-Llamazares Á, Gueze M, Cabeza M, Reyes-García V. Local perceptions as a guide for the sustainable management of natural resources: Empirical evidence from a small-scale society in Bolivian Amazonia. Ecol. Soc. 2016; 21. DOI:10.5751/ES-08092-210102.

Fuentes A. Ethnoprimatology and the Anthropology of the Human-Primate Interface. Annual Review of Anthropology. 2012. 41(1):101-117. DOI10.1146/annurev-anthro-092611-145808.

Gadd M. Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environmental Conservation. 2005; 32(1): 50-63.

Gadd ME. Elephant ecology and conservation in African rangelands. Ph.D. dissertation, University of California at Davis, CA, USA: 2003; 166.

Geris, K.L., Berghman, L.R., Kuhn, E.R., Darras, V.M. The drop in plasma thyrotropin concentrations in fasted chickens is caused by an action at the level of the hypothalamus: role of corticosterone. Domestic Animal Endocrinology. 1999; 16, 231–237.

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJA, Laurance WF, Lovejoy TE, Sodhi NS. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature. 2011; 478: 378–381.

Habib KE, Gold PW, Chrousos GP. 2001. Neuroendocrinology of stress, in: Neuroendocrinology. 2001; pp. 695–728. doi:10.1007/978-0-387-30405-2_14.

Harcourt AH, Pennington H & Weber AW. Public attitudes to wildlife and conservation in the Third World. Oryx. 1986; 20: 152–154.

Hill CM. Perspectives of “Conflict” at the Wildlife–Agriculture Boundary: 10 Years On. Human Dimensions of Wildlife: An International Journal. 2015. DOI:10.1080/10871209.2015.1004143.

Hill CM. Primate Crop Feeding Behavior, Crop Protection, and Conservation. International Journal of Primatology. 2017. DOI 10.1007/s10764-017-9951-3.

Hill CM, Webber AD. Perceptions of nonhuman primates in human-wildlife conflict scenarios. Am. J. Primatol. 2010; 72: 919–924. DOI:10.1002/ajp.20845.

Hockings K and Humle T. Best Practice Guidelines for the Prevention and Mitigation of Conflict Between Humans and Great Apes, Survival. IUCN/SSC, 2009 Primate Specialist Group. DOI:10.2305/IUCN.CH.2009.SSC-OP.37.en.

Hockings KJ and Sousa C. Human-Chimpanzee Sympatry and Interactions in Cantanhez National Park, Guinea-Bissau: Current Research and Future Directions. Primate Conservation. 2013; 26(1):57-65. DOI: http://dx.doi.org/10.1896/052.026.0104.

Hockings KJ, McLennan MR, Carvalho S, Ancrenaz M, Bobe R, Byrne RW, Dunbar RIM, Matsuzawa T, McGrew WC, Williamson EA, Wilson ML, Wood B, Wrangham RW and Hill CM. Apes in the Anthropocene: flexibility and survival. Trends in Ecology & Evolution. 2015. DOI: 10.1016/j.tree.2015.02.002.

Howells ME, Pruetz J and Gillespie TR. Patterns of Gastro-Intestinal Parasites and Commensals as an Index of Population and Ecosystem Health: The Case of Sympatric Western Chimpanzees *(Pan troglodytes verus)* and Guinea Baboons *(Papio hamadryas papio)* at Fongoli, Senegal. American Journal of Primatology. 2011; 73:173–179.

Hulbert AJ, Else PL. Basal metabolic rate: history, composition, regulation, and usefulness. Physiol. Biochem. Zool. 2013; 77, 869–876. doi:10.1086/ 422768.

Humle T, Boesch C, Campbell G, Junker J, Koops K, Kuehl H & Sop T. *Pan troglodytes ssp. Verus.* The IUCN Red List of Threatened Species 2016: e.T15935A102327574. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T15935A17989872.en. Downloaded on 02 May 2018.

Humle T, Maisels F, Oates JF, Plumptre A & Williamson EA. *Pan troglodytes*. The IUCN Red List of Threatened Species 2016: e.T15933A102326672. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T15933A17964454.en. Downloaded on 02 May 2018.

Hvenegaard GT. Economic aspects of primate tourism associated with primate conservation. In: Primate Tourism: A Tool for Conservation? Cambridge: Cambridge University Press; 2014. p. 259–77.

Jaimez NA, Bribiescas RG, Aronsen GP, Anestis SA, Watts DP. Urinary cortisol levels of gray-cheeked mangabeys are higher in disturbed compared to undisturbed forest areas in Kibale National Park, Uganda. Animal Conservation. 2011; 15(3):242-247. doi: 10.1111/j.1469-1795.2011.00508.x.

Keeling L and Jensen P. Abnormal Behaviour, Stress and Welfare. In: Jensen P (ed). The Ethology of Domestic Animals: An Introductory Text, 2nd edition. 2009; CAB International, Wallingford (UK), pp. 85-101.

Kitaysky, A.S., Romano, M.D., Piatt, J.F., Wingfield, J.C., Kikuchi, M. The adrenocortical response of tufted puffin chicks to nutritional deficits. Hormones and Behavior. 2005; 47, 606–619.

Kormos R, Boesch C, Bakar MI and Butynski T. West African Chimpanzees. Status Survey and Conservation Action Plan. 2003 IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 219.

Kulp J, Heymann EW. Ranging, activity budget, and diet composition of red titi monkeys *(Callicebus cupreus)* in primary forest and forest edge. Primates. 2015; 1–6.

Lane J. Can non-invasive glucocorticoid measures be used as reliable indicators of stress in animals? Animal Welfare 2006; 15: 331-342.

Lawton J. and May R. Extinction rates. Oxford University Press, UK. 1994.

Lay DCJ. Stress. In: Mills DS (ed). The Encyclopedia of Applied Animal Behaviour and Welfare. 2010. CAB International, Wallingford (UK), pp. 582-584.

Lee D, Martinez B, Crocker D, Oritz R. Thyroid hormone changes associated with prolonged food deprivation in adult male northern elephant seals. The FASEB Journal. 2014; 28: Supplement 1101.6.

Levine S. Stress: an historical perspective, in: Steckler T, Kalin NH, Reul JMHM. (Eds.), Handbook of Stress and the Brain. Elsevier B.V., 2005; pp. 3–23.

Manteca X, Amat M, Salas M and Temple D. Animal-based indicators to assess welfare in zoo animals. CAB Reviews. 2016; 11, No. 010.

Maréchal L, Semple S, Majolo B, Qarro M, Heistermann M, MacLarnon A. Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques. Biol Conserv. 2011 Sep; 144(9):2188– 93.

Martínez-Mota R, Valdespino C, Sánchez-Ramos MA, Serio-Silva JC. Effects of forest fragmentation on the physiological stress response of black howler monkeys. Anim Conserv. 2007; 10(3):374–9.

Mason JW. A historical view of the stress field (Part I). J. Human Stress. 1975; 1, 6–12. doi:10.1080/0097840X.1975.9940405.

McLennan MR. Beleaguered Chimpanzees in the Agricultural District of Hoima, Western Uganda. Primate Conserv. 2008; 23: 45–54. DOI:10.1896/052.023.0105.

McLennan MR, Hill CM. Troublesome neighbours: Changing attitudes towards chimpanzees *(Pan troglodytes)* in a human-dominated landscape in Uganda. J. Nat. Conserv. 2012; 20: 219–227. DOI:10.1016/j.jnc.2012.03.002.

McLennan MR, Spagnoletti N and Hockings KJ. The Implications of Primate Behavioral Flexibility for Sustainable Human Primate Coexistence in Anthroponcenic Habitats. IntJPrimatol. 2017; 38:105–121. DOI10.1007/s10764-017-9962-0.

Michalski F, Peres CA. Anthropogenic determinants of primate and carnivore local extinctions in a fragmented forest landscape of southern Amazonia. Biol. Conserv. 2005; 124: 383–396. DOI:10.1016/j.biocon.2005.01.045.

Moberg, G. Biological response to stress: implications for animal welfare, in: Moberg, G.P., Mench, J.A. (Eds.), The Biology of Animal Stress: Basic Principles and Implications for Animal Welfare. CABI, Wallingford, Oxon, 2000; pp. 1–21.

Möstl E and Palme R. Hormones as indicators of stress. Domestic Animal Endocrinology 2002; 23: 67-74.

Muehlenbein MP, Wallis J. Considering risks of pathogen transmission associated with primate-based tourism. In: Primate Tourism: A Tool for Conservation? Cambridge; New York: Cambridge University Press; 2014. p. 278–87.

Muñoz P, Diallo B and Rodriguez X. Estudio socio-económico de Comunidad Rural de Dindefelo. Región de Kédougou-Senegal. Instituto Jane Goodall España 2014, *sin publicar.*

Nelson RJ. Aggression and Social Behaviour. In: Nelson RJ (ed). An Introduction to Behavioural Endocrinology. 1995. Sinauer Associates, Inc. Publishers, Sunderland (USA), pp. 443-484.

Neumann ID. Brain Oxytocin: A Key Regulator of Emotional and Social Behaviours in Both Females and Males. Journal of Neuroendocrinology. 2008. 20: 858-865.

Neumann ID, Wigger A, Torner L, Holsboer F and Landgraf R. Brain oxytocin inhibits basal and stress-induced activity of the hypothalamo-pituitary-adrenal axis in male and female rats: partial action within the paraventricular nucleus. Journal of Neuroendocrinology. 2000. 12: 235–243.

Norconk MA, Boinski S, Forget PM. Primates in 21st century ecosystems: Does primate conservation promote ecosystem conservation? Am. J. Primatol. 2011; 73: 3–8.

Núñez I, Gonzalez-Gaudiano EJ, Barahona A. La biodiversidad: historia y contexto de un concepto. Interciencia. 2003; 28(7):387-393.

Pacheco L, Azua NR, Fernández-García JM, Aransay N, Guallar F, Gaubert P. First record of Johnston's Genet Genetta johnstoni in Senegal. Small Carnivore Conservation. 2013; 48: 89–91.

Pacheco L, Fraixedas S, Fernández-Llamazares Á, Estela N, Mominee R, Guallar F. Perspectives on sustainable resource conservation in community nature reserves: A case study from Senegal. Sustainability. 2012; 4: 3158–3179. DOI: 10.3390/su4113158.

Palme R, Robia Ch, Messmann S, Hofer J and Möstl E. Measurement of faecal cortisol metabolites in ruminants: a non-invasive parameter of adrenocortical function. Wiener Tierärztliche Monatsschrift 1999; 86: 237-241.

Pérez-Acosta AM, Sánchez AR, Vargas MC. Albert Ellis (1913-2007): Pionero de los modelos mediacionales de intervención. Behavioral Psychology. 2008; 16: 2: 341–348.

Pruetz JD. Studying Apes in a Human Landscape. In: Primate Ethnographies. K. Strier, Ed. Pearson Publishers. 2013. ISBN.

Pruetz J, Bertolani P. Chimpanzee *(Pan troglodytes verus)* Behavioral Responses to Stresses Associated with Living in a Savannah-Mosaic Environment: Implications for Hominin Adaptations to Open Habitats. PaleoAnthropology. 2009; 252–262. DOI:10.4207/PA.2009.ART33.

Ramón M, Llana M, Estela N, Pacheco L, Hockings K, Hill C. The fruit of discord? *Saba senegalensis* use by chimpanzees and local people in Senegal. Poster. 7th European

Federation for Primatology Meeting. 21-25 August 2017. University of Strasbourg, France.

Rangel-Negrín A, Coyohua-Fuentes A, Chavira R, Canales-Espinosa D, Dias PAD. Primates living outside protected habitats are more stressed: The case of black howler monkeys in the Yucatán Peninsula. PLoS ONE. 2014; Nov 6; 9(11):e112329. doi: 10.1371/journal.pone.0112329 PMID: 25375243.

Rimbach R, Link A, Heistermann M, Gómez-Posada C, Galvis N, Heymann EW. Effects of logging, hunting, and forest fragment size on physiological stress levels of two sympatric ateline primates in Colombia. Conserv Physiol. 2013; 1(1):cot031.

Romero LM, Butler LK. Endocrinology of Stress. Int. J. Comp. Psychol. 2007; 20, 89–95.

Romero LM, Wikelski M. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. P.N.S.A. 2001; 13, 7366–7370.

Sapolsky R. Neuroendocrinology of the stress response, in: Becker JB, Breedlove SM, Crews D. (Eds.). Behavioral Endocrinology, MIT Press, Cambridge, 1992, pp. 287–324.

Sapolsky RM, Romero LM and Munk A. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews 2000; 21:55–89.

Schew WA, McNabb FMA, Scanes CG. Comparison of the ontonogenesis of thyroid hormones, growth hormone, and insulin-like growth factor-I in ad libitum and food-restricted (altricial) European starlings and (precocial) Japanese quail. General and Comparative Endocrinology. 1996; 101, 304– 316.

Setchell JM, Fairet E, Shutt K, Waters S, Bell S. Biosocial Conservation: Integrating Biological and Ethnographic Methods to Study Human–Primate Interactions. Int J Primatol. 2017; 38:401–426. DOI 10.1007/s10764-016-9938-5.

Stetz J, Hunt K, Kendall KC, Wasser SK. Effects of exposure, diet, and thermoregulation on fecal glucocorticoid measures in wild bears. PLoS One. 2013; 8: e55967. https://doi.org/10.1371/journal.pone. 0055967 PMID: 23457488.

Sheriff MJ, Dantzer B, Delehanty B, Palme R, Boonstra R. Measuring stress in wildlife: techniques for quantifying glucocorticoids. Oecologia. 2011; 166, 869–87. doi:10.1007/s00442-011-1943-y.

Sheriff MJ, Krebs CJ, Boonstra R. Assessing stress in animal populations: Do fecal and plasma glucocorticoids tell the same story? Gen. Comp. Endocrinol.2010; 166, 614–619.

Silva, J.E. The thermogenic effect of thyroid hormone and its clinical implications. Annals in Internal Medicine. 2003; 139, 205–213.

Silva, J.E. Thermogenic mechanisms and their hormonal regulation. Physiologcial Reviews. 2006; 86, 435–464.

Shutt K, Heistermann M, Kasim A, Todd A, Kalousova B, Profosouva I, et al. Effects of habituation, research and ecotourism on faecal glucocorticoid metabolites in wild western lowland gorillas: Implications for conservation management. Biol Conserv. 2014; 172:72–9.

Sousa J, Ainslie A, Hill CM. Sorcery and nature conservation. Environmental Conservation. 2017; 1-6. DOI: 10.1017/S0376892917000327.

Talló O. Hair cortisol in cattle as a measure of long-term adrenal activity. PhD Thesis. 2016. Universitat Autònoma de Barcelona.

Thomas JA, Telfer MG, Roy DB, Preston CD, Greenwood JJ, Asher J, Fox R, Clarke RT, Lawton JH. Comparative losses of British butterflies, birds, and plants and the global extinction crisis. Science. 2004; 303: 1879–1881. DOI:10.1126/science.1095046.

Torres J, Brito JC, Vasconcelos MJ, Catarino L, Gonçalves J, Honrado J. Ensemble models of habitat suitability relate chimpanzee *(Pan troglodytes)* conservation to forest and landscape dynamics in Western Africa. Biological Conservation. 2010; 143: 416–425.

Tutin CEG, Fernandez M. Responses of wild chimpanzees and gorillas to the arrival of primatologists: behavior observed during habituation. In: Box HO, editor. Primate responses to environmental change. London: Chapman & Hall. P. 1991; 187–197.

Vales I. Psicobiología del estrés. En: Manual de bases biológicas del comportamiento humano. 2011. Universidad de la República de Uruguay. Departamento de Publicaciones, Unidad de Comunicación de la Universidad de la República (UCUR).

Vanlangendonck N, Nuñez G, Chaves A, Gutiérrez-Espeleta GA. New Route of Investigation for Understanding the Impact of Human Activities on the Physiology of Non-Human Primates. J Primatol. 2015; 4: 123. doi:10.4172/2167-6801.1000123.

Waller MT, Pruetz J. Competition Between Chimpanzees and Humans : The Effects of Harvesting Non- timber Forest Products. Ethnoprimatology. 2016; 157–177. DOI:10.1007/978-3-319-30469-4.

Walpita, C.N., Grommen, S.V.H., Darras, V.M., Van der Geyten, S. The influence of stress on thyroid hormone production and peripheral deiodination in the Nile tilapia. General and Comparative Endocrinology. 2007; 152, 18–25.

Wasser SK, Cristobal-Azkarate JA, Booth RK, Hayward L, Hunt K, Ayres K, et al. Non-invasive Measurement of Thyroid Hormone in Feces of a Diverse Array of Avian and Mammalian Species. Gen. Comp. Endocrinol. 2010; 168: 1-7. https://doi.org/10.1016/j.ygcen.2010.04.004 PMID: 20412809.

Wasser SK, Lundin JI, Ayres K, Seely E, Giles D, Balcomb K. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales *(Orcinus orca).* PLoS ONE. 2017; 12(6): e0179824. https://doi.org/10.1371/journal. pone.0179824.

Webber AD and Hill CM. Using Participatory Risk Mapping (PRM) to identify and understand people's perceptions of crop loss to animals in Uganda. PLoS One. 2014; 9(7). DOI:10.1371/journal.pone.0102912.

Wittig, R. M. et al. Social support reduces stress hormone levels in wild chimpanzees across stressful events and everyday affiliations. Nat. Commun. 2016; 7, 13361 doi: 10.1038/ncomms13361.

Wood EC, Tappan GG, Hadj A. Understanding the drivers of agricultural land use change in south-central Senegal. J. Arid Environ. 2004; 59: 565–582. DOI:10.1016/j.jaridenv.2004.03.022.

Wunderink YS, Martinez-Rodriguez G, Yufera M, Klaren PHM. Food deprivation induces chronic stress and affects thyroid hormone metabolism in Senegalese sole *(Solea senegalensis)* post-larvae. Comparative biochemistry and physiology. Part A, Molecular and Integrative Physiology. 2012; 162:317-22.

OBJETIVOS

El objetivo general de la presente tesis es avanzar en el estudio de la conservación de chimpancés *(Pan troglodytes verus)* en libertad en la Reserva de Dindéfélo, Senegal.

Los objetivos específicos son:

1. Estudiar las percepciones locales para mejorar la gestión de la conservación de chimpancés en la Reserva.

2. Medir las respuestas fisiológicas (concentración de metabolitos de cortisol fecal y T3) de los chimpancés en la Reserva para evaluar el efecto de las actividades antropogénicas.

3. Evaluar las respuestas de comportamiento de los chimpancés para valorar si las actividades antropogénicas influyen en el bienestar de los chimpancés.

CHAPTER 1

Local Perceptions of Conservation of Wild Chimpanzees *(Pan troglodytes verus)* in the Réserve Naturelle Communautaire de Dindéfélo, Southeast Senegal

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Chapter based on an article under review in **Folia Primatologica**

Abstract

Our objective was to study local perceptions of the conservation of wild chimpanzees *(Pan troglodytes verus)* in the Réserve Naturelle Communautaire de Dindéfélo (RNCD), southeast Senegal, to design specific actions to improve conservation management. We conducted 338 semi-structured interviews in three main villages in RNCD. Three quarters of the population were farmers. Of those interviewed, 29% received elementary education. Two of the three villages participated in an environmental project to plant trees as fences. On average, 66% of the respondents were animists. Of the respondents who were afraid to see a chimpanzee, 68% said this was because they attack. Seventy-seven percent washed their clothes in the forest river because there was more water than in the village wells. Of the interviewees who threw their old clothes into the forest, 50% did so because it was traditional. Ninety-six percent of respondents stated that chimpanzees do not eat their crops. The main problems the locals had with the Reserve were lack of water and basic resources and not being allowed to cut trees in protected areas. There was a significant relationship between education level, participation in the environmental project and animism, on one hand, with local perceptions about chimpanzee conservation, on the other hand. Locals who had not received elementary education thought, to a greater extent, that chimpanzees do not attack as opposed to those who had gone to school. Locals who were not participating in environmental project argued that there were practically no fires in the last year in the RNCD, as compared to those who were participating in the project. Ninety-three percent of the respondents had the animistic belief that “if old clothes were burnt, children would become sick” and these people are all afraid of chimpanzees, while of those who did not have this animistic belief, only 6% were afraid ($\chi^2 = 1.57$, $P < 0.02$). It is suggested that a better knowledge of local perceptions would be helpful to design a specific course of action to improve chimpanzee conservation and foster a sustainable coexistence with humans.

1. Introduction

Currently we are experiencing a crisis of biodiversity due to the extinction of species, habitat destruction and fragmentation, land conversion for agriculture, climate change and pollution [Gibson et al., 2011]. Every day, biodiversity is lost at a rate of up to a thousand times the natural rate, according to the International Union for Conservation of Nature (IUCN). There is a strengthening of the hypothesis that the natural world is experiencing the sixth major extinction in history [Thomas et al., 2004; Estrada et al., 2017].

Research and conservation management needs studies on the perceptions of the local population to design guidelines that promote sustainable co-existence between humans and wildlife [Conforti et al., 2003; Campbell-Smith et al., 2010; McLennan et al., 2012; Pacheco et al., 2012; Costa et al., 2013; Hockings et al., 2013; Fernández-Llamazares et al., 2016]. Working with local people is essential because they have specific knowledge of the area and manage natural resources. Also, if psychological variables are known, this can facilitate how to generate changes in behaviour and habits in people, according to the theory of Ellis. Ellis postulated knowing the thoughts, emotions and behaviours of people in order to make behavioural changes [Pérez-Acosta, 2008; Costa, 2010; Costa et al., 2013]. Conservation is complex and requires multidisciplinary work where the social sciences play an important role in effective management of the biodiversity [Hill et al., 2010; Costa et al., 2013; Hill, 2015; 2017; Webber and Hill, 2014; McLennan, et al., 2017]. Human activities are one of the main causes of extinction of the primates on our planet because of population growth, increase market demands, agricultural expansion, logging, mining, fossil fuel extraction, hunting, climate change, illegal trades, among others. There is an increase in human-chimpanzee conflicts. The ethnoprimatological field work is an effective for identifying specific problems and workable in situ solutions for primate conservation [Torres et al., 2010; Hockings and Sousa, 2013; Hockings et al., 2015; Estrada et al., 2017; Sousa et al., 2017]. A biosocial approach to understand the interactions between humans and wildlife that an openness and flexibility that provides more effective results for a sustainable coexistence [Setchell, 2017].

Ethnoprimatology is a powerful tool and a new approach to primate studies in the Anthropocene because there is a global and fast challenge that causes primates and humans to co-exist and interact. Humans influences primates and vice versa, for example, human-primates interface such as expansion of agriculture and crop foraging,

pathogen transmission or new tourism, among others [Fuentes, 2012; Hockings et al., 2015]. This interface is global, from the Neotropics, Africa and Asia [Estrada et al., 2017]. In Uganda, researchers [Hill, 2000; Hill and Webber, 2010; McLennan and Hill, 2012; Webber and Hill, 2014] have studied interactions between chimpanzees and local people concerning crop foraging and, thanks to local perceptions, they were able to design specific programs to mitigate conflicts. In Guinea-Bissau, studies have been carried out on the interaction of human chimpanzees in crops from an anthropogenic and ecological perspective to manage the attacks on people and the loss of habitat [Costa, 2010; Hockings and Sousa, 2013; Sousa et al., 2017].

Several research papers in ethnoprimatology study relationships among variables such as gender, age, education and economic level, among others, with the perception about conservation [Gadd, 2005; Costa, 2010]. Gadd, in 2005, studied local attitudes towards elephant conservation in Kenya and took into account the education and wealth of the local people. Estrada took into account multiple factors in the extinction of species such as population increase, high levels of poverty and inequality, global market, literacy or education, among others [Estrada et al., 2017]. In the Réserve Naturelle Communautaire de Dindéfélo (RNCD), children often have to help the family at home with housework and labour, such as farming fields, so that they often do not go to school.

The RNCD area is one of the poorest in Senegal and various NGOs assist in health, education and, environment, among others [Kormos et al., 2003]. *Trees for the future* is a project to revitalize lands damaged by deforestation. They provide tree seed to farmers, technical training and on-site planning assistance. Over 115 million trees have been planted in dozens of countries of the world and hundreds of thousands of acres of soil revitalized while changing people's lives. In the RNCD, the project has been working a few years in the village of Segou, Nandoumary was newly incorporated into the project, and Dindéfélo was not participating in the project yet. Locals learn to plant trees to use as fences for their homes and crops.

In Senegal, traditional beliefs prevailed until the Muslim religion arrived. Now they live together although animism is hidden more. Understood animism as a traditional belief that there are spirits in the forest, areas inhabited by the devil, superstitions related to the disease, among others. Where chimpanzees are related to something bad, bad luck or even death. The local ethnic group performs initiation rituals for adolescents or uses protection amulets made by the marabou. This coincides with other research in other countries such as Guinea-Bissau, where they studied local perceptions about the conservation of chimpanzees in Muslims and non-Muslims, if they considered that

animals and forests are forever or if they could be extinguished and what they thought about the chimpanzees, whether they are good or bad [Costa, 2010; Costa et al., 2013; Casanova et al., 2016]. In Senegal, the Peul/Fulbe/Fula/Fulani ethnic group tells stories, for example, like a long time ago a mother was with her baby in the forest when a chimpanzee with her baby approached. The chimpanzee came and took the baby from the woman. The mother chimpanzee killed the human baby, gave it back to the woman, and left. Another story told among the Peul is that if you walk through the forest and you find a chimpanzee with a gesture of attack, when you come home someone in your family will have died. They are death beliefs related to chimpanzees that coincide with other countries and affect conservation. When NGOs explain their programs to help chimpanzees, many locals do not understand it for this reason [Sousa, 2017].

The chimpanzee *(Pan troglodytes)* is an endangered species, according to the IUCN Red List in 2016. This species has suffered a significant reduction in population over the last 20-30 years due to loss of habitat, human population growth, diseases like Ebola or political instability in some regions. The current trend of this species is declining [Humle et al., 2016]. The latest estimation of the total population size of the *Pan troglodytes verus* is 18,000 to 65,000 in West Africa. In Senegal, this species is close to extinction. *P. t. verus* is one of the most endangered subspecies, estimated a population of 200-400 chimpanzees in Senegal [Humle et al., 2016; Pruetz and Bertolani, 2009]. In a census conducted in the RNCD, it has estimated 36-91 chimpanzees in 2014 [*unpublished*; Waller and Pruetz, 2016].

In the RNCD, as well as in other countries, there is great human presence in the forest and numerous encounters between humans and wildlife [Hockings and Humle, 2009; McLennan and Hill, 2012; Pacheco et al., 2012; Hockings and Sousa, 2013]. Many people are inside or within the limits of the Reserve. It is one of the poorest regions of Senegal, which means that people use forest resources such as water and trees to survive [Kormos et al., 2003; Michalski et al., 2005; McLennan, 2008; Pruetz and Bertolani, 2009; Pacheco et al., 2012; Ramón et al., 2017]. The river water is used for drinking, washing clothes and bathing. The forest is used as the town dump and latrine. Additionally, trees are cut down for building houses and every year large areas of forests are burnt to open new fields for crops, as in other research areas [Tappan et al., 2004; Wood et al., 2004; Hockings and Humle, 2009; Hockings and Sousa, 2013].

These resources are essential for the survival of chimpanzees. In the dry season, with high temperatures and water shortages, an increased number of encounters between humans and chimpanzees in small gallery forests are reported [Hockings and Humle,

2009; Pacheco et al., 2012]. Previous studies in the Reserve show that the local population in 6 of the 10 villages seems to have constant conflicts with chimpanzees at water points [Pacheco et al., 2012]. Besides, the fruits of March-April are only found in gallery forests. Chimpanzees are forced to be in close proximity to humans, less than 30 meters. This is compounded by a great increase in uncontrolled tourism to cool off in Dindéfélo waterfall. In May 2015, for instance, 300 tourists arrived in 30 minutes *(personal observation)*. Another example of natural resources competition is that, in June, the diet of chimpanzees is basically the fruit of lare *(Saba senegalensis).* However, the local population collects tons illegally to trade in local and national markets [Duvall, 2008; Norconk and Boinski, 2011; Pacheco et al., 2012; Hockings and Sousa, 2013; Pruetz, 2013; Waller and Pruetz, 2016]. In 2014, only 25 tons of S. senegalensis were collected legally [Muñoz et al., 2014 *unpublished*]. Throughout the year, trees are cut down, this presents the chimpanzees with a problem because they build their nests in these trees. By burning forests, chimpanzees lose their food, resting areas and, finally, their habitat [Kormos et al., 2003].

The RNCD would be an example of the problem of conservation of chimpanzees. In this area, the Peul ethnicity dominates [Pruetz and Bertolani, 2009; Pacheco et al., 2012]. This ethnic group has changed from nomadism to a sedentary state. Many people are unaware of the official laws and are governed by local tradition. Islam co-exists with animism, in the original Peul religion, which is still present. The total population has increased in the last five years to a total of 1,236 inhabitants. The extended family is an economic model of subsistence. The local economy hardly exceeds the limit of subsistence and is based on agriculture, logging and livestock [Kormos et al., 2003; Muñoz et al., 2014 *unpublished*].

The objective of the research is to study the local perceptions to draw lines of action to improve the management of chimpanzee conservation in RNCD. It is therefore interesting to investigate whether there is competition for natural resources and delve deeper into the psychological thought-process to understand the motivation of the population variables. The main goals are to investigate whether the local population perceives natural resources as a competition with chimpanzees and to design specific lines of action to improve conservation management and sustainable coexistence in this complex period of the Anthropocene.

2. Materials and methods

2.1. Study area

The RNCD (12º24'N, 12º18'W) covers an area of 14,050 ha. It is located in the region of Kedougou, in the extreme southeast of Senegal. The RNCD borders Guinea-Conakry to the south, the Gambia River to the east and, to the north with small towns and farmland [Pacheco et al., 2012; 2013]. It is The Sudan savannah and The Guinean forest that make up a mosaic of patches of forests, crops and pastures. The Sudan savannah consists of grasslands with patches of trees interspersed with lateritic soils. The Guinean forest is made up of semi-deciduous forests, canyons and drainage galleries [Pruetz and Bertolani, 2009].

This savannah-forest mosaic is the result of human activities such as logging and fires. The population depends on forest resources. On the Reserve, 10 villages with 6,951 inhabitants and 651 houses are distributed [Pacheco et al., 2012]. The total population has been increasing in recent years. Due to a subsistence economy, locals open crops in poor soils every year, extract fruits to sell them and their cattle feed in the forests. Faced with water scarcity, the inhabitants of the protected area flock to the rivers of the forests.

2.2 Interviews

We conducted 338 semi-structured interviews in three of the 10 villages of RNCD because they were the sites of research of the Instituto Jane Goodall España (IJGE). The three villages had different characteristics. Dindéfélo is a tourist small town in Senegal, and its population lives close to the forest. Segou is characterized by how its gentle people cooperate with conservation, and Nandoumary (Diogoma II) is noted for its deforestation and lack of resources. Forests of Segou and Dindéfélo are in the limits of the Reserve, and Nandoumary is inside the protected area.

Before anything else, permission from the heads of every village and the authorities was asked by means of the presentation of the research and following the social and cultural protocols of their ethnicity. Interviews were conducted with the help of several local interpreters, French to Pular (local language), in each village. Before the interviews, the interpreters were trained on how to do surveys. The survey was also done to the interpreters to clarify each question and avoid misunderstandings or inappropriate questions. A preliminary study was performed to investigate the traditional beliefs with the help of locals to be able to design the interview questions. Some of the information

obtained in the interviews was by living with local people two years and the reliable help of local people.

The houses where the interviews were conducted were chosen randomly in each neighborhood. In each house the husband, the wife, the grandparents and the teenage son of a family were interviewed to study possible generational differences. The age of 15 years old was chosen because it is when youngsters begin to marry.

Before the interview, an informed consent from the volunteer was obtained. Surveys were performed individually to maintain everyone´s confidentiality. In a socio-economic study by the IJGE in 2014, in the group surveys men generally answered and women were silent, so an individual interview was chosen to enhance the participation of women.

Information was asked regarding how locals perceived chimpanzees, the three variables of Ellis (feelings, thoughts and behaviours) [Pérez-Acosta et al., 2008] when they saw a chimpanzee, possible competition for water from the river, if there was problem of deforestation, whether chimpanzees fed on their crops, among others (Table A.1). The answers were 3 options (yes, no, unsure) except of the last question, which was open for them to explain problems and possible solutions. The answers to the questions have finally been grouped for a better understanding of the reader but were not led at any time. The average duration was 30 minutes per interview. The interviews were conducted from March to November 2015.

CATEGORY	QUESTIONS	ANSWERS			
CHIMPANZEES	1. What do you do when you see a chimp?	Continue 63.02% n=213	Run 36.39% n=123	Unsure 0.59% n= 2	Others --
	2. What do you feel when you see a chimp?	Calm 45.56% n=154	Afraid 53.85% n= 182	Unsure 0.59% n= 2	Others --
	3. Why are people afraid of chimpanzees?	Attack 67.75% n= 229	Don´t attack 26.33% n=89	Unsure 5.92% n=20	Others --
	4. When did you see chimps?	Dry season 44.38% n= 150	Wet season 29.59% n=100	Unsure 26.04% n= 88	Others --
	5. Do you know people who have been attacked by chimpanzees?	Yes 11.83% n= 40	No 87.87% n=297	Unsure 0.30% n=1	Others --
WATER	6. Why do you wash clothes in the river?	More water 77.51% n=262	There is nowhere else 21.89% n= 74	Unsure 0.59% n= 2	Others --
	7. Why do you have to throw the old clothes in the forest?	Tradition 50.30% n= 170	There is nowhere else 35.80% n= 121	Doesn´t do it 4.44% n=15	Unsure 9.47% n=32
TREES	8. -Thirty years ago, were there more trees in town?	Yes 71.89% n=243	No 14.79% n=50	Unsure 13.31% n=45	Others --
	9. Do chimpanzees feed crops?	Yes 3.25% n= 11	No 95.86% n=324	Unsure 0.89% n= 3	Others --
	10. When you go to pick fruits of the forest but there are no, is it because chimpanzees have eaten them?	Yes 26.04% n=88	No 71.30% n=241	Unsure 2.66% n=9	Others --
	11. How many forest fires have there been in the last year?	0 fires 2.96% n= 10	1 fire 33.73% n=114	2 o more fires 39.05% n=132	Others --
	12. Have chimpanzees stolen honey from your hives?	Yes 25.15% n= 85	No 66.75% n=225	Unsure 8.28% n= 28	Others --
	13. Would you like to protect livestock within a fence all year round?	Yes 89.69% n= 294	No 8.92% n=38	Unsure 1.38% n= 6	Others --
PROBLEMS AND SOLUTIONS	14. How can The Reserve help the people? (Problems)	1º problem: water 34.91% n=118	2º problem: resources 17.16% n=58	3º problem: felling 15.38% n=52	No problem 32.21% n=110
	15. And how can you get them? (Solutions)	1º solution: wells 30.18% n=102	2º solution: resources 15.09% n=51	3º solution: education 19.31% n=113	Unsure 45.27% n=72

Table A.1. Questions of the interview about chimpanzee conservation.

Also comments on the respondent´s attitude and nonverbal behaviour were written down. Likewise, information has also been taken into account outside the interviews,

such as co-existence with local people, conflicts, meetings, events, local workers´ opinions of IJGE and observations of land-use and human-chimpanzee interactions.

2.3. Statistical analysis

Percentages of the characteristics of the local population and interview answers about the conservation of chimpanzees were calculated. Chi-squared tests were used to investigate whether there was an association between some characteristics of the local population and the most representative questions of chimpanzee conservation. Due to the large amount of data, the most representative questions were selected to calculate the associations between the local perception on conservation of chimpanzees with education, *Trees for the Future* project and animism. Statistical analysis were performed with SAS. The significance level considered was $P < 0.05$.

3. Results

3.1. Characteristics of the local population

Ten percent of the local population was interviewed in each village (Dindéfélo = 209; Segou = 101; Nandoumary = 28). Fifty-three percent of those interviewed were women and 47% were men. Forty-seven percent of respondents were under 30 years old, 34% between 31 and 45, 12% between 46 and 60 and 7% were older than 60. The average number of women per husband was one. The mean of children per family was four. Also three-fourths of the population were farmers. On average, 66% of the respondents were animists (Table A.2).

1. If a pregnant woman saw a chimpanzee, would the baby behave like a chimpanzee?	Yes 48.25% n=165	No 46.75% n=158	Unsure 4.44% n= 15
2. If you log in the devil´s area, would it make you sick?	Yes 89.05% n=301	No 8.28% n=28	Unsure 2.66% n=9
3. If the old clothes were burnt, would children become sick?	Yes 91.42% n=309	No 7.69% n=26	Unsure 0.89% n= 3
4. If you throw stones at animals, it would hurt your arm?	Yes 64.50% n=218	No 30.18% n=102	Unsure 5.33% n=18
5. Is eating Patas monkey *(Erythrocebus patas)* meat good to curing disease "inflammation" and help women who cannot have children?	Yes 49.70% n=168	No 43.20% n=146	Unsure 7.10% n=24
6. Do many baobabs together attract the devil?	Yes 52.37% n=177	No 14.20% n=48	Unsure 33.43% n=113

Table A.2. Description of some animistic beliefs of the Peul ethnic group in the RNCD (Senegal).

Of those interviewed, 29% received elementary education. Elementary education varied significantly depending on the gender of the respondents, the village and the age. Sixty-seven percent of the men and 33% of the women have gone to school ($\chi^2 = 22.81$, $P < 0.0001$). In Dindéfélo, 25% of the respondents have not received elementary education, whereas in Segou the percentage was 70%, and in Nandoumary 75% ($\chi^2 = 49.73$, $P < 0.0001$). Furthermore, 56% of the population between 46 and 60 years old have not gone to school, as opposed to 29% aged between 15-30 who have gone to elementary school ($\chi^2 = 44.24$, $P < 0.0001$).

Depending on the village, the percentage of respondents who participated in *Trees for the Future* formation project varied ($\chi^2 = 158.66$, P <0.0001). Forty-five percent of the respondents from Segou participated in the formation, whereas 18% of the respondents from Nandoumary, and 0% of the one of Dindéfélo, did this formation.

3.2. Questions about chimpanzee conservation

The results indicate differentiated responses in the questions on the conservation of chimpanzees (Table A.1). Fifty percent threw old clothes in the forest by tradition, as they had always done so. Of this percentage, 20% regarded the forest as the town dump, 6% did not want to throw old clothes away at home because their cows ate it and died, 4% put the old clothes on the branches of trees to not burn and 3% did it because the marabou said to (priest in animism).

With respect to the trees, 96% of respondents said that chimpanzees do not feed their fields of crops, but rather baboons did *(Papio papio),* so local people shot them. Seventy-

one percent of respondents, when they looked for fruits of the forest and did not find them, did not blame chimpanzees but did blame the baboons. Ninety percent of respondents would like to keep their livestock inside a fence all year, but locals needed food and water for animals and local population could not afford this.

The main problems of the locals with the Reserve were: 1) lack of water (35%); 2) lack of basic resources such as food, health, education, work and electricity (17%), and 3) logging, not being allowed to cut trees in protected areas (15%). Thirty-two percent answered that there was no problem. In interviews, Peul people were shy, willing and trying to avoid conflicts. If the question is formulated as "is there any problem?" most respondents answered “no”. But, if asked "what can the Reserve do to help the local people?" most respondents listed various problems.

As a possible solution to the lack of water, they requested deep wells and washhouses (30%). Second, 15% appealed requested basic resources such as food, medicine, school supplies, work and mills to transform the fruits. Finally, they suggested education as another solution (19%).

In addition, 45% said they did not know the solutions and that others had to solve the problems. However, 87% of respondents had a positive attitude, collaborative, and were supporters of chimpanzee conservation.

3.3. Associations between characteristics of the local population and chimpanzee conservation.

The results presented in Tables 3, 4 and 5 show the relationships existing between education, the *Trees for the Future* project and animist beliefs with the most representative questions of chimpanzee conservation questions.

Table 3 shows associations between education and some questions of chimpanzee conservation, with one significant relationship between education and some chimpanzee conservation questions (Table A.3).

CATEGORIES	INTERVIEW QUESTIONS	EDUCATION		
		SCHOOL %	HIGH SCHOOL %	NO SCHOOL %
CHIMPANZEES	2. What do you feel when you see a chimp?			
	Calm	29.2	10.3	42.2
	Fear	29.6	11.5	42.3
			$\chi^2 = 0.08$, P = 0.96	
	3. Why are people afraid of chimpanzees?			
	Attack	33.6	10.4	34.9
	Don´t attack	14.6	12.3	65.1
			$\chi^2 = 19.32$, P < 0.0001	
WATER	6. Why do you wash clothes in the river?			
	More water	28.6	11.8	45
	There is nowhere else	31	6.7	35.1
			$\chi^2 = 1.90$, P = 0.39	
	7. Why you have to throw the old forest clothes?			
	Habit	25.8	11.7	42.3
	Nowhere	27.2	12.4	50.4
	Doesn´t do it	33.3	0	53.3
			$\chi^2 = 2.39$, P = 0.66	
TREES	8. Thirty years ago, were there more trees in town?			
	Yes	27.9	11.1	42.3
	No	32	10	48
			$\chi^2 = 0.20$, P = 0.90	
	11. How many forest fires have there been in the last year?			
	0 fires	20	10	60
	1 fire	35	10.5	8.6
	2 o more fires	21.9	11.3	50
			$\chi^2 = 6.23$, P = 0.18	

Table A.3. Associations between education and some questions of chimpanzee conservation.

Table 4 presents associations between the *Trees for the Future* project and some questions of chimpanzee conservation. These results show four significant relationships between the project and the local perception of the conservation of chimpanzees.

CATEGORIES	INTERVIEW QUESTIONS	*TREES FOR THE FUTURE* PROJECT	
		YES	NO
		%	%
CHIMPANZEES	2. What do you feel when you see a chimp?		
	Calm	19.5	69.5
	Afraid	11.5	81.9
		$\chi^2 = 4.98$, P < 0.0255	
	3. Why are people afraid of chimpanzees?		
	Attack	8.7	86.4
	Don´t attack	33.7	47.1
		$\chi^2 = 40.05$, P < 0.0001	
WATER	6. Why do you wash clothes in the river?		
	More water	14.8	75.1
	There is nowhere else	14.8	81.1
		$\chi^2 = 0.04$, P = 0.84	
	7. Why do you have to throw the old clothes in the forest?		
	Tradition	17.6	70.5
	There is nowhere else	14	78.5
	Doesn´t do it	13.3	86.6
		$\chi^2 = 1.23$, P =0.54	
TREES	8. Thirty years ago, were there more trees in town?		
	Yes	17.7	71.6
	No	4	90
		$\chi^2 = 6.61$, P < 0.0101	
	11. How many forest fires have there been in the last year?		
	0 fires	10	90
	1 fire	11.4	82.4
	2 o more fires	24.2	62.8
		$\chi^2 = 9.20$, P< 0.0100	

Table A.4. Associations between *Trees for the Future* Project and some questions of chimpanzee conservation.

Finally, Table 5 shows associations between Animism and some questions of chimpanzee conservation. Eleven significant associations between animism and items related to the conservation of primates were found.

INTERVIEW QUESTIONS	ANIMISM											
	1. BABY CHIMP		2.DEVIL'S AREA		3.CLOTHES BURNED		4.STONE ANIMALS		5.MONKEY MEAT		6.BAOBABS	
	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
	%		%		%		%		%		%	
2. What do you feel when you see a chimp?												
Calm	47.4	48	87	11.7	89.6	9.7	57.8	35	42.9	50	48	16.9
Afraid	49.4	46.1	90.6	5.5	92.9	6	69.8	26.4	55.5	37.4	55.5	12.1
	$\chi^2 = 0.13$, P = 0.71		$\chi^2 = 3.9$, P< 0.0482		$\chi^2 = 1.57$, P< 0.02107		$\chi^2 = 3.86$, P< 0.0495		$\chi^2 = 5.77$, P < 0.0163		$\chi^2 = 2.4$, P = 0.30	
3. Why are people afraid of chimpanzees?												
Attack	45.4	48.4	87.8	8.3	91.3	7.4	65.5	28.4	56.8	34.5	43.2	10.5
Don´t attack	52.8	46.1	92.1	7.9	89.9	10.1	67.4	31.5	37.1	61.8	77.5	22.5
	$\chi^2 = 0.63$, P= 0.43		$\chi^2 = 0.04$, P= 0.82		$\chi^2 = 0.56$, P = 0.45		$\chi^2 = 0.07$, P = 0.78		$\chi^2 = 15.26$, P< 0.0001		$\chi^2 = 62.13$, P< 0.0001	
6. Why do you wash clothes in the river?												
More water	48.8	47.7	87.4	9.5	91.2	8.4	67.9	26.3	49.2	43.5	56.1	15.6
There is nowhere else	48.6	44.5	95.9	4	91.9	5.4	52.7	43.2	52.7	41.9	39.2	9.5
	$\chi^2 = 0.05$, P = 0.81		$\chi^2 = 2.45$, P = 0.12		$\chi^2 = 0.65$, P = 0.42		$\chi^2 = 7.47$, P < 0.0063		$\chi^2 = 0.15$, P= 0.69		$\chi^2 = 13.94$, P < 0.0009	
7. Why do you have to throw the old clothes in the forest?												
Tradition	50.6	46.5	91.8	7	91.1	8.2	68.8	26.5	51.8	41.2	54.1	15.3
There is nowhere else	51.2	43.8	87.6	9.9	91.7	7.4	63.6	33.1	42.9	52.1	58.7	14.9
Doesn´t do it	26.7	60	100	0	100	0	80	6.7	66.7	26.7	73.3	6.7
	$\chi^2 = 2.51$, P= 0.28		$\chi^2 = 2.23$, P= 0.33		$\chi^2 = 1.35$, P= 0.51		$\chi^2 = 4.44$, P= 0.11		$\chi^2 = 5.09$, P= 0.0782		$\chi^2 = 2.53$, P = 0.64	
8.-Thirty years ago, were there more trees in town?												
Yes	53.5	43.2	90.9	7	90.5	8.2	65	30	51	44	53.5	12.3
No	32	66	90	8	94	6	68	26	44	46	58	12
	$\chi^2 = 8.34$, P< 0.0039		$\chi^2 = 0.06$, P= 0.8		$\chi^2 = 0.31$, P = 0.58		$\chi^2 = 0.28$, P = 0.59		$\chi^2 = 0.35$, P = 0.55		$\chi^2 = 0.37$, P = 0.83	
11. How many forest fires have there been in the last year?												
0 fires	50	50	80	10	80	20	50	50	30	70	30	50
1 fire	46.5	50.9	89.5	9.6	94.7	4.4	70.2	25	58.8	33.3	50.9	14
2 o more fires	57.6	38.6	90.9	7.6	88.6	9.8	61.4	34.1	43.2	52.3	59.8	9.8
	$\chi^2 = 3.56$, P = 0.17		$\chi^2 = 0.38$, P = 0.82		$\chi^2 = 4.67$, P = 0.09		$\chi^2 = 3.72$, P = 0.15		$\chi^2 = 10.08$, P < 0.0065		$\chi^2 = 14.34$, P< 0.0063	

Table A.5. Associations between Animism and some questions of chimpanzee conservation.

4. Discussion

4.1. Characteristics of the local population

The characteristics of the studied population coincide with those of other studies of local perceptions on chimpanzee conservation in other African countries. They are local groups with low life expectancies, subsistence economies, high population growth rates, low participation in basic education, and traditional beliefs with implications for biodiversity conservation. Gambia, Togo, Benin and Burkina Faso are countries that stand out because chimpanzees are already extinct there and, as a result, may be examples that provide clues to prevent the same thing from happening in other countries like Senegal and Ghana, where there are very few chimpanzees left. These countries share high human population densities [Kormos et al., 2003]. There is an estimated world population increase from 7 billion in 2012 to 9 billion in 2050, where the highest growth is in tropical nations. Today, 2 billion people live in regions where primate species live, and are characterized by high levels of poverty. This growth increases the demand of the markets, which affects crops, wood, minerals and oil that come from zones of primates. This increases deforestation and habitat fragmentation and, thus, the decline of the primate population. In turn, poverty in these regions increases. It is the current conservation challenge [Estrada, 2017].

Senegal is among the poorest countries in the world, as are also Guinea Bissau and Burkina Faso. In Burkina, around 90% of the population depends on subsistence agriculture. In Senegal, the economy is mainly based on agriculture (especially peanuts), fishing and tourism. Most of these countries live below the poverty level, where less than 40% of the population has access to health service, potable water and sanitation [Kormos et al., 2003]. Senegal also shares with other African countries the performance of several international NGOs with cooperation projects, which help people in health care, education and the, environment, among others.

These African countries have many ethnic groups with different cultures and traditional beliefs, such as animism in the RNCD of the Peul ethnic group, like the Nalu and Balanta in Guinea-Bissau [Costa, 2010; Casanova et al., 2014], 60 ethnic groups in The Ivory Coast [Kormos et al., 2003] or the Malika people in Mali [Duvall, 2008].

4.2. Conservation of chimpanzees

Local people were afraid of chimpanzees because they thought chimps attack. If locals found a chimpanzee in the forest, they would stop and watch. If the chimpanzee went

away, local people continued with their activity, but if they saw something strange about the chimpanzee, the local people would run towards the village. The knowledge of these three psychological variables (emotions, thoughts and behaviours) would allow researchers to design a specific program to work on the distorted beliefs of the local population. These local perceptions towards chimpanzees in Senegal coincide with those of other countries such as Uganda [McLennan and Hill, 2012; Webber and Hill, 2014] and Guinea Bissau [Costa et al., 2013; Sousa, 2014; 2017]. In the RNCD, just as in Uganda, the locals see more chimpanzees currently, which could be a sign of habitat fragmentation [McLennan and Hill, 2012]. In several investigations it has been found that locals were supporters of chimpanzee conservation as long as they lived in the woods and the population could benefit from them as crop protection against other animals, work, projects or ecotourism. On the contrary, if chimpanzees entered their towns, competed for natural resources (fruits, crops, water, among others), attacked humans, or were a source of food or money for illegal trafficking, local perception would change and locals would kill them [Watkins, 2009; McLennan and Hill, 2012; Costa, 2013; Sousa et al., 2014]. In Dindéfélo, some respondents commented that if the chimpanzees entered the village, there would be a problem.

Water was a resource which humans and wildlife compete for in south-eastern Senegal and northern Guinea [Kormos, 2003; Hockings and Humle, 2009]. In the RNCD, there were conflicts between humans and chimpanzees for water [Pacheco et al., 2012] because they struggled to obtain it at the same time and in the same place, especially during the dry season, which caused stress to both parties. In the RNCD, locals used the river as their washing place because there was plenty of water and they found it easier to wash themselves there. Also, they did not use deep wells because they had to wait for their turn and the water was hard to extract. This meant that, in addition to using the river as a toilet and shower, they left the soap plastic containers in the forest as well as their worn clothing. As a result of this, a possible source of contamination and zoonosis would be created. Cows and baboons were also observed eating the abandoned clothes and, afterwards, found their dead bodies with clothes inside *(personal observations).* Aside from this, the problem of garbage in the Reserve has not been completely solved through an American project with wastebaskets because the garbage of wastebaskets was later burnt. Local people did not want their clothes to be burnt. They had the animistic belief that if the clothes were burnt, this could make many people from the community become ill. So, it is important to consider this animist belief to solve the problem. An awareness program could be carried out, work on these beliefs and create a recycling project that included old clothes and plastics to provide local

people with work. Also, out of the new extracted material, new fabrics and affordable local clothing could be made.

Most locals remembered the existence of more trees 30 years ago, as also happens in Uganda. However, others thought that there were not any problems of deforestation, which coincides with local opinions in Uganda and Guinea-Bissau about the fact that the forest will last forever (77%), or that the forest will not run out of resources (38%) [McLennan, 2008; Watkins, 2009; McLennan and Hill, 2012; Casanova et al., 2014]. This was the reason why locals complained about bans in the Reserve against logging and burning down trees. In addition, they claim that they are poor and need forest resources to live on.

It is worth noting that in the RNCD chimpanzees did not feed crops, which contrasts with the vast majority of research in other countries, such as Uganda and Guinea-Bissau [Hockings, 2007; Costa et al., 2013; Hockings and Sousa, 2013; Bessa et al., 2015]. The expansion of agriculture is one of the main causes of deforestation and the extinction of species such as chimpanzees [Kormos et al., 2003] as in Mali [Duvall, 2008], Guinea-Bissau [Costa et al., 2013; Hockings and Sousa, 2013], Gambia, Republic of Guinea, Sierra Leone, The Ivory Coast, Ghana, Benin, Burkina Faso and Nigeria [Hockings and Humle, 2009]. So, this matter would require further studies to investigate the variables that influence the situation of the RNCD for chimpanzees who live in human-dominated landscapes but do not feed from crops, to help with this problem in other countries.

As in Guinea-Bissau and Uganda, baboons in the RNCD were perceived to be more harmful than were chimpanzees in crops [Watkins, 2009; McLennan and Hill, 2012; Costa et al., 2013] and fruits of the forest [Kormos et al., 2003; Watkins, 2009.]. Locals commented that “chimpanzees only took what they needed” [Webber and Hill, 2014]. However, there was a competition for fruits, such as *S. senegalensis*, because human extraction was in large quantities for national trade [Hockings and Humle, 2009; Pacheco et al., 2012; Waller and Pruetz, 2016]. Fires were recurrent every year in every village of the Reserve mainly to open up more croplands. Also, in the RNCD honey was barely stolen by chimpanzees, unlike in Uganda [McLennan and Hill, 2012].

The fundamental problem in the RNCD is the lack of water. At the end of 2015, in Dindéfélo, drilling for water was carried out in order to extract and supply water to several villages through taps. The drilling was done by the government in a highly protected area of the reserve, up to 40 meters down, in an important area of chimpanzees. If the drilling had taken place in an area outside the reserve, it would have been an excellent project for the local population and would also have benefitted the biodiversity of the Reserve.

If taps worked, it would not be necessary to improve the public washhouse built by the IJGE. In Segou and Nandoumary, it would be necessary to build deeper water wells, facilitate their access, and build public laundries (large, centrally located and with plenty of water).

The locals proposed solutions like wells, washhouses, basic resources (food, medicines, school supplies, among others) and education. Through IJGE projects for the establishment of nature reserves, research and monitoring of the primate population, local job creation, promotion of local management, green fences, nurseries, recovery of natural corridors, projects for women, among others, it is intended to combat the extinction of chimpanzees and provide basic resources to the local population in the RNCD. Also, it is important to develop educational projects, raise awareness of the conservation of chimpanzees, the expansion of protected areas, promote zoning (for humans and for wildlife), and of the promotion of co-management for the conservation among local people, governmental and non-governmental organizations. Furthermore, it is worth considering such issues as bio construction, sustainable development, family planning, sustainable farming systems, education for women, promoting positive attitudes toward chimpanzees, forest fires prevention, recovery of the fruit orchards, reinforcements for sustainable towns like Segou, urgent projects for Nandoumary (sustainable agriculture, reforestation, water wells and, washhouses, among others), medical and health support and, solar panels, among others. The characteristics of the population require measures for the management of conservation with short-term benefits and low- cost local efforts. It would also be necessary to bring the law closer to this remote area with Agent des Eaux et Forêts, which supported the role of Eco-guards in the Reserve, as in Guinea-Bissau [Costa, 2010].

Dindéfélo is a village near the mountains, so human presence is very close to the forest every day, and it also has a great tourist attraction for its natural waterfall. It would be essential to control the massive influx of people into the forest with ecotourism and trained and certified local staff because tourism with wildlife, when humans are so close, can be dangerous to both [Horowitz, 1998; Adams, 2003; Okello, 2005; Costa, 2010; Laudati, 2010; McLennan and Hill, 2012; Hockings and Sousa, 2013; 2014].

4.3. Influences of education, *Trees for the Future* project and animist beliefs about the perception of chimpanzee conservation.

Locals who had not received elementary education thought, to a greater extent, that chimpanzees do not attack as opposed to those who had gone to school. This could be explained because if local knowledge is based only on the experience of the vast majority of the times they go to the forest, chimpanzees do not attack them. In some research, it has been found that basic education is another variable that influences the local perception of conservation, as well as gender, age, status, lineage, access to land, power, wealth [Gadd, 2005; Costa, 2010]. Gadd [2005] found in Kenya that locals without elementary education were more open to wildlife tourism and conservation programs because their situation improved. Estrada [2017] postulates that multiple solutions are needed for the global problem of species extinction. A master formula is to transform conservation into benefits for the locals and also defray their needs, such as food security, health or education [Gillingham and Lee, 1999; Ayivor, 2013; Estrada et al., 2017].

In Zimbabwe, researchers have found that the locals did not know the protected area well despite having lived there for years. Education and awareness programs are necessary for people to be aware of conservation and wildlife projects. These programs could change local perceptions and increase participation in conservation management [Gandiwa, 2014]. This coincides with our findings that locals who were not participating in *Trees for the Future* project argued that there were practically no fires in the last year in the RNCD, as compared to those who were participating in the project. In the same way in The Ivory Coast, child environmental education projects have increased environmental awareness and positively influenced attitudes towards nature [Borchers et al., 2014]. In Congo, they observed a relationship between poverty and lack of conservation of wildlife because they killed animals to eat them. In this way, they gave economic incentives to children attending educational conservation projects, among other measures. This approach helped to reduce poaching of protected species, which lead to the more sustainable amount of wildlife in the Congo [Breuer and Mavinga, 2009].

Several studies have found influences of religion on conservation of biodiversity. In Guinea-Bissau, Muslims tend to plant fruit trees, so primates are bad because they eat these fruits. Non-Muslims, on the other hand, grow rice, which is less attractive to chimpanzees, so chimpanzees are not perceived as bad. A relationship has been found between the Muslims and anthropo-centrism. Some local communities find similarities between chimpanzees and humans, which favours positive attitudes toward

chimpanzees because, if they could not be human and had to choose between animal kingdom species, they would choose to be chimpanzees [Costa, 2010; 2013; Casanova, 2014].

The widespread traditional belief that if the clothes are burned, the community will become seriously ill would explain that the clothes are hung in the trees in the forest because, in case of a fire, that would not burn. These clothes are eaten by cows and baboons in the forest. Dead animal bodies have been found with clothes inside of them. A wastebasket project to solve the garbage problem was not being effective concerning clothes for this reason. As for baobabs, for example, in Dindéfélo they are practically not seen, and the few that are left are felled, which would be related to the animistic idea that if there are many baobabs *(Adansonia digitata)* together they attract the devil. Nevertheless, the belief that if felled in the area of the devil, you would become ill. Our results show relationships between animism and fear of chimpanzees by thinking that chimpanzees attack. The Peul tell stories about chimpanzees that kill human babies or that if one encounters them in the forest, afterwards they will find a dead family member at home. That a human baby behaves like a chimp for the Peul is a bad thing. Stories are related to bad luck, the devil, traditional medicine, healing, among others. It could relate in some ways to African sorcery, as in Sierra Leone, where the people say that witches dress like chimpanzees, so body parts are used for rituals and acquire magical powers [Richards, 2000; Hill, 2015; Sousa et al., 2017]. In Madagascar, the belief in bad luck also exists together with bad omens about future disaster, yet they just see some particular species of primates *(Daubentonia madagascariensis)* as the messengers of the devil, so that they believe it is necessary to kill them [Baker, 2013]. Other ancestral beliefs can favour the killing of chimpanzees, as in Ghana, Nigeria and Togo it is for meat [Kormos et al., 2003]. On other occasions, chimpanzees are killed for medical purposes because of the belief in devils living inside of these animals [Webber and Hill, 2014]. In Mali, locals do not eat meat, but the Maninka people use it as traditional medicine [Duvall, 2008], as in Guinea-Bissau [Sousa et al., 2014]. In the RNCD, they use the Patas monkey *(Erythrocebus patas)* meat to cure diseases or infertility. With respect to chimpanzees, animist stories translate into fear of chimpanzees and, for now, of respect.

However this negative perception of chimpanzees of Dindéfélo and Nandoumary is different in Segou, because they say that chimpanzees are good because they are like humans and, as a consequence, show a positive attitude toward chimpanzee conservation. In Guinea-Bissau and Uganda, locals do not eat chimpanzees because they see them as being humanlike [Kormos et al., 2003; Hill and Webber, 2010; McLennan, 2010; Costa et al., 2013; Sousa et al., 2014]. This point of view of

chimpanzees being like humans makes a big difference in local perception because it contributes to enhance tolerance, better co-existence, and support for chimpanzee conservation [Watkins, 2009]. Locals from Guinea Bissau said that chimpanzees had been men who were punished by God for being lazy or fishing on banned days [Sousa et al., 2014] is the same idea as in the RNCD. Another story found by Sousa is that the chimpanzee was a blacksmith transformed into a bush by God [Sousa et al., 2017]. In Uganda the idea that chimpanzees only eat what they need makes these primates more human for certain local communities. There are even communities that convert them into flagships or totems. In The Ivory Coast, people do not kill chimpanzees because they are their totem, or in Uganda the chimpanzees are not eaten out of tradition. However, if locals believe that primates are transgressing social rules such as crop raiding or attacks on humans, such positive attitudes become negative and people can kill them [Hill and Webber, 2010].

This is the problem of the age of the Anthropocene with human population growth, greater demand for markets, expansion of agriculture, fragmentation of habitats, crops feeding and human-wildlife conflicts. Thanks to knowledge of local perceptions, we believe that the solution for the RNCD is the zoning and expansion of protected areas rather than promoting human-chimp co-existence [Hill, 2017]. Thus, humans would have their area for crops and helps with programs to improve sustainable agriculture and wildlife would have their protected habitat. Washhouses and orchards are needed for local population. Also important are scholarships, environmental education and work based on the traditional beliefs of the local population. Family planning and the search for a sustainable balance are also very important. According to Estrada, several investigations on local perceptions and conservation agree on the importance of considering them because local perceptions improve the effectiveness to achieve a sustainable coexistence in this complex period of the Anthropocene [Michalski, 2005; Brooks et al., 2006; Vodouhê, 2010; Junker et al., 2012; Estrada et al., 2017; Rust, 2017].

5. Conclusion

In conclusion, in one of the poorest areas of Senegal there are ethnic groups with religion and animist beliefs that have an influence on biodiversity conservation. Fear of chimpanzees translates into a fragile respect that can be broken at any time and become a greater threat to these primates. There are conflicts over basic resources (water and trees) in the RNCD. There were significant correlations between local perceptions and education, the environmental project and animism. Local perceptions allow us to design

a specific course of action to improve chimpanzee conservation and sustainable coexistence in this complex period of the Anthropocene.

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7. References

Adams WM, Infield M (2003). Who is on the Gorilla's payroll? Claims on tourist revenue from a Ugandan National Park. World Dev. 31: 177–190.

Ayivor JS, Gordon C, Ntiamoa-baidu Y (2013). Protected Area Management and Livelihood Conflicts in Ghana : a Case Study of Digya National Park. Parks 19: 37–50.

Baker L (2013). Links between local folklore and the conservation of Sclater's monkey *(Cercopithecus sclateri)* in Nigeria. Afr Primates 8: 17–24.

Bessa J, Sousa C, Hockings KJ (2015). Feeding ecology of chimpanzees *(Pan troglodytes verus)* inhabiting a forest-mangrove-savanna-agricultural matrix at Caiquene-Cadique, Cantanhez National Park, Guinea-Bissau. Am. J. Primatol. 77: 651–665. DOI:10.1002/ajp.22388.

Borchers C, Boesch C, Riedel J, Guilahoux H, Ouattara D, Randler C (2014). Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. Int. J. Sci. Educ. Part B 4: 240–259. DOI:10.1080/21548455.2013.803632.

Breuer T and Mavinga FB (2009). Education for the Conservation of Great Apes and Other Wildlife in Northern Congo—the Importance of Nature Clubs. American Journal of Primatology 71:1–8.

Brooks TM, Mittermeier RA, Fonseca GAB, Gerlach J, Hoffmann M, Lamoreux JF, Mittermeier CG, Pilgrim JD, Rodrigues ASL (2006). Global Biodiversity Conservation Priorities. Science 80: 313, 58–61. DOI:10.1126/science.1127609.

Campbell-Smith G, Simanjorang HVP, Leader-Williams N, Linkie M (2010). Local attitudes and perceptions toward crop-raiding by orangutans *(Pongo abelii)* and other nonhuman primates in Northern Sumatra, Indonesia. Am. J. Primatol. 72: 866–876. DOI:10.1002/ajp.20822.

Casanova C, Sousa C and Costa S (2014). Are animals and forests forever? Perceptions of wildlife at Cantanhez Forest National Park, Guinea-Bissau Republic, Memórias Environmental Anthropology 16:69-104.

Conforti VA, Azevedo FC (2003). Local perceptions of jaguars *(Panthera onca)* and pumas (Puma concolor) in the Iguacu National Park area , south Brazil. Biological Conservation 111: 215–221. DOI:10.1016/S0006-3207(02)00277-X.

Costa S (2010). Social perceptions of Nonhumans in Tombali (Guinea-Bissau, West Africa): a contribution to chimpazee *(Pan troglodytes verus)* conservation. Thesis. University of Stirling.

Costa S, Casanova C, Sousa C, Lee P (2013). The Good, The Bad and The Ugly: Perceptions of Wildlife In Tombali (Guinea-Bissau, West Africa). J. Primatol. 2:1. DOI:http://dx.doi.org/10.4172/2167-6801.1000110.

Duvall CS (2008). Human settlement ecology and chimpanzee habitat selection in Mali. Landsc. Ecol. 23: 699–716. DOI:10.1007/s10980-008-9231-x.

Estrada A (2017). Human Population Growth, Poverty. In The International Encyclopedia of Primatology. 1–6. ISBN.

Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E, Di Fiore A, Nekaris K, Nijman V, Heymann EW, Lambert JE, Rovero F, Barelli C, Setchell JM, Gillespie TR, Mittermeier RA, Arregoitia LV, de Guinea M, Dobrovolski SR, Shanee S, Shanee N, Boyle SA, Fuentes A, MacKinnon KC, Amato KR, Meyer ALS, Wich S, Sussman RW, Pan R, Kone I, Li B (2017). Impending extinction crisis of the world's primates: Why primates matter. Sci. Adv. 3.

Etiendem DN, Hens L, Pereboom Z (2011). Traditional knowledge systems and the conservation of cross river gorillas: A case study of Bechati, Fossimondi, Besali, Cameroon. Ecol. Soc. 16, 6.

Fernández-Llamazares Á, Gueze M, Cabeza M, Reyes-García V (2016). Local

perceptions as a guide for the sustainable management of natural resources: Empirical evidence from a small-scale society in Bolivian Amazonia. Ecol. Soc. 21. DOI:10.5751/ES-08092-210102.

Fuentes A (2012). Ethnoprimatology and the Anthropology of the Human-Primate Interface. Annu. Rev. Anthropol. 41:101–17.

Gadd M (2005). Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environmental Conservation 32(1): 50-63.

Gandiwa E, Zisadza-Gandiwa P, Muboko N, Libombo E (2014). Local People's Knowledge and Perceptions of Wildlife Conservation in Southeastern Zimbabwe. J. Environ. Prot. 475–481.

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJA, Laurance WF, Lovejoy TE, Sodhi NS (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. Nature. 478: 378–381.

Gillingham S, Lee PC (1999). The impact of wildlife-related benefits on the conservation attitudes of local people around the Selous Game Reserve, Tanzania. Environ. Conserv. 26: 218–228.

Hill CM (2000). Conflict of Interest between People and Baboons: Crop Raiding in Uganda. International Journal of Primatology 21: 2.

Hill CM (2015). Perspectives of "Conflict" at the Wildlife–Agriculture Boundary: 10 Years On. Human Dimensions of Wildlife: An International Journal. DOI:10.1080/10871209.2015.1004143.

Hill CM (2017). Primate Crop Feeding Behavior, Crop Protection, and Conservation. International Journal of Primatology. DOI 10.1007/s10764-017-9951-3.

Hill CM, Webber AD (2010). Perceptions of nonhuman primates in human-wildlife conflict scenarios. Am. J. Primatol. 72: 919–924. DOI:10.1002/ajp.20845.

Hockings KJ (2007). Human-chimpanzee coexistence at Bossou , the Republic of Guinea: A chimpanzee perspective. A thesis submitted for the degree of Department of Psychology. 1–272.

Hockings K and Humle T (2009). Best Practice Guidelines for the Prevention and Mitigation of Conflict Between Humans and Great Apes, Survival. IUCN/SSC, Primate Specialist Group. DOI:10.2305/IUCN.CH.2009.SSC-OP.37.en

Hockings KJ and Sousa C (2013). Human-Chimpanzee Sympatry and Interactions in

Cantanhez National Park, Guinea-Bissau: Current Research and Future Directions. Primate Conservation 26(1):57-65. DOI: http://dx.doi.org/10.1896/052.026.0104.

Hockings KJ, McLennan MR, Carvalho S, Ancrenaz M, Bobe R, Byrne RW, Dunbar RIM, Matsuzawa T, McGrew WC, Williamson EA, Wilson ML, Wood B, Wrangham RW and Hill CM (2015). Apes in the Anthropocene: flexibility and survival. Trends in Ecology & Evolution. DOI: 10.1016/j.tree.2015.02.002.

Horowitz LS (1998). Integrating indigenous resource management with wildlife conservation: a case study of Batang Ai National Park, Sarawak, Malaysia. Hum. Ecol. 26: 371–403.

Humle, T., Maisels, F., Oates, J.F., Plumptre, A. & Williamson, E.A. 2016. Pan troglodytes. The IUCN Red List of Threatened Species 2016: e.T15933A102326672.http://dx.doi.org/10.2305/IUCN.UK.20162.RLTS.T15933A17964454.en.

Humle, T., Boesch, C., Campbell, G., Junker, J., Koops, K., Kuehl, H. & Sop, T. 2016. *Pan troglodytes ssp. verus*. The IUCN Red List of Threatened Species 2016: e.T15935A102327574.http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T15935A17989872.en.

Junker J, Blake S, Boesch C, Campbell G, Toit L du, Duvall C, Ekobo A, Etoga G, Galat-Luong A, Gamys J, Ganas-Swaray J, Gatti S, Ghiurghi A, Granier N, Hart J, Head J, Herbinger I, Hicks TC, Huijbregts B, Imong IS, Kuempel N, Lahm S, Lindsell J, Maisels F, McLennan M, Martinez L, Morgan B, Morgan D, Mulindahabi F, Mundry R, N'Goran KP, Normand E, Ntongho A, Okon DT, Petre CA, Plumptre A, Rainey H, Regnaut S, Sanz C, Stokes E, Tondossama A, Tranquilli S, Sunderland-Groves J, Walsh P, Warren Y, Williamson EA, Kuehl HS (2012). Recent decline in suitable environmental conditions for African great apes. Divers. Distrib. 18: 1077–1091. DOI:10.1111/ddi.12005.

Kormos R, Boesch C, Bakar MI and Butynski T. (eds.). (2003). West African Chimpanzees. Status Survey and Conservation Action Plan. IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 219.

Laudati A (2010). Ecotourism: The modern predator? i/Implications of gorilla tourism on local livelihoods in Bwindi impenetrable national park, Uganda. Environ. Plan. D Soc. Sp. 28: 726–743.

McLennan MR (2008). Beleaguered Chimpanzees in the Agricultural District of Hoima, Western Uganda. Primate Conserv. 23: 45–54. DOI:10.1896/052.023.0105.

McLennan MR (2010). Chimpanzee Ecology and Interactions with People in an Unprotected Human-Dominated Landscape at Bulindi, Western Uganda. Thesis Department of Anthropology & Geography. Oxford Brookes University.

McLennan MR, Hill CM (2012). Troublesome neighbours: Changing attitudes towards chimpanzees (Pan troglodytes) in a human-dominated landscape in Uganda. J. Nat. Conserv. 20: 219–227. DOI:10.1016/j.jnc.2012.03.002.

McLennan MR, Spagnoletti N and Hockings KJ (2017). The Implications of Primate Behavioral Flexibility for Sustainable Human Primate Coexistence in Anthroponcenic Habitats. IntJPrimatol. 38:105–121. DOI10.1007/s10764-017-9962-0.

Michalski F, Peres CA (2005). Anthropogenic determinants of primate and carnivore local extinctions in a fragmented forest landscape of southern Amazonia. Biol. Conserv. 124: 383–396. DOI:10.1016/j.biocon.2005.01.045.

Norconk MA, Boinski S, Forget PM (2011). Primates in 21st century ecosystems: Does primate conservation promote ecosystem conservation? Am. J. Primatol. 73: 3–8.

Okello MM (2005). Land Use Changes and Human–Wildlife Conflicts in the Amboseli Area, Kenya. Hum. Dimens. Wildl. 10: 19–28. DOI:10.1080/10871200590904851.

Pacheco L, Azua NR, Fernández-García JM, Aransay N, Guallar F, Gaubert P (2013). First record of Johnston's Genet Genetta johnstoni in Senegal. Small Carnivore Conservation. 48: 89–91.

Pacheco L, Fraixedas S, Fernández-Llamazares Á, Estela N, Mominee R, Guallar F (2012). Perspectives on sustainable resource conservation in community nature reserves: A case study from Senegal. Sustainability. 4: 3158–3179. DOI:10.3390/su4113158.

Pérez-Acosta AM, Sánchez AR, Vargas MC (2008). Albert Ellis (1913-2007): Pionero de los modelos mediacionales de intervención. Behavioral Psychology. 16: 2: 341–348.

Pruetz JD (2013). Studying Apes in a Human Landscape. In: Primate Ethnographies. K. Strier, Ed. Pearson Publishers. ISBN.

Pruetz J, Bertolani P (2009). Chimpanzee *(Pan troglodytes verus)* Behavioral Responses to Stresses Associated with Living in a Savannah-Mosaic Environment: Implications for Hominin Adaptations to Open Habitats. PaleoAnthropology 252–262. DOI:10.4207/PA.2009.ART33.

Ramón M, Llana M, Estela N, Pacheco L, Hockings K, Hill C. The fruit of discord? Saba senegalensis use by chimpanzees and local people in Senegal. Poster. 7th European Federation for Primatology Meeting. 21-25 August 2017. University of Strasbourg, France.

Richards P (2000). Chimpanzees as political animals in Sierra Leone. In: Natural Enemies: People–Wildlife Conflicts in Anthropological Perspective (J. Knight. ED.) London, UK: European Association of Social Anthropologists. pp. 78–103. London UK Press.

Rust NA, Abramsb A, Challenderc D, Chaprond G, Ghoddousie A, Glikmanf JA, Gowang CH, Hughesh C, Rastogii A, Saidc A, Suttonj A, Taylork N, Thomasl S, Unnikrishnanm H, Webbern AD, Wordinghamo G, Hill CM (2017). Quantity Does Not Always Mean Quality: The Importance of Qualitative Social Science in Conservation Research. Society & Natural Resources. DOI:https://doi.org/10.1080/08941920.2017.1333661.

Setchell JM, Fairet E, Shutt K, Waters S, Bell S (2017). Biosocial Conservation: Integrating Biological and Ethnographic Methods to Study Human–Primate Interactions. Int J Primatol. 38:401–426. DOI 10.1007/s10764-016-9938-5.

Sousa J, Ainslie A, Hill CM (2017). Sorcery and nature conservation. Environmental Conservation. 1-6. DOI: 10.1017/S0376892917000327.

Sousa J, Vicente L, Gippoliti S, Casanova C (2014). Local knowledge and perceptions of chimpanzees in Cantanhez National Park, Guinea-Bissau. Am. J. Primatol. 76: 122–134. Doi:10.1002/ajp.22215.

Tappan GG, Sall M, Wood EC, Cushing M (2004). Ecoregions and land cover trends in Senegal. J. Arid Environ. 59: 427–462. DOI:10.1016/j.jaridenv.2004.03.018.

Thomas JA, Telfer MG, Roy DB, Preston CD, Greenwood JJ, Asher J, Fox R, Clarke RT, Lawton JH (2004). Comparative losses of British butterflies, birds, and plants and the global extinction crisis. Science. 303: 1879–1881. DOI:10.1126/science.1095046.

Torres J, Brito JC, Vasconcelos MJ, Catarino L, Gonçalves J, Honrado J (2010). Ensemble models of habitat suitability relate chimpanzee *(Pan troglodytes)* conservation to forest and landscape dynamics in Western Africa. Biological Conservation. 143: 416–425.

Vodouhê FG, Coulibaly O, Adégbidi A, Sinsin B (2010). Community perception of biodiversity conservation within protected areas in Benin. For. Policy Econ. 12: 505–512. DOI:10.1016/j.forpol.2010.06.008.

Waller MT, Pruetz J (2016). Competition Between Chimpanzees and Humans : The Effects of Harvesting Non- timber Forest Products. Ethnoprimatology 157–177. DOI:10.1007/978-3-319-30469-4.

Watkins CA (2009). Natural resource use strategies in a forest-adjacent Ugandan village. Hum. Ecol. 37: 723–731. DOI:10.1007/s10745-009-9268-8.

Webber AD and Hill CM (2014). Using Participatory Risk Mapping (PRM) to identify and understand people's perceptions of crop loss to animals in Uganda. PLoS One. 9(7). DOI:10.1371/journal.pone.0102912.

Wood EC, Tappan GG, Hadj A (2004). Understanding the drivers of agricultural land use change in south-central Senegal. J. Arid Environ. 59: 565–582. DOI:10.1016/j.jaridenv.2004.03.022

CHAPTER 2

The Impact of Anthropogenic Activities on Faecal Cortisol and T3 on Wild Chimpanzees *(Pan troglodytes verus)* in West Africa

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Abstract

Our objective was to measure faecal cortisol metabolites of chimpanzees from a Reserve in Senegal to assess if anthropogenic activities had an impact and consequently, estimate their welfare. Hundred and fifty-five fresh faecal samples were collected in 4 sites with different characteristics (fires, crops, human pressure and control) from 2014 to 2015. The analysis of faecal cortisol was performed by Enzyme-Linked ImmunoSorbent Assay (EIA) and validation protocol has been performed. The curves with standard and faecal samples showed parallel displacement (standard curve $y = 0.1488x - 0.0987$, $R^2 = 0.9692$, pooled faecal samples $y = 0.149x - 0.0080$, $R^2 = 0.9137$). T3 hormone analysis was also performed to assess nutritional stress. It has been found that the months of study had a significant effect on hormones ($P < 0.0001$); however, within the months, there was no effect of the sites ($P = 0.1336$). The non-effect of the sites would rule out the impact of protected areas and the habituation of chimpanzees to human presence. The effect of the months may be related to anthropogenic activities like the competition for water and fruits of the forest. There was a relationship between lack of food and nutritional stress. In addition, intrinsic factors of chimpanzee species could be added, such as travel to foraging seasonal forest fruits, mating season or agonistic interactions between groups. Thus, faecal cortisol and T3 metabolites analysis are a valid tool to assess chimpanzees stress and wellbeing.

1. Introduction

Currently, we are experiencing a crisis of biodiversity [Gibson et al, 2011] due to the world population growth, increasing market demands, expansion of agriculture, fragmentation of habitats, deforestation, growth of economic inequalities, and disappearance of species that strengthens the hypothesis of the sixth extinction of the history [Thomas et al., 2004]. The most affected areas are the Neo tropics where the population of large primates is decreasing alarmingly [Estrada et al., 2017].

The impact of human activities on biodiversity [Butchart, 2010] gives its name to the current Anthropocene era [Crutzen and Stoermer, 2000; Corlett, 2015; Hockings et al., 2015]. Human disturbance has consequences on primates in behaviour, demography, morbidity, health and physiology [Bishop et al., 1981; Cooke et al., 2014]. Most studies in primates have found higher levels of stress regarding anthropogenic activities such as tourism [Behie et al., 2010; Rangel-Negrín et al., 2014; Maréchal et al., 2014; Muehlenbein et al., 2014; Shutt et al., 2014], habitat fragmentation [Behie, 2010; Rangel-Negrín et al., 2014; Martínez-Mota et al, 2007], disturbed habitat [Jaimez et al., 2012], compared to other studies that found no clear effects of human activities [Vanlangendonck et al., 2015; Hvenegaard et al., 2014; Rimbach et al., 2013; Aronsen et al., 2015]. As a result further studies are needed to know the effects in humanized areas in chimpanzees to improve conservation management. In Senegal there are anthropogenic activities such as the expansion of agriculture, gold mines, forest fruits competition, transmission of diseases, poaching and illegal trade of chimpanzees *(Pan troglodytes verus).* As a result, human-wildlife conflict is increasing [Boyer-Ontl et al., 2014; Humle et al., 2016; Pruetz, 2011].

Recent studies investigate the anthropogenic impact on the conservation of primates at the physiological level [Aronsen et al., 2015; Carlitz et al., 2016; Rangel-Negrín et al., 2014; Shut et al., 2014; Smith-Aguilar et al., 2016; Vanlangendonck et al., 2015; Wittig et al., 2016]. A physiological indicator to evaluate stress is to assess the changes of cortisol levels in blood or other biological matrixes. A stimulus can trigger the stress response in an individual by the activation of the hypothalamic-pituitary-adrenocortical (HPA) axis that releases glucocorticoids such as cortisol [Arck et al., 2001; Cocks L, 2007; Wittig et al., 2016]. In primates, the glucocorticoid hormone cortisol is secreted in response to various stressors to address them within a short time. Elevated cortisol secretion for prolonged periods of time severely diminishes individual health due to a decrease of the immune response, multiple organ dysfunction, rise in infertility, reduction growth and appearance of abnormal behaviours [Rangel-Negrín et al., 2014; Carlitz et

al., 2016; Chrousos, 1992, 2009; Arck et al., 2001; Cocks L, 2007; Santos et al., 2000; Möstl and Palme, 2002; Sheriff et al., 2010; Romero et al., 2001].

The quantification of cortisol can be carried out in plasma, saliva, urine and faeces [Cocks L, 2007; Mormède et al., 2007]. In some studies, concentrations of faecal cortisol metabolites (FCM) have been studied as a non-invasive biomarker of the severity of anthropogenic impacts on primates [Carlitz et al., 2016; Maréchal et al., 2011; Rimbach et al., 2013; Shutt et al., 2014]. Faeces are easy to collect and the animals are not disturbed. The FCM reliably reflects the levels of free cortisol in the blood [Sheriff et al., 2010]. There are studies that have found an increase in stress levels in the face of tourism exposure [Romero and Wikelski, 2001; Behie et al., 2010]. High levels of stress due to tourism can negatively affect animal health, reproductive success, survival [Romero and Wikelski, 2001; French et al., 2010], and, even, population decline [Charbonnel et al., 2008]. Recent studies have found changes in cortisol levels in the face of anthropogenic disturbances such as contamination, exposure to humans, lack of protection of natural areas and fragmentation of habitats [Behie et al., 2010; Carlitz et al., 2016; Rangel-Negrín et al., 2014; Vanlangendonck et al., 2015].

FCM and thyroid hormone metabolites (T3) are used to monitor stress by disturbance or nutrition within and between years. These two endocrine systems work closely [Wunderink et al., 2012]. FCM rapidly rise in response to poor nutrition, cold temperature and disturbance stressors, mobilizing glucose to provide energy to deal with the immediate emergency [Sapolsky et al., 2000; Stetz et al., 2013]. The FCM signal from nutritional stress should be lower when there is abundance of food while the highest when human disturbance is high [Ayres et al., 2012]. Thyroid hormone (*triiodothyronine*, T3) produces a more conservative response to nutritional and thermal stress, functioning by adjusting metabolism. On the first occasion that food is scarce T3 levels are low to allow the body to use all available fuel to search for food. If the conditions of lack of food persist, T3 abruptly declines, lowering metabolism to prevent the body from exhausting its remaining fuel stores [Douyon and Schteingart, 2002; du Dot et al., 2009; Lee et al., 2014; Wasser et al., 2010]. T3 is relatively unresponsive to disturbance stress [Wasser et al., 2017].

The aim of this research is to measure concentration of cortisol and T3 metabolites in faeces of chimpanzees in the Réserve Naturelle Communautaire de Dindéfélo (RNCD) to assess the effect of anthropogenic activities in the different study sites in the various months of the two years of the investigation. If cortisol levels are higher in those areas

and months of greater anthropogenic activity, it could be an important indicator of stress, and a threat to welfare, of the chimpanzees in the Reserve.

2. Materials and methods

2.1. Study sites and sample collection

The RNCD (12º24'N, 12º18'W) covers an area of 14,050 ha. It is located in the region of Kedougou, in the extreme southeast of Senegal. It is The Sudan savannah and The Guinean forest that make up a mosaic of patches of forests, crops and pastures as result of human activities. The Sudan savannah consists of grasslands with patches of trees interspersed with lateritic soils. The Guinean forest is made up of semi-deciduous forests, canyons and drainage galleries [Pacheco 2012, 2013; Pruetz, 2009].

Rainfall averages less than 1,000 mm annually. The wet season is from June to September / October and the dry season from November to April / May. In the dry season temperatures exceed 40 degrees Celsius, especially from March to May. The softest temperatures are from June to January, around 25 degrees Celsius [Pruetz, 2009].

The research permit was granted by Direction Des Eaux Et Forêts, Chasses Et Conservation Des Sols of Dakar (Senegal) and the Ministry of Agriculture, Food and Environment of the Government of Spain. Fresh faecal samples were collected during transects to search for chimpanzees in the RNCD. These transects were made by tracks of chimpanzees found (nests, food rests, excrements, fingerprints), vocalizations or, to a lesser extent, by local reports. The collection of samples began in 2014 from April to July. Then the collection was interrupted due to the prevention protocol for the Ebola epidemic. In 2015, when Ebola alert decreased, it was possible to collect more samples in the last four-month period. The faeces were collected in 5 sites of the RNCD in 2014 but in 2015 only in 3 sites because 2 were closed by Ebola alert. One of these 2 closed sites was eliminated due to lack of data. Finally, 4 sites had different characteristics: Nandoumary (Djogoma II)-fires, Dindéfélo-human pressure, Sabe-crops (Republic of Guinea) and Segou-control.

The faecal samples were collected in 4 groups of chimpanzees: 1) 20 individuals approximately semi-habituated in Segou in the process of identification, which have less human impact (control group). From this group of animals, faecal samples were collected in May 2014 and in the last quarter of 2015; 2) 10 habituated and identified chimpanzees in Dindéfélo where there is a high frequency of encounters between humans and wildlife due to the proximity of the village to the forest. In the last area, there is an increase of

people in the forest during, the months of April and May. Due to the high temperatures the local people look for refreshment in the tourist waterfall. In addition, the local people go to the forest to catch water because other spots are dry. It also coincides with the fact that chimpanzee foods are in the same place and time. From this group, samples were collected in all the months of collection; 3) approximately, 20 chimpanzees in Nandoumary, difficult to identify because they are not habituated and maintain a long distance with humans. In a characteristic area due to the lack of basic resources such as water and numerous hectares are burned every year to open crops in a poor land. From these groups of chimpanzees, faecal samples were collected in the last four-month period of 2015; 4) around 47 chimpanzees in Sabe (Republic of Guinea), where the water is even scarcer and the forests are fragmented by many crops. From these groups of chimpanzees, faeces were collected in April and May of 2014 (Table 1).

In 2014, Segou and Dindéfélo groups were observed together with other chimpanzees in the Dindéfélo forest, with the hypothesis that they could be from the same community. Chimpanzees from Nandoumary were observed in Sabe. Also Sabe chimpanzees were observed in Nadoumary. So that could be another community. During 2015, four male chimpanzees from Nandoumary visited Dindéfélo with high frequency, showing agonistic behaviours towards resident males. Finally, the resident females of Dindéfélo have been observed next to the 4 foreign males, the resident juvenile male of Dindéfélo has not been seen again and the resident adult male was later observed with lesions on the genitals [Franch et al., 2017].

Table 1. Characteristics of the study sites.

Study groups	**Segou Control**	**Dindéfélo Human pressure**	**Nandoumary Fires**	**Sabe Crops**
Year	2015	2014-2015	2015	2014
Sample collection months	Last four-month period 2015	All months of collection	Last quarter of 2015	April and May 2014
Levels of forest fragmentation	1	2	4	3
RNCD	In the limits of the Reserve	In the limits of the Reserve	Inside the Reserve	Outside the Reserve
Human impact	Minimum	Encounters humans-wildlife	Forest fires	Crops
Number of chimpanzees	20	10	20	47
Number of samples	29	73	32	21

Fresh faecal samples were collected opportunistically during transects, from beneath night nests and behavioural samplings non-invasively [Edwards and Ullrey, 1999]. The excrement was opened and 5 grams were collected from the centre of the sample. It was

introduced inside the tube and labelled with the corresponding data. After the samples were dried in a dryer at 60 degrees for two hours or in the sun for 5 hours. Then, 5 ml of silica gel was added. The samples were stored at room temperature [Arandjelovic et al., 2011; Murray et al., 2013; Nugraha et al., 2016; Nsubuga et al., 2004; Rangel-Negrín et al., 2014]. After the samples were taken to the laboratory of the Autonomous University of Barcelona, with the appropriate permits, where they were stored in a freezer at -20ºC.

The data of date, time, temperature, humidity, habitat type and GPS coordinates were recorded in the table. The characteristics of the faeces noted were form, texture, smell, size, one or more samples in the same place, location (transect, under a nest, path), individual and content. In the end, a total of 155 faecal samples were collected. The objective was to collect samples of all individuals from each site and several samples over time of the same individuals.

2.2. Faecal hormone analysis and validation tests

We analysed all faecal samples of *P. t. verus* using a previously validated EIA (Enzyme Immunoassay kit). After the hormone extraction procedure from the collected faeces, the quantification of FCM was performed through EIA (DetectX® Cortisol Enzyme Immunoassay, Cenador Assays Inc., Ann Arbor, MI, EE. UU.). Chimpanzees' pooled faecal extracts, when added to the standard curve points, exhibited an accuracy of R^2 = 0.99. The intra-assay coefficient of variation was 6.2% and the inter-assay coefficient was 9.85%. The average recovery percentage (MEAN ± SD) was 103.25 ± 5.97%. The sensitivity was 1.760 ng of FCM/100mg dry faeces. The curves with standard and samples showed parallel displacement (standard curve y = 0.1488x - 0.0987, R^2 = 0.9692; pooled faecal samples y = 0.149x - 0.0080, R^2 = 0.9137). All samples were run in duplicate, and mean FCM values are reported as ng/100 mg (dry faeces). Subsequently, T3 analysis was performed on 60 faecal samples randomly selected, previously validated EIA (Enzyme Immunoassay kit).

2.3. Statistical analysis

FCM data were not normally distributed but approximated normal distribution with log transformation of faecal data. ANOVA test was carried out to examine the effect of the month, the site and their interaction (month x site effect) on cortisol concentrations. The residual maximum likelihood was used as a method of estimation and the least square

means of fixed effects (LSMEANS). Differences of Least Squares Means with adjustment of Turkey-Kramer were used to compare the months between them. Spearman correlation coefficient between FCM and T3 was calculated. Statistical analyses were performed by means of the Statistical Analysis System (SAS® 9.2. Institute Inc., Cary, NC). The significance level considered was $P < 0.05$.

3. Results

The results indicated homogeneity between the two methods of drying samples (32±60 ng/100 mg drying in the sun and 38±30 ng/100 mg with dryer). The descriptive statistics are presented in Table 2. In FCM levels, the age of the faeces was not a covariate ($P = 0.34$).

Table 2. Mean±SD and (range) of faecal cortisol metabolites level (ng/ 100 mg dry faeces) of chimpanzees sampled according to the month number, temperatures and year. Different lowercase letters indicate significant differences between months ($P < 0.05$).

Month number	Temperatures	Year	Mean +/- SD (range)
4 April (N=30)	High	2014	10.4±11.4 (1.4, 43.6)[a]
5 May (N=14)	High	2014	16.2±14.4 (1.4, 43.5)[a,b]
6 June (N=19)	High	2014	27.5±27.1 (4.0, 96.8)[b,c]
7July (N=4)	High/Soft	2014	3.2±1.4 (2.1, 5.3)[a]
9 September (N=8)	Soft	2015	43.4±31.5 (22.5, 117.9)[c]
10 October (N=21)	Soft	2015	56.5±108.1 (8.1, 519.9)[c]
11 November (N=28)	Soft	2015	35.4±30.1 (6.4, 138.0)[c]
12 December (N=31)	Soft	2015	50.7±71.7 (5.3, 363.3)[c]

A significant effect of the month on FCM has been found ($P < 0.0001$). When comparing the months between them, there were significant differences (Table 2). In the last quarter of 2015, FCM values were higher than in the first quarter of 2014.

However, within the month there was no effect of the site on FCM ($P = 0.13$). There could be a trend in month 11 ($P = 0.06$). In month 5 (May), FCM levels tended to be higher in site 1 (Dindéfélo) than site 3 (Sabe). In month 11 (November), FCM levels tended to be

higher in site Dindéfélo than site Segou (Table 3). No further significant differences between sites were observed.

Table 3. Mean±SD of faecal cortisol metabolites level (ng/100 mg dry faeces) according to the site in month 5 and 11. Different capital letters indicate significant differences between months ($P < 0.05$).

Month number	**Site Dindéfélo** N=73	**Site Nandoumary** N=32	**Site Sabe** N=21	**Site Segou** N=29
5 May (N=14)	31.3±13.4	No samples	10.6±11.8	No samples
11 November (N=28)	47.9±40.8	38.7±27.8	No samples	17.8±8.0

Apparently high cortisol values were included because there was not much difference in the statistics. The descriptive statistics of T3 are presented in Table 4. In T3 the age of the faeces was not a covariate ($P = 0.48$).

Table 4. Mean±SD and (range) of T3 (ng/100mg dry faeces) of chimpanzees sampled according to the month number, temperatures and year. Different lowercase letters indicate significant differences between months ($P < 0.05$).

Month number	**Temperatures**	**Year**	**Mean +/- SD (range)**
4 April (N=30)	High	2014	3.7±0.9 (2.5, 5.3) [a]
5 May (N=14)	High	2014	6.4±5.6 (2.7, 19.9) [a]
6 June (N=19)	High	2014	4.4±1.0 (3.1, 6.1) [a]
7 July (N=4)	High/Soft	2014	2.9±0.4 (2.5, 3.6) [a]
9 September (N=8)	Soft	2015	9.3±4.9 (5.9, 19.2) [b]
10 October (N=21)	Soft	2015	9.4±3.2 (5.1, 14.8) [b]
11 November (N=28)	Soft	2015	5.4±1.3 (3.8, 7.8) [a,b]
12 December (N=31)	Soft	2015	7.1±1.8 (3.9, 9.3) [a,b]

There was a significant effect of the months on T3 levels, with higher levels in the last quarter of the year, with the exception of November (table 4).

However, within the month there was no effect of the site on T3 (*P* = 0.09). Only a tendency in month 5 to be higher in site 1 was detected (*P* = 0.06) (table 5).

Table 5. Mean±SD of T3 (ng/100 mg dry faeces) according to the site in month 5 (May).

Month number	**Site Dindéfélo N=24**	**Site Nandoumary N=11**	**Site Sabe N=8**	**Site Segou N=11**
5 May 2014 (N=14**)**	12.5±7.5	No samples	3.93±0.8	No samples

When comparing FCM with T3, they followed a similar evolution (Figure 2). FCM and T3 were significantly correlated r_s = +0.74 (P<0.0001). The possible variables that could be related to FCM and T3 in each month are outlined in table 6.

Figure 1. Comparison of faecal cortisol metabolites (FCM, ng/100mg dry faeces) and faecal thyroid hormone (*triidothyronine*, T3, ng/100mg dry faeces) in RNCD.

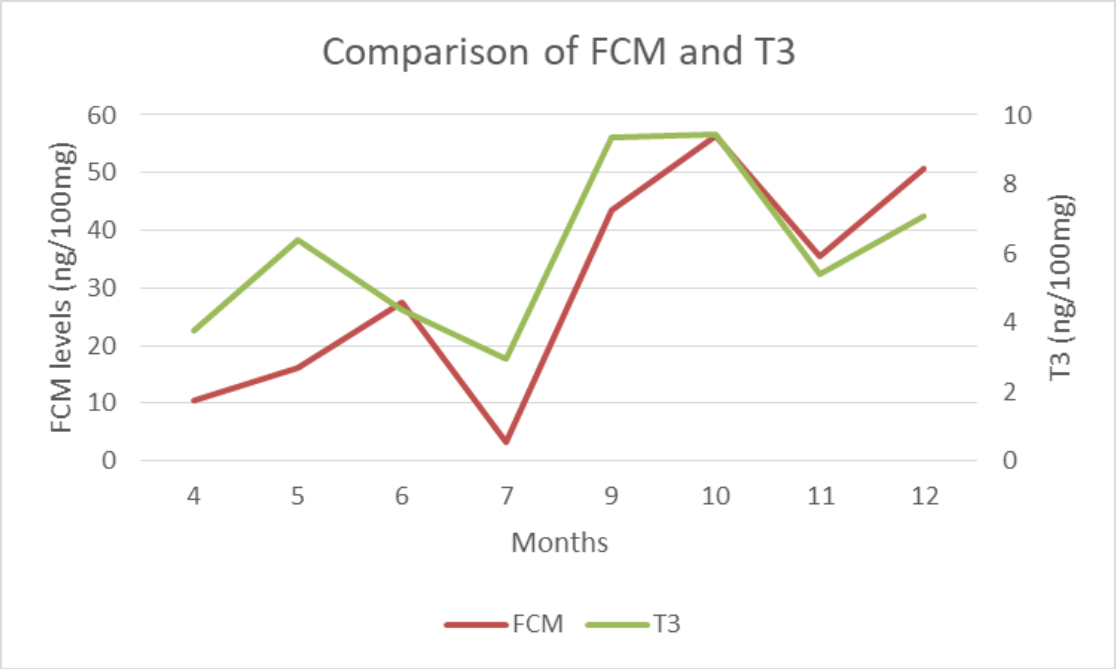

Table 6. Human disturbance, food availability and other factors in each month (number) of study in RNCD.

Month number	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**
Human Disturbance	high	very high	very high	low	low	low	low	low
Food availability	++	+++	++	+	++	+++	++	+++
Others factors			Mating season		Water Well + Chimp War	Water well	Travel	Feed competition inter groups

The availability of food was quantified based on the remains found in the excrement (Table 7).

Table 7. Availability of food for chimpanzees in percentages according to the content found in the faeces. The contents of faeces 1 were the remains found in greater quantity. The contents of faeces 2 were the remains found in smaller amount.

YEAR	MONTH	CONTENTS OF FAECES 1			CONTENTS OF FAECES 2		
		FRUIT	SCIENTIFIC NAME	%	FRUIT	SCIENTIFIC NAME	%
2014	APRIL	N'dologa	*Pseudospondias microcarpa*	58.97	No data		41.06
		Termites		12.82	Termites		17.95
		No data		12.82	Hyibbe	*Ficus sur*	15.38
		Kewe	*Oxytenanthera abyssinica*	5.13	Kewe	*Oxytenanthera abyssinica*	10.26
		Goumbambe	*Cola cordifolia*	2.56	Ants		7.69
		Lare	*Saba senegalensis*	7.69	Bee		2.56
					Nete	*Parkia biglobosa*	2.56
					Hair		2.56
	MAYO	Thieke	*Ficus sp*	48.15	No data		25.93
		Lare	*Saba senegalensis*	37.04	Nete	*Parkia biglobosa*	25.93
		Ede	*Sclerocarya birrea*	7.1	Termites		18.52
		Thiouko Choly		7,41	Kewe	*Oxytenanthera abyssinica*	14.81
					Thiouko chedu	*Lannea acida*	11.11
					Goumbambe	*Cola cordifolia*	3.70
	JUNE	Lare	*Saba senegalensis*	98.15	No data		90.74
		Thieke	*Ficus sp*	1.85	Goumbambe	*Cola cordifolia*	7.41
					Thiale badi	*Opilia celtidifolia*	1.85
	JULY	Lare	*Saba senegalensis*	75.00	No data		75.00
		Bani	*Pterocarpus erinaceus*	25.00	Thiale badi	*Opilia celtidifolia*	25.00
	AUGUST	Poore	*Landolphia heudelotii*	100.0	Thieke	*Ficus sp*	66.67
					No data		33.33
2015	SEPTEMBER	Thiale	*Spondias mombin*	62.50	No data		50.00
		Koukou	*Diospyros mespiliformis*	25	Leaves		25,00
		Kewe	*Oxytenanthera abyssinica*	12.50	Kewe	*Oxytenanthera abyssinica*	25.00
	OCTOBER	Thiale	*Spondias mombin*	85.71	Kewe	*Oxytenanthera abyssinica*	33.33
		Boyle	*Hexalobus monopetalus*	9.52	No data		28.57
		Koukou	*Diospyros mespiliformis*	4.76	Koukou	*Diospyros mespiliformis*	9.52
					Hyibbe	*Ficus sur*	4,76
					Leaves		4,76

					Thiouko chedu	*Lannea acida*	4,76
					Boyle	*Hexalobus monopetalus*	4,76
					Laka	*Cissus populnea*	4,76
					Bones		4,76
	NOVEMBER	Laka	*Cissus populnea*	29,63	Hyibbe	*Ficus sur*	25,92
		Bhohé	*Adansonia digitata*	25,93	Thieke	*Ficus sp*	14,81
		Bumme	*Vitex madiensis*	18,52	Bhohé	*Adansonia digitata*	14,81
		Thiale badi	*Opilia celtidifolia*	11,11			
		Hyibbe	*Ficus sur*	7,41	Thiale	*Spondias mombin*	11,11
		Thieke	*Ficus sp*	3,70	Kelly	*Grewia bicolor*	11,11
		Diabhe(Tamarindo)	*Tamarindus indica*	3,70	No data		7,41
					Laka	*Cissus populnea*	7,41
					Ants		3,70
					Seleki	*Grewia sp.*	3,70
	DECEMBER	Bhohé	*Adansonia digitata*	60,61	Bhohé	*Adansonia digitata*	33,33
		Kelly	*Grewia bicolor*	15,15	No data		18,18
		Thieke	*Ficus sp*	12,12	Hyibbe	*Ficus sur*	18,18
		Diabhe(Tamarindo)	*Tamarindus indica*	9,09	Diabhe(Tamarindo)	*Tamarindus indica*	12,12
		Koukou	*Diospyros mespiliformis*	3,03	Kelly	*Grewia bicolor*	9,09
					Leaves		3,03
					Thieke	*Ficus sp*	3,03
					Koukou	*Diospyros mespiliformis*	3,03

4. Discussion

The results showed significant effects in concentration of FCM and T3 in relation to the months of the year but not in relation to the study areas. The stress was higher in the months of May and June of 2014 on one side, and even more in the last four months of the year 2015. However, in July, FCM levels dropped significantly.

In April and May temperatures reached their highest quotas, around 35º Celsius [Pruetz, 2009] and most of the water points were dry. So humans and chimpanzees competed for basic resources in the small gallery forests [Pruetz, 2011]. Encounters intensify and distances are reduced, which causes chimpanzees to run away and in many cases humans also [Pacheco et al., 2012]. Humans caught water from the river (wash clothes and kitchen utensils, shower and drink) and chimpanzees found water and its fruits in these small gallery forests. Both took refuge from extreme temperatures. In addition, the first forest fires started to open crops. More than 75% of these apes' home range is

burned annually [Pruetz and Herzog, 2017]. It was also the time of greatest tree felling in the forest and collection of dead wood. Given the scarcity of resources, the transhumant took their animals at forest to feed. The local cows also fed of the forest. The Eco guards reinforced their vigilance and the conflicts with locals grew up due to the competition of natural resources. Several studies have been found relationships between increases in stress in primates and human disturbances [Aguilar-Melo et al., 2013; Dantzer et al., 2014; Dunn et al., 2013; Gómez-Espinosa et al., 2013; Jacobson et al., 2017; Jaimez, 2011; Shutt et al, 2014; Vanlangendonck et al, 2015]. However, in April FCM levels were low for high human disturbance, which could be explained by chimpanzees were observed in areas not so dominated by humans. Also the levels of T3 were low [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016] which could be explained because the N'dologa *(Pseudospondias microcarpase)* was running out and the lare *(Saba senegalensis)* did not finish ripening to feed [Bertolani and Pruetz, 2011; McGrew et al., 1988].

In May**,** FCM levels increased. Chimpanzees were observed in areas with anthropogenic activity such as washing in the river and high season tourism to bathe in rivers and waterfalls. In Dindéfélo, the highest peak of tourism was registered during the study, 300 tourists were counted in 30 minutes, even less than 40 meters far from chimpanzee resting areas. Numerous studies have been found high levels of cortisol related to anthropogenic activities [French et al., 2010; Maréchal et al., 2011; Shutt et al., 2014]. The lack of water and food is extreme until the rains arrive. Domestic animals were starved for food in the forest. The forest fires intensified to prepare the crops before the first rains. In Segou, chimpanzees were observed screaming when they were faced with fire unlike the quiet monitoring of the chimpanzees of Fongoli [Pruetz and LaDuke, 2010]. The fruit of this month was the lare *(S. senegalensis)* by which chimpanzees and humans compete [Pruetz, 2011; Ramón et al., 2017]. Thieke *(Ficus sp)* and *S. senegalensis*'s availability could explain the rise in T3 levels [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016].

In June, the rains started. The temperatures went down and gave a rest until September (27ºCelsius) [Pruetz, 2009]. However the human disturbance continued in the forest until July. Harvesting of *S. senegalensis* fruits occurred as a key activity by local people in June [Pruetz, 2011; Ramon et al., 2017] which could explain increases in FCM. Further one meeting that took place in Dindéfélo between several groups of chimpanzees. Of those who were identified by Segou and Dindéfélo but there were more groups. It was a social meeting, the primates were calm, but there were many females in oestrus which could explain as well the increase in FCM concentrations. Balestri et al [2014] found

higher faecal cortisol levels in lemurs during gestation and mating season. Takeshita et al [2014] discovered higher concentrations of faecal cortisol in macaques during the mating season than lactating season. Alike in Barbary macaques, some authors have been found elevations of T3 in mating season [Cristóbal-Azkarate et al., 2016] that were explained by the high energy activity [Emery Thompson and Georgiev, 2014], intrasex competition [Heistermann et al., 2008], benefits by increasing its aerobic capacity [Hayes and Garland, 2007] and as T3 promotes testis maturation and semen quality [Wagner et al., 2008]. However, *S. senegalensis* was running out and the chimpanzees fed on the scarce fruits as: douki *(Cordyla pinnata)*, Kewe *(Oxytenanthera abyssinica)* [Bertolani and Pruetz, 2011], thieke *(Ficus sp)*, goumbambe *(Cola cordifolia),* thiale badi *(Opilia celtidifolia),* thiouko chedu *(Lannea acida)* and nete *(Parkia biglobosa)* which would be related to a decrease in T3 levels [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016].

In July, the rains reached the highest quotas (190 mm) [Pruetz, 2009]. The abundance of water allowed humans to have easy access near their homes and then they did not go to the forest which would be related to lower peak faecal cortisol metabolites in chimpanzees. Regarding the availability of food, chimpanzees fed what's left of *S. senegalensis* and bani *(Pterocarpus erinaceus),* thiale badi *(O. celtidifolia),* douki *(C. pinnata),* lengue *(Afzelia Africana),* goumbambe *(C. cordifolia)* and kewe *(O. abyssinica)*. It seemed one of the months with less trophic resources. When chimpanzees eat *O. abyssinica* it seemed that there was not much to feed because the bamboo is all year round. Which could explain the lowest peak of T3 it has been found [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016]. The availability of food was more related to the observation of fruits and phenology than to the content of seeds found in the faeces.

In September**,** FCM levels started to increase. The temperatures were still warm and, the rains were plentiful and the rivers had their greatest flows. People did not usually go to the forest, however in Dindéfélo there was a clearing of a large area of land in a highly restricted area to the passage of people, to build a great water well. This well would supply water to several villages with running water. During this month the noise of chainsaws and drills was daily in the forest. Several females' chimpanzees were observed vocalizing of fear to less than 40 meters from the drill for the construction of the water well. Further some shot also happened when a chimpanzee approached crop fields in Nandoumary although in the Reserve there is no problem of crop feeding with chimpanzees, it is more with Guinea Baboons *(Papio papio)* or Green Monkeys (*Chlorocebus sabaeus)*.

Also there was a war between two groups of chimpanzees. Four Nandoumary males fought Dindéfélo's group. Broken branches and blood were found after hours of very loud vocalizations. Later the females came to be with the males of Nandoumary. The adult male resident was not seen him again that year, only tracks (food and excrements) [Franch et al., 2017]. Months later, he was observed with lesions in the external genitalia. The juvenile male has not been seen again. There are numerous studies that support increases in cortisol with aggressive behaviour in primates [Muller and Wrangham, 2004; Rangel-Negrín et al., 2014; Yamanashi et al., 2016]. It has been found increases in cortisol levels associated with agonistic interactions more frequently in those groups of primates that lived in smaller habitats [Gómez-Espinosa et al., 2013].

Regarding the availability of food, the food continued to be scarce, although there was a little more than in July, thiale *(Spondias mombin),* Koukou *(Diospyros mespiliformis)* and Kewe *(O. abyssinica*) [McGrew et al., 1988]. The temperatures continued to fall. These factors could partially explain the increases in T3 [Cristóbal-Azkarate et al., 2016; Silva, 2003, 2006], however, more studies are needed at this point.

In October it is the month with the highest levels of FCM and T3. It continues without human disturbance in the forests except in Dindéfélo which continued the excavation to build a large water well. Chimpanzees were again observed vocalizing with fear near this excavation which could explain the high levels of cortisol. The amount of thiale *(S. mombin)* was higher and low temperatures which could explain the high levels of T3 [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016; Silva, 2003, 2006].

In November**,** FCM levels dropped. Chimpanzees began to be observed in areas where there were Bhohé *(Adansonia digitata)* [Bertolani and Pruetz, 2011; McGrew et al., 1988] and are usually less humanized areas which could explain the decline in faecal cortisol. Although there was little food and especially the chimpanzees had to travel to find fruits of that time that was *A. digitata,* which could explain that faecal cortisol levels remained high [Carlitz et al., 2016; Rangel.Negrín et al., 2014]. Bhohé's availability was still low, which could be related to the decrease in T3 levels [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016].

In December, most chimpanzees were found in the Nandoumary area and where there was *A. digitata*. On the one hand, there could be stress from the displacement until finding the food [Behie et al, 2010, Bertolani and Pruetz, 2011; Dunn et al., 2013; Muller and Wrangham, 2004] and the rise in FCM could perhaps be explained as well by a possible competition for food when several groups met in the same area. Several studies have been found relationships between elevations of faecal cortisol and inter-group

competition for food [Behie, 2010, Rangel-Negrín et al., 2014]. On the other hand, when there was more food availability, *A. digitata*, the levels of T3 risen [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016].

In addition, significant relationships were found when comparing the months of April-July with the months of September-December. Variations in cortisol levels depending on the season in protected habitats have been previously reported for black howler monkeys in the Yucatán Peninsula [Rangel-Negrín et al., 2014]. High faecal cortisol levels have been found in lemurs in the dry season due to the high effort to feed [Cavigelli, 1999]. The macaques had more travel time during the dry season and increases in cortisol levels [Gómez-Espinosa et al., 2013]. In dry season decreases the availability of food [Pruetz, 2011, Schaffner, 2012], animals spend more energy in looking for food which is associated with increases in stress [Foerster et al., 2012]. It has been found levels of cortisol higher in the dry season in primates and suggested a metabolic adaptation to maintain homeostasis in the drier one with, hotter conditions [Carnigie et al., 2011]. Also this lack of food availability during the dry season has also been linked to anthropogenic activities and fragmented habitats [Rangel-Negrín et al., 2014]. Our results did not coincide so much with the seasons but with the second and last quarter in high levels of FCM and T3, on the one hand, and, on the other hand, in July the levels deplomated. These values could be related with the mentioned variables (anthropogenic activities, availability of water and food, temperature and social dynamics of primates) [Borg et al., 2014; Cristóbal-Azkarate et al., 2016; Martínez-Mota, 2007; Silva, 2003, 2006].

In contrast to our starting hypothesis, there were no significant effects of the site on hormonal levels, which would rule out the effects of habitat fragmentation, protected areas and habituation of chimpanzees. Other studies did not find cortisol variations due to habitat fragmentation [Balestri et al, 2014] or fragment size [Rimbach, 2013]. However, Carlitz [2016] found increases in cortisol in forest fragments like Martínez-Mota [2007]. There are also studies that have found more stress in primates in unprotected areas, specifically, black howler monkeys living in unprotected habitats had higher FCM levels due to increased physiological stress associated with anthropogenic disturbance, within-group competition for resources and possibly food scarcity [Rangel-Negrín et al., 2014; Martínez-Mota, 2007]. Several studies have been found higher levels of stress in non-habituated primates [Carlitz et al., 2016; Muehlenbein, 2012; Shutt et al, 2014].

Other research with primates has been found, contrary to expectations, that certain anthropogenic activities or disturbances were not related to high levels of cortisol and argue other factors such as group social dynamics, predation rate, food availability or

combination of these factors [Aronsen et al. al, 2015; Chapman et al., 2006; Smith-Aguilar et al., 2016]. Recently, research has been published suggesting that aggressiveness to the extreme of being lethal in chimpanzees *(P. troglodytes)* and bonobos *(Pan paniscus)* is the result of adaptive strategies to gain resources as food or mates and it is not the result of human impact [Wilson et al, 2014]. Diverse studies have been found relationships between aggressiveness and high cortisol levels in primates [Muller and Wrangham, 2004; Rangel, 2014; Yamanashi et al., 2016]. FCM and T3 were significantly positively correlated which matches Wasser's results with moose that they were selecting for forage over security [Wasser et al., 2011].

The implications derived from this study in a dry zone with high extreme temperatures that leads to competition for basic resources (water and food) between humans and chimpanzees would be to consider hormonal analysis as a useful tool [McGrew et al., 2004] to study stress in chimpanzees and an indicator of welfare of these animals in wild. It would be necessary to look for projects that provide alternative areas of refuge and water for humans, as well as washhouses and in this way chimpanzees would have their habitat more protected. It is important to control the massive influx of tourists to waterfalls in gallery forests especially in the hottest months. Reforestation of *S. senegalensis* and *A. digitata* scarce trophic resource for chimpanzees and humans would be necessary. In Nandoumary an agroforestry project is urgently needed to provide food for humans and protect chimpanzee habitat. Sabe need to build a deep well of water.

Due to the scarce number of studies in wild chimpanzees wellbeing, more research is needed to obtain more homogeneous data and to have the identified chimpanzees as an experimental unit in order to extrapolate the information, to get an appropriate method to collect faeces in places without electricity, storage and analysis and samples of all months of several years.

5. Conclusion

FCM levels increased in months with greater anthropogenic activity but also due to lack of food availability or social dynamics of chimpanzees such as mating season, agonistic interactions or inter-groups fed competition. So it would be necessary to build washhouses and water wells in the villages and to control the number of people accessing the protected areas of the Reserve. T3 correlated with the availability of food and temperatures according to the months of the years. In order to improve the conservation of chimpanzees and achieve sustainable coexistence with local people, it

is necessary to take into account several factors: anthropogenic activity, food availability and dynamics of the chimpanzee species.

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7. References

Aguilar-Melo AR, Andresen E, Cristóbal-Azkarate J, Arroyo-Rodríguez V, Chavira R, Schondube J, Serio-Silva JC, Cuarón Ad. Behavioral and Physiological Responses to Subgroup Size and Number of People in Howler Monkeys Inhabiting a Forest Fragment Used for Nature-Based Tourism. American Journal of Primatology. 2013. doi: 10.1002/ajp.22172.

Arandjelovic M, Head J, Rabanal LI, Schubert G, Mettke E, Boesch C, Robbins MM, Vigilant L. Non-Invasive Genetic Monitoring of Wild Central Chimpanzees. PLoS ONE. 2011; 6(3):e14761. doi:10.1371/journal.pone.0014761.

Arck PC, Rose M, Hertwig K, Hagen E, Hildebrandt M, Klapp BF. Stress and immune mediators in miscarriage. Hum Reprod. 2001; Jan 7; 16(7):1505–11. PMID: 11425839.

Aronsen GP, Beuerlein MM, Watts DP, Bribiescas RG. Redtail and red colobus monkeys show intersite urinary cortisol concentration variation in Kibale National Park, Uganda. Conserv Physiol. 2015; 3(1): cov006.

Ayres KL, Booth RK, Hempelmann JA, Koski KL, Emmons CK, Baird RW. Distinguishing the Impacts of Inadequate Prey and Vessel Traffic on an Endangered Killer Whale *(Orcinus orca)* Population. PLoS One. 2012; 7: e36842. https://doi.org/10.1371/journal.pone.0036842 PMID: 22701560.

Balestri M, Barresi M, Campera M, Serra V, Ramanamanjato JB. Habitat Degradation and Seasonality Affect Physiological Stress Levels of Eulemur collaris in Littoral Forest Fragments. PLoS ONE. 2014. 9(9): e107698. doi:10.1371/journal.pone.0107698.

Beehner JC, McCann C. Seasonal and altitudinal effects on glucocorticoid metabolites in a wild primate *(Theropithecus gelada).* Physiology & Behavior. 2008; 95: 508–514. doi:10.1016/j.physbeh.2008.07.022.

Behie AM, Pavelka MS, Chapman CA. Sources of variation in fecal cortisol levels in howler monkeys in Belize. Am J Primatol. 2010; 72(7):600–6. doi: 10.1002/ajp.20813 PMID: 20166191.

Bertolani P and Pruetz JD. Seed Reingestion in Savannah Chimpanzees *(Pan troglodytes verus)* at Fongoli, Senegal. Int J Primatol. 2011. 32:1123–1132 Doi: 10.1007/s10764-011-9528-5.

Bishop N, Hrdy SB, Teas J, Moore J. Measures of human influence in habitats of South Asian monkeys. International Journal of Primatology. 1981; 2:153-167. doi:10.1007/BF02693446.

Borg C, Majolo B, Qarro M, Semple S. Comparison of body size, coat condition and endoparasite diversity of wild Barbary macaques exposed to different levels of tourism. Anthrozoos 2014; 27, 49–63. doi:10.2752/175303714X13837396326378.

Boyer-Ontl KM, Pruetz JD. Giving the Forest Eyes: The Benefits of Using Camera Traps to Study Unhabituated Chimpanzees *(Pan troglodytes verus)* in Southeastern Senegal. Int J Primatol. 2014; 35: 881–894. doi: 10.1007/s10764-014-9783-3.

Butchart SHM, Walpole M, Collen B, van Strien A, Scharlemann JPW, Almond REA, Baillie JEM, Bomhard B, Brown C, Bruno J, Carpenter KE, Carr GM†, Chanson J, Chenery AM, Csirke J, Davidson NC, Dentener F, Foster M, Galli A, Galloway JN, Genovesi P, Gregory RD, Hockings M, Kapos V, Lamarque J, Leverington F, Loh J, McGeoch MA, McRae L, Minasyan A, Hernández Morcillo M, Oldfield TEE, Pauly D, Quader S, Revenga C, Sauer JR, Skolnik B, Spear D, Stanwell-Smith D, Stuart SN, Symes A, Tierney M, Tyrrell TD, Vié J, Watson R. Global Biodiversity: Indicators of Recent Declines. Science. 2010; Vol. 328, Issue 5982, pp. 1164-1168. doi: 10.1126/science.1187512.

Carlitz EHD, Miller R, Kirschbaum C, Gao W, Hänni DC, van Schaik CP. Measuring Hair Cortisol Concentrations to Assess the Effect of Anthropogenic Impacts on Wild Chimpanzees *(Pan troglodytes)*. PLoS ONE. 2016; 11(4): e0151870.

doi:10.1371/journal.pone.0151870.

Carnegie SD, Fedigan LM and Ziegler TE. Social and Environmental Factors Affecting Fecal Glucocorticoids in Wild, Female White-Faced Capuchins *(Cebus capucinus).* Am. J. Primatol. 2011; 73:1–9.

Cavigelli SA. Behavioural patterns associated with faecal cortisol levels in free-ranging female ring-tailed lemurs, *Lemur catta.* Animal behaviour, 1999; 57, 935–944.

Chapman CA, Naughton-Treves L, Lawes MJ, Wasserman MD, Gillespie TR. Population declines of colobus in Western Uganda and conservation value of forest fragments. Int J Primatol 2007. 28: 513-528.

Chapman CA, Wasserman MD, Gillespie TR, Speirs ML, Lawes MJ, Saj TL, Ziegler TE. Do food availability, parasitism, and stress have synergistic effects on red colobus populations living in forest fragments? Am J Phys Anthropol. 2006 Dec; 131(4):525-34. doi: 10.1002/ajpa.20477.

Charbonnel N, Chaval Y, Berthier K. Stress and demographic decline: a potential effect mediated by impairment of reproduction and immune function in fluctuating vole populations. Physiol. Biochem Zool. 2008; 81, 63–73.

Chrousos GP. Stress and disorders of the stress system. Nat Rev Endocrinol. 2009 Jul; 5(7):374–81.doi: 10.1038/nrendo.2009.106 PMID: 19488073.

Chrousos GP, Gold P. The concepts of stress and stress system disorders: Overview of physical and behavioral homeostasis. JAMA. 1992 Mar 4; 267(9):1244–52. PMID: 1538563.

Cocks L. Factors Affecting Mortality, Fertility, and Well-being in Relation to Species Differences in Captive Orangutans. Int J Primatol. 2007 Apr 1; 28(2):421–8.

Cooke SJ, Blumstein DT, Buchholz R, Caro T, Fernández-Juricic E, Franklin CE, Metcalfe J, O'Connor CM, St. Clair CC, Sutherland WJ, Wikelski M. Physiology, Behavior, and Conservation. Physiol. Biochem. Zool. 2014; 87, 1–14. doi:10.1086/671165.

Corlett RT. The Anthropocene concept in ecology and conservation. Trends Ecol. Evol. 2015; 30, 36–41.

Cristóbal-Azkarate J, Maréchal L, Semple S, Majolo B, MacLarnon A. Metabolic strategies in wild male Barbary macaques: evidence from faecal measurement of thyroid hormone. Biol. Lett. 2016; 12: 20160168. http://dx.doi.org/10.1098/rsbl.2016.0168

Crutzen PJ and Stoermer EF. The Anthropocene. Int. Geosphere Biosphere Programme Newsl. 2000; 41, 17–18.

Dantzer B, Fletcher QE, Boonstra R, Sheriff MJ. Measures of physiological stress: a transparent or opaque window into the status, management and conservation of species? Conserv Physiol. 2014 Jun 27; 2(1):cou023. doi: 10.1093/conphys/cou023. eCollection 2014.

Douyon L, Schteingart DE. Effect of obesity and starvation on thyroid hormone, growth hormone, and cortisol secretion. Endocrinol. Metab. Clin. 2002; 31, 173-89.

du Dot TJ, Rosen DAS, Trites AW. Energy reallocation during and after nutritional stress in Steller sea lions: low quality diet reduces capacity for physiological adjustments. Physiol. Biochem. Zool. 2009; 82: 516-530. https://doi.org/10.1086/603637 PMID: 19637969.

Dunn JC, Cristóbal-Azkarate J, Schulte-Herbrüggen B, Chavira R, Veà JJ. Travel Time Predicts Fecal Glucocorticoid Levels in Free-Ranging Howlers *(Alouatta palliata).* Int J Primatol. 2013; doi: 10.1007/s10764-013-9657-0.

Ellenberg U, Setiawan AN, Cree A, Houston DM, Seddon PJ. Elevated hormonal stress response and reduced reproductive output in yellow-eyed penguins exposed to unregulated tourism. Gen. Comp. Endocrinol. 2007; 152, 54–63.

Emery Thompson M, Georgiev AV. The high price of success: costs of mating effort in male primates. Int. J. Primatol. 2014; 35, 609–627. doi:10. 1007/s10764-014-9790-4.

Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E, Di Fiore A, Nekaris K, Nijman V, Heymann EW, Lambert JE, Rovero F, Barelli C, Setchell JM, Gillespie TR, Mittermeier RA, Arregoitia LV, de Guinea M, Dobrovolski SR, Shanee S, Shanee N, Boyle SA, Fuentes A, MacKinnon KC, Amato KR, Meyer ALS, Wich S, Sussman RW, Pan R, Kone I, Li B. Impending extinction crisis of the world's primates: Why primates matter. *Sci. Adv*. 2017. 3, e1600946.

Foerster S, Cords M, Monfort SL. Seasonal Energetic Stress in a Tropical Forest Primate: Proximate Causes and Evolutionary Implications. PLoS ONE. 2012; 7(11): e50108. https://doi.org/10.1371/journal.pone.0050108.

Franch L, Llorente M, Pachecho L. Relationship Strategists: Social Networks Analysis of Chimpanzees *(Pan troglodytes verus)* in West Africa. Communication. VI Iberian Primatological Conference. 2017. University of Burgos, Spain.

French SS, DeNardo DF, Greives TJ, Strand CR, Demas GE. Human disturbance alters

endocrine and immune responses in the Galapagos marine iguana *(Amblyrhynchus cristatus).* Horm. Behav. 2010; 58, 792–799.

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJA, Laurance WF, Lovejoy TE, Sodhi NS. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature. 2011; 478, 378–381.

Gómez-Espinosa E, Rangel-Negrín A, Chavira R, Canales-Espinosa D, Américo P, Dias D. The Effect of Energetic and Psychosocial Stressors on Glucocorticoids in Mantled Howler Monkeys *(Alouatta palliata).* Am J Primatol. 2014 Apr;76(4):362-73. doi: 10.1002/ajp.22240. Epub 2013 Nov 26.

Hayes JP, Garland T. The evolution of endothermy: testing the aerobic capacity model. Evolution. 2007; 49, 836–847. doi:10.2307/2410407.

Heistermann M, Brauch K, Mo¨hle U, Pfefferle D, Dittami J, Hodges K. Female ovarian cycle phase affects the timing of male sexual activity in free-ranging Barbary macaques *(Macaca sylvanus)* of Gibraltar. Am. J. Primatol. 2008; 70, 44–53. doi:10.1002/ajp.20455.

Hockings KJ, McLennan MR, Carvalho S, Ancrenaz M, Bobe R, Byrne RW, Dunbar RIM, Matsuzawa T, McGrew WC, Williamson EA, Wilson ML, Wood B, Wrangham RW and Hill CM. Apes in the Anthropocene: flexibility and survival. Trends in Ecology & Evolution. 2015. doi: 10.1016/j.tree.2015.02.002.

Humle T, Boesch C, Campbell G, Junker J, Koops K, Kuehl H. and Sop T. *Pan troglodytes ssp. verus*. The IUCN Red List of Threatened Species 2016: e.T15935A102327574.http://dx.doi.org/10.2305/IUCN.UK.2016 2.RLTS.T15935A17989872.en.

Hvenegaard GT. Economic aspects of primate tourism associated with primate conservation. In: Primate Tourism: A Tool for Conservation? Cambridge: Cambridge University Press; 2014. p. 259–77.

Jacobson SL, Freeman HD, Santymire RM, Ross SR. Atypical experiences of captive chimpanzees *(Pan troglodytes)* are associated with higher hair cortisol concentrations as adults. R. Soc. Open sci. 2017; 4: 170932. http://dx.doi.org/10.1098/rsos.170932.

Jaimez NA, Bribiescas RG, Aronsen GP, Anestis SA, Watts DP. Urinary cortisol levels of gray-cheeked mangabeys are higher in disturbed compared to undisturbed forest areas in Kibale National Park, Uganda. Animal Conservation. 2011; 15(3):242-247

doi: 10.1111/j.1469-1795.2011.00508.x.

Lee D, Martinez B, Crocker D, Oritz R. Thyroid hormone changes associated with prolonged food deprivation in adult male northern elephant seals. The FASEB Journal 2014; 28: Supplement 1101.6.

Maréchal L, Semple S, Majolo B, Qarro M, Heistermann M, MacLarnon A. Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques. Biol Conserv. 2011 Sep; 144(9):2188– 93.

Martínez-Mota R, Valdespino C, Sánchez-Ramos MA, Serio-Silva JC. Effects of forest fragmentation on the physiological stress response of black howler monkeys. Anim Conserv. 2007; 10(3):374–9.

McGrew WC, Baldwin PJ, Tutin CEG. Diet of wild chimpanzees *(Pan troglodytes verus)* at Mt. Assirik, Senegal: I. Composition. Am. J. Primatol. 1988; 16: 3: 213-226. doi.org/10.1002/ajp.1350160304.

McGrew WC, Ensminger AL, Marchant LF, Pruetz JD, Vigilant L. Genotyping Aids Field Study of Unhabituated Wild Chimpanzees. Am. J. Primatol. 2004; 63:87–93.

Mormède P, Andanson S, Aupérin B, Beerda B, Guémené D, Malmkvist J, Manteca X, Manteuffel G, Prunet P, van Reenen C, Richard S and Veissier I. Exploration of the hypothalamic-pituitary-adrenal function as a tool to evaluate animal welfare. Physiology and Behavior. 2007; 92: 317-339.

Möstl E and Palme R. Hormones as indicators of stress. Domestic Animal Endocrinology. 2002; 23: 67-74.

Muehlenbein MP, Wallis J. Considering risks of pathogen transmission associated with primate-based tourism. In: Primate Tourism: A Tool for Conservation? Cambridge; New York: Cambridge University Press; 2014. p. 278–87.

Muller MN, Wrangham RW. Dominance, cortisol and stress in wild chimpanzees *(Pan troglodytes schweinfurthii).* Behavioral Ecology and Sociobiology. 2004; 55(4):332-340

doi:10.1007/s00265-003-0713-1.

Murray CM, Heintz ME, Lonsdorf EV, Parr LA, Santymire RM. Validation of a Field Technique and Characterization of Fecal Glucocorticoid Metabolite Analysis in Wild Chimpanzees *(Pan troglodytes).* American Journal of Primatology. 2013; 75(1) doi10.1002/ajp.22078.

Nugraha TP, Heistermann M, Agil M, Purwantara B, Supriatna I, Gholib G, van Schaik CP, Weingrill T. Validation of a field-friendly extraction and storage method to monitor fecal steroid metabolites in wild orang-utans. Primates. 2016; 58(2). doi: 10.1007/s10329-016-0583-6.

Pacheco L, Azua NR, Fernández-García JM, Aransay N, Guallar F and Gaubert P. First record of Johnston's Genet *Genetta johnstoni* in Senegal. Small Carnivore Conservation. 2013. 48, 89–91.

Pacheco L, Fraixedas S, Fernández-Llamazares Á, Estela N, Mominee R, Guallar F. Perspectives on sustainable resource conservation in community nature reserves: A case study from Senegal. Sustainability. 2012. 4, 3158–3179. doi:10.3390/su4113158.

Palme R, Robia Ch, Messmann S, Hofer J and Möstl E. Measurement of faecal cortisol metabolites in ruminants: a non-invasive parameter of adrenocortical function. Wiener Tierärztliche Monatsschrift 1999; 86: 237-241.

Pruetz JD. Chimpanzees in Bandafassi Arrondissement, Southeastern Senegal: Field Surveys as a Basis for the Sustainable Community-Based Conservation. Pan Africa News. 2011; 18(2).

Pruetz J and Bertolani P. Chimpanzee *(Pan troglodytes verus)* Behavioral Responses to Stresses Associated with Living in a Savannah-Mosaic Environment: Implications for Hominin Adaptations to Open Habitats. PaleoAnthropology. 2009; 252–262. doi:10.4207/PA.2009.ART33.

Pruetz JD and Herzog NM. Savanna Chimpanzees at Fongoli, Senegal, Navigate a Fire Landscape. Current Anthropology. 2017; 58, 16.

Pruetz JD and LaDuke TC. Brief Communication: Reaction to Fire by Savanna Chimpanzees *(Pan troglodytes verus)* at Fongoli, Senegal: Conceptualization of ''Fire Behavior'' and the Case for a Chimpanzee Model. American journal of physical anthropology. 2010; 141:646–650. DOI 10.1002/ajpa.21245.

Ramón M, Llana M, Estela N, Pacheco L, Hockings K, Hill C. The fruit of discord? *Saba senegalensis* use by chimpanzees and local people in Senegal. Poster. 7th European Federation for Primatology Meeting. 21-25 August 2017. University of Strasbourg, France.

Rangel-Negrín A, Coyohua-Fuentes A, Chavira R, Canales-Espinosa D, Dias PAD. Primates living outside protected habitats are more stressed: The case of black howler

monkeys in the Yucatán Peninsula. PLoS ONE. 2014; Nov 6; 9(11):e112329. doi: 10.1371/journal.pone.0112329 PMID: 25375243.

Rimbach R, Link A, Heistermann M, Gómez-Posada C, Galvis N, Heymann EW. Effects of logging, hunting, and forest fragment size on physiological stress levels of two sympatric ateline primates in Colombia. Conserv Physiol. 2013; 1(1):cot031.

Romero LM, Wikelski M. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. P.N.S.A. 2001; 13, 7366–7370.

Salas M. Assessment of Welfare in Captive Wild Ungulates. Thesis Department of Animal and Food Science. 2017. Autonomous University of Barcelona.

Santos J, Benjamin M, Yang P-C, Prior T, Perdue MH. Chronic stress impairs rat growth and jejunal epithelial barrier function: role of mast cells. Am J Physiol—Gastrointest Liver Physiol. 2000 Jun 1; 278(6):G847–54. PMID: 10859213.

Sapolsky RM, Romero LM, Munck AU. How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrinol. Rev. 2000; 21: 55-89.

Stetz J, Hunt K, Kendall KC, Wasser SK. Effects of exposure, diet, and thermoregulation on fecal glucocorticoid measures in wild bears. PLoS One 2013; 8: e55967. https://doi.org/10.1371/journal.pone. 0055967 PMID: 23457488.

Schaffner CM, Rebecchini L, Aureli F, Ramos-Fernandez G, Vick LG. Spider monkeys cope with the negative consequences of hurricanes through changes in diet, activity budget and fission-fusion dynamics. Int J Primatol. 2012; 33: 922–936.

Sheriff MJ, Krebs CJ, Boonstra R. Assessing stress in animal populations: Do fecal and plasma glucocorticoids tell the same story? Gen. Comp. Endocrinol.2010; 166, 614–619.

Shutt K, Heistermann M, Kasim A, Todd A, Kalousova B, Profosouva I, et al. Effects of habituation, research and ecotourism on faecal glucocorticoid metabolites in wild western lowland gorillas: Implications for conservation management. Biol Conserv. 2014; 172:72–9.

Smith-Aguilar SE, Ramos-Fernández G, Getz WM. Seasonal Changes in Socio-Spatial Structure in a Group of Free-Living Spider Monkeys *(Ateles geoffroyi).* PLoS ONE. 2016; 11(6): e0157228. doi:10.1371/journal.pone.0157228.

Takeshita RS, Bercovitch FB, Huffman MA, Mouri K, Garcia C, Rigaill L, Shimizu K. Environmental, biological, and social factors influencing fecal adrenal steroid

concentrations in female Japanese macaques *(Macaca fuscata).* Am J Primatol. 2014 Nov;76(11):1084-93. doi: 10.1002/ajp.22295. Epub 2014 May 16.

Thomas JA, Telfer MG, Roy DB, Preston CD, Greenwood JJ, Asher J, Fox R, Clarke RT, Lawton JH. Comparative losses of British butterflies, birds, and plants and the global extinction crisis. Science. 2004; 303, 1879–1881. doi:10.1126/science.1095046.

Vanlangendonck N, Nuñez G, Chaves A, Gutiérrez-Espeleta GA. New Route of Investigation for Understanding the Impact of Human Activities on the Physiology of Non-Human Primates. J Primatol. 2015; 4: 123. doi:10.4172/2167-6801.1000123.

Wagner MS, Wajner SM, Maia AL. The role of thyroid hormone in testicular development and function. J. Endocrinol. 2008; 199, 351–365. doi:10.1677/JOE-08-0218.

Wasser SK, Cristobal-Azkarate JA, Booth RK, Hayward L, Hunt K, Ayres K, et al. Non-invasive Measurement of Thyroid Hormone in Feces of a Diverse Array of Avian and Mammalian Species. Gen. Comp. Endocrinol. 2010; 168: 1-7. https://doi.org/10.1016/j.ygcen.2010.04.004 PMID: 20412809.

Wasser SM, Keim JL, Taper ML and Lele SR. The influences of wolf predation, habitat loss, and human activity on caribou and moose in the Alberta oil sands. Front Ecol Environ 2011; 9(10): 546–551, doi:10.1890/100071.

Wasser SK, Lundin JI, Ayres K, Seely E, Giles D, Balcomb K, Hempelmann J, Parsons K, Booth R. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales *(Orcinus orca).* PLoS ONE. 2017: 12(6): e0179824. https://doi.org/10.1371/journal.pone.0179824.

Wilson ML, BoeschC, Fruth B, Furuichi T, Gilby IC, Hashimoto C, Hobaiter CL, Hohmann G, Itoh N, Koops K, Lloyd JN, Matsuzawa T, Mitani JC, Mjungu DC, Morgan D, Muller MN, Mundry R, Nakamura M, PruetzJ, Pusey AE, Riedel J, Sanz C, Schel AM, Simmons N, Waller M, Watts DP, White F, Wittig RM, Zuberbühler C, & Wrangham RW. Lethal aggression in Pan is better explained by adaptive strategies than human impacts. Nature. 2014; 513: 414-418. doi:10.1038/nature13727.

Whitten PL, Stavisky R, Aureli F, Russell E. Response of fecal cortisol to stress in captive chimpanzees *(Pan troglodytes).* Am J Primatol. 1998; 44(1):57-69. doi: 10.1002/(SICI)1098-2345(1998)44:1<57::AID-AJP5>3.0.CO;2-W.

Wittig RM, Crockford C, Weltring A, Langergraber KE, Deschner T, Zuberbühler K. Social support reduces stress hormone levels in wild chimpanzees across stressful events and everyday affiliations. Nat. Commun. 2016; 7, 13361 doi: 10.1038/ncomms13361.

Wunderink YS, Martinez-Rodriguez G, Yufera M, Klaren PHM. Food deprivation induces chronic stress and affects thyroid hormone metabolism in Senegalese sole *(Solea senegalensis)* post-larvae. Comparative biochemistry and physiology. Part A, Molecular and Integrative Physiology. 2012; 162:317-22.

Yamanashi Y, Teramoto M, Morimura N, Hirata S, Inoue-Murayama M, Idani G. Effects of Relocation and Individual and Environmental Factors on the Long-Term Stress Levels in Captive Chimpanzees *(Pan troglodytes):* Monitoring Hair Cortisol and Behaviors. PLoS One. 2016 Jul 27; 11(7):e0160029. Doi: 10.1371/journal.pone.0160029. eCollection 2016.

CHAPTER 3

Behavioural and Physiological Responses of Western Chimpanzees to Anthropogenic Activities

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Abstract

The Western Chimpanzee *(Pan troglodytes verus)* is critically endangered by, among other threats, anthropogenic activities. The aim of this research is to measure the behavioural responses (activity budget and flight) and faecal cortisol metabolites (FCM) of chimpanzees to assess whether anthropogenic activities influence the levels of stress and well-being in a human-dominated landscape. Dindéfélo is divided into 3 zones that coincide with different levels of anthropogenic activity plus another control zone was added, with restricted access to humans. The behaviours were observed between April and July 2014 and 2015 to compare the dry and wet seasons (3,042 minutes). Faecal samples were collected from 2014 to 2015 (73 faecal samples). The analysis of FCM was performed by Enzyme Immunoassay (EIA). The Analysis of Maximum Likelihood Parameter Estimates model was used to assess the significance between the different categories of activity budget and flight with the independent variables (zone, number of people, anthropogenic activity and year). To analyse the relationship between flight categories and cortisol levels, Spearman correlation coefficient was calculated. As the number of people increased in the presence of chimpanzees, feeding decreased. The flight was higher in 2015 than in 2014, year chimpanzees flighted more in the zone of high anthropogenic activity and they also suffered the agonistic interactions of invading chimpanzees. The high peaks of FCM coincide with high anthropogenic activity in the dry season and travel to forage during wet season but no significant relationships were found between FCM and flight behaviours. More studies and measures are needed to achieve sustainable coexistence in this complex period of the Anthropocene.

1. Introduction

The current loss of biodiversity has a common denominator in human activities [Butchart, 2010]. Nowadays, anthropogenic impacts play an important role in the survival of non-human primates [Carlitz et al., 2016]. Human disturbance has consequences on primates in behaviour, physiology, health, morbidity and demography [Bishop et al., 1981; Cooke et al., 2014]. Most studies in primates have found negative effects in anthropogenic activities such as tourism [Behie et al., 2010; Maréchal, 2011; Muehlenbein and Wallis, 2014; Shutt et al., 2014], habitat fragmentation [Rangel-Negrín et al., 2014; Martínez-Mota et al., 2007], human presence [Vanlangendonck et al., 2015], disturbed habitat [Jaimez et al., 2012] compared to other studies that have not found clear effects of human activities [Hvenegaard, 2014; Rimbach et al., 2013; Aronsen et al., 2015]. There are also studies on chimpanzees where it was found an adaptation to humanized environments [Hockings KJ, 2009; Hockings et al, 2012, 2015; Humle and Matsuzawa, 2004] compared to other studies that observed negative effects [Carlitz, 2014; McLennan and Hill, 2010]. Therefore, further studies are needed in order to know the effects of humanized zones on chimpanzees to improve conservation management.

One of the concerns for the conservation of chimpanzees in humanized zones is the competition for natural resources [Colquhoun, 2005; Hill, 2002; Hockings and Humle, 2009; McLennan, 2008, 2010; van Lavieren and Wich, 2010]. There is a growth of the human population in poor areas that need natural resources to survive. Nonhuman primates have seen reduced their natural habitat and coincide with humans in confined spaces [McLennan and Hill, 2010]. Natural resources competition is one of the human-great ape conflicts because the results of their interaction have negative social, cultural or ecological effects [Hockings and Humle, 2009]. During the dry season in Senegal, water is very scarce. In gallery forests, humans and chimpanzees coincide, which afraid both. In Dindèfèlo, humans go to the forest river, very close to the town, to get water to drink and cook. Groups of women go to wash clothes with their children, shower and use the forest as a latrine and garbage dump. At the same time, chimpanzees feed on fruits that grow near the river, drink and where they shelter from the heat in the dry season [Pruetz, 2016; Pacheco et al., 2012]. In this season is also an excess of tourism in Dindèfèlo owing to its famous tourist waterfall of 40 degrees Celsius that refreshes people, especially between March and May [Pruetz, 2009]. In addition many water points dry out and chimpanzees are forced to look for fixed water in these small gallery forests. The chimpanzee *(Pan troglodytes verus)* is critically endangered according to the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN) [Humle et al., 2016].

Recent studies investigate the anthropogenic impact on the conservation of chimpanzees at the physiological level [Aronsen et al., 2015; Carlitz et al., 2016; Rangel-Negrín et al., 2014; Shut et al., 2014; Smith-Aguilar et al., 2016; Vanlangendonck et al., 2015; Wittig et al., 2016]. A useful tool for measuring physiological responses is through the assessment of changes in cortisol levels. A stimulus can trigger the stress response in an individual by the activation of the hypothalamic-pituitary-adrenocortical (HPA) axis that releases glucocorticoids such as cortisol [Arck et al., 2001; Cocks L, 2007; Wittig et al., 2016]. In primates, the glucocorticoid hormone cortisol is secreted into the bloodstream in response to various stressors and plays an important role in increasing the available energy and thus the body copes with the stressor, while simultaneously decreasing the anabolic pathways that are not essential for immediate survival. Consequently, the increased secretion of cortisol allows the body to cope with stressors within a short time. The high secretion of cortisol for prolonged periods of time severely reduces individual health due to a decrease in the immune response, dysfunction of several organs, increased infertility, decreased growth and appearance of abnormal behaviour [Rangel-Negrin et al., 2014; Carlitz et al., 2016; Chrousos, 1992, 2009; Arck et al., 2001; Cocks L, 2007; Santos et al., 2000; Möstl and Palme, 2002; Sheriff et al., 2010; Romero et al., 2001].

The quantification of cortisol can be carried out in plasma, saliva, urine and faeces [Cocks L, 2007; Mormède et al., 2007]. In some studies, faecal cortisol metabolites (FCM) have been studied as a non-invasive biomarker of the severity of anthropogenic impacts on primates [Carlitz et al., 2016; Maréchal et al., 2011; Rimbach et al., 2013; Shutt et al., 2014]. Faeces are easy to collect and the animals are not disturbed. The FCM reliably reflects the levels of free cortisol in the blood [Sheriff et al., 2010]. There are studies that have found an increase in stress levels in the face of tourism exposure [Romero and Wikelski, 2001; Behie et al., 2010]. High levels of stress due to tourism can negatively affect animal health, reproductive success, survival [Romero and Wikelski, 2001; French et al., 2010], and even population decline [Charbonnel et al., 2008]. Recent research have found changes in cortisol levels in the face of anthropogenic disturbances such as contamination, exposure to humans, lack of protection of natural areas and fragmentation of habitats [Carlitz et al., 2016; Rangel-Negrín et al., 2014].

To investigate more specifically the impact of anthropogenic activities on the conservation of wild apes, studies have been carried out on the activity budget [Carlitz et al, 2016; McLennan et Hill, 2010; Martínez-Mota et al, 2007; Rangel-Negrín et al, 2014]. Activity budgets are an indicator of whether animals can adapt to adverse conditions [Carlitz et al., 2016]. In southern Senegal, chimpanzees show a set of

characteristic behaviours adapted to certain heat stressors, lack of water and open environments of savannah mosaic. In Fongoli, chimpanzees minimize energy expenditure in the hottest months [Pruetz and Bertolani, 2009].

Another behavioural measure to study stress of wild chimpanzees is flight [McLennan and Hill, 2010]. Cortisol predisposes the animal to flight or aggression. Flight is the predominant response in populations of primates that have lived through hunting [Bertolani and Boesch, 2008] or live in low-visibility rainforest [Tutin and Fernandez, 1991]. When chimpanzees have no previous experience with humans, there are studies that have found curiosity responses to human presence [Morgan and Sanz, 2003]. In contrast, in places with an increase of human population, chimpanzees are habituated and usually ignore them or can sometimes show loads of aggressiveness towards humans [Grieser, 1996]. The habituation of great apes in Africa is defined as the acceptance by wild animals of human observers as a neutral element in their environment [Tutin and Fernandez, 1991] over several years without using food [Bertolani and Boesch, 2008].

The aim of this study is to measure the behavioural responses (activity budget and flight) and FCM of wild chimpanzees to compare if the anthropogenic activities of the different zones of study influence the levels of stress in a human-dominated landscape.

2. Materials and methods

Our research complied with the Republic of Senegal law and was approved by the corresponding authorities (CITES certificate by Service des Eaux, Fôrets et Chasses) also in Spain with Ministerio de Agricultura, Alimentación y Medio Ambiente. This study complied with the Guidelines for the Treatment of Animals in Behavioural Research and Teaching from the Animal Behaviour Society.

2.1. Study area and animals

Dindéfélo is one of the limits where the Reserve begins in the northwest. The Reserve Naturelle Communautaire de Dindéfélo (RNCD) (12º24'N, 12º18'W), in the extreme southeast of Senegal, covers an area of 14, 050 ha. It is The Sudan savannah and The Guinean forest that make up a mosaic of patches of forests, crops and pastures. The Sudan savannah consists of grasslands with patches of trees interspersed with lateritic

soils. The Guinean forest is made up of semi-deciduous forests, canyons and drainages gallery [Pacheco et al, 2012; Pruetz and Bertolani, 2009].

Rainfall to the southeast of Senegal is 800 mm annually. The wet season is from June to September. May and October can be considered months of transition. From November to April they constitute the dry season because there is no rain, the trees lose their leaves, and natural and man-induced fires sweep large protected areas. The maximum temperatures in the dry season exceed 40 degrees Celsius [Pruetz and Bertolani, 2009]. In Dindéfélo, in May 2015, 300 tourists were counted in just 30 minutes in the gallery forest where the great waterfall is located to cool off from the high temperatures. However, in the wet season, the gallery forests becomes free of tourists and locals because they can wash clothes closer to the village.

Dindéfélo is the reference town of the Reserve because it has an institute, shops, public transport and, and a tourist waterfall, among others facilities. Dindéfélo in the local language means “next to the mountain”, it is very close to the protected forest. The locals, with a subsistence economy and traditional practices, go daily to the forest for natural resources (water, trees, fruits and wood) where they coincide with wild animals. The protected area of Dindéfélo follows the zoning of the Management Plan of the RNCD for the Conservation of Chimpanzees with the collaboration of Instituto Jane Goodall España (IJGE) (Figure 1). The zone 1 of high protection, are mainly gallery forests, zone 2 of medium protection, are basically the slopes (semi-deciduous forests) and zone 3 of low protection, and is the rest of the Reserve (arboreal savannah). A fourth zone has been added, which is gallery forest but also highly protected and therefore not accessible to the public. These zones are the experimental areas of this study where zone 1 would be of high anthropogenic activity, zone 2 medium, zone 3 low and zone 4 control group.

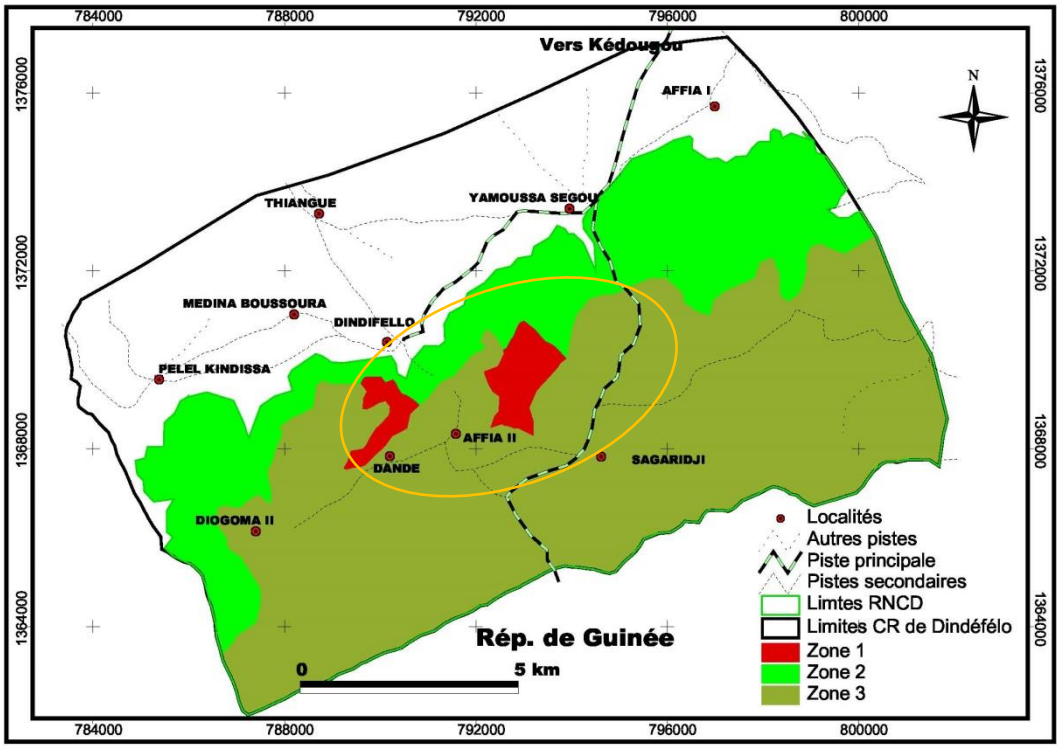

Figure 1. Map showing the Réserve Naturelle Communautaire de Dindéfélo (RNCD) within the Communauté Rurale (CR) area. The zoning is divided into three areas: 1) gallery forests; 2) semi-deciduous forests and 3) savannah. The study site at Dindéfélo is encircled.

The study chimpanzee group resident in Dindéfélo was composed by 10 identified chimpanzees (1 adult male, 3 adult females, 1 aged female, 1 juvenile male, 2 infantile males and 2 babies). This group could belong to the same community of chimpanzees of the Reserve (18 chimpanzees in Segou, 20 chimpanzees in Nandoumary/Diogoma II) and another trans boundary area unprotected in Guinea with about 47 chimpanzees [Franch et al, 2017]. The chimpanzees of Dindéfélo are identified and semi-habituated to the IJGE researchers. The habituation was carried out from 2010 to 2013 in the presence of 1 researcher and 2 field assistants at a minimum distance of 30 meters for security reasons and to protect both health, in a total of 6 days a week (36 hours). When the chimpanzees were found, the humans sat quietly and simulated chimpanzee behaviours such as grooming. Field data were taken while habituation was carried out. If the chimpanzees left, they were not followed.

2.2. Behavioural data collection

The behaviours were observed between the months of April and July 2014 and 2015 to compare the two seasons (dry and wet), two months per season. The minutes collected in each station was homogeneous (1,590 minutes in the dry season and 1,452 minutes in the wet season). We used 15 min group scan sampling to detect if the behavioural and physiological responses of the chimpanzees vary in the different study areas due to the anthropogenic impact. To study the activity budget, the following categories were registered: feeding, resting, traveling, grooming, playing and parental care [Carlitz et al., 2016; Pruetz and Bertolani, 2009]. To investigate the behavioural responses of flight, adapted from McLennan and Hill [2010], the following response categories were noted: "Ignore", "Monitor", "Stealthy retreat", "Threaten", "Flight", and "Hide". "Ignore" was defined as "after noticing the individual continues with previous activity". "Monitor" was defined as "look or be aware of the researchers". "Stealthy retreat" was defined as "get away from tree or on the ground cautious and almost silent". "Threaten" was defined as "rapid movement towards people or towards another direction, loud vocalizations (Waa barks, roar pant-hoods; Goodall, 1986), buttress drumming, vegetation shaking or thrashing, slapping the ground, fixed stare". The definition of "Flight" was "Sliding out of a tree, walking fast or running on the ground". "Hide" was defined as "move behind a tree or vegetation which the individual continues with previous or other activity or peers at" [Tutin and Fernández, 1991; McLennan and Hill, 2010]. In addition, the party size is defined as all individuals encountered in a single day, following Boesch [1996].

The chimpanzees were located through vocalizations, food remains, excrement, fingerprints or local reports. Data of the responses of each individual of the group were randomly taken [McLennan and Hill, 2010; Grieser, 1996; van Krunkelsven et al., 1999]. Chimpanzees camouflaged by dense vegetation were not recorded. Only juvenile and infantile data were taken into account when they were judged as independent of adults. The data sampling was done by a single observer in two time slots per day, one from 7:30 a.m. to 8:30 a.m. and another one from 12 a.m. to 1 p.m., from Monday to Saturday. Three thousand and forty two minutes were collected in total. The responses of the chimpanzees (visual and vocal) were also recorded.

Reproductive state was recorded according to the definition of Murray [2009]: pregnant, lactating, and no pregnant, no lactating (NPNL). In addition, the category of tumescent was added because this condition was observed and it was wanted to know if it would affect the stress levels of the chimpanzees. Females exhibit conspicuous sexual

swellings for about 10-13 days during which they are sexually receptive, and they ovulate when maximally tumescent [Deschner et al. 2003; Emery Thompson 2005].

2.3. Faecal sample collection, validation tests and hormone analyses

The collection of samples started in 2014 from April to July. Then the collection was interrupted due to the prevention protocol for the Ebola epidemic. Once the Ebola infections remitted, faecal samples were collected again from September to December 2015. The collection of samples was on the Dindéfélo site in the 4 different areas of zoning. Fresh faecal samples were collected opportunistically during transects, from beneath night nests and behavioural samplings non-invasively [Edwards and Ullrey, 1999]. The excrement was opened and 5 grams were collected from the centre of the sample. It was introduced inside the tube and labelled with the corresponding data. After the samples were dried in a dryer at 60 degrees for two hours or in the sun for 5 hours. Then, 5 ml of silica gel was added. The samples were stored at room temperature [Arandjelovic et al., 2011; Murray et al., 2013; Nugraha et al., 2016; Nsubuga et al., 2004; Rangel-Negrín et al., 2014]. After the samples were taken to the laboratory of the Autonomous University of Barcelona, with the appropriate permits, where they were stored in a freezer at -20ºC.

The data of date, time, temperature, humidity, habitat type and GPS coordinates were recorded in the table. The characteristics of the faeces noted were form, texture, smell, size, one or more samples in the same place, location (transect, under a nest, path), individual and content. In the end, a total of 73 faecal samples were collected. The objective was to collect samples of all individuals of the study site and several samples over time of the same individuals.

We analysed all faecal samples of *P. t. verus* using a previously validated EIA (Enzyme Immunoassay kit) (DetectX® Cortisol Enzyme Immunoassay, Cenador Assays Inc., Ann Arbor, MI, EE. UU.). Chimpanzees' pooled faecal extracts, when added to the standard curve points, exhibited an accuracy of $R^2 = 0.99$. The intra-assay coefficient of variation was 6.2% and the inter-assay coefficient was 9.85%. The average recovery percentage (MEAN ± SD) was 103.25 ± 5.97%. The sensitivity was 1.760 ng of cortisol/100mg dry faeces. The curves with standard and faecal samples showed parallel displacement (standard curve $y = 0.1488x - 0.0987$, $R^2 = 0.9692$; pooled faecal samples $y = 0.149x - 0.0080$, $R^2 = 0.9137$). All samples were run in duplicate, and mean FCM values are reported as ng/100 mg (dry faeces).

2.4. Statistical analysis

The percentages of each category of activity budget and flight were calculated. Analysis of Maximum Likelihood Parameter Estimates model was used to assess the effect of the independent variables (zone, month, season, year, number of people, anthropogenic activity, reproductive state and distance) on each behavioural variables of the activity budget (feeding, resting, traveling, grooming, playing and parental care) and flight reaction ethogram ("ignore", "monitor", "stealthy retreat", "threaten", "flight", and "hide"). The negative binomial dispersion parameter was estimated by maximum likelihood. The residual maximum likelihood was used as a method of estimation and the least square means of fixed effects (LSMEANS) were used when analysis of variance indicated differences ($P < 0.05$). Spearman correlation coefficients between cortisol levels and each behavioural category from the flight reaction were calculated. Statistical analyses were performed by means of the Statistical Analysis System (SAS® 9.2, Institute Inc., Cary, NC). The significance level considered was $P < 0.05$.

3. Results

In the activity budget, grooming each other, grooming themselves, playing and parental care have been eliminated because the results showed low frequencies and high variability. Thus, the statistics were carried out with the following variables: feeding, resting and travel (Table 1).

Table 1. Mean, SD, minimum and maximum of percentages of activity budget and flight behaviours of chimpanzees caused by anthropogenic activities at Dindéfélo, Senegal.

Behaviour variables	Mean	SD	Minimum	Maximum
Feeding	19.6	24.8	0	100.0
Resting	17.6	25.5	0	98.2
Travel	52.9	32.1	0	100.0
Grooming each other	1.9	5.7	0	28.6
Grooming themselves	2.1	8.7	0	68.7
Playing	2.8	6.9	0	32.0
Parental care	2.4	7.0	0	50.0
Ignore	38.8	30.3	0	100.0
Monitor	9.9	13.2	0	53.3
Stealthy retreat	42.7	33.8	0	100.0
Threaten	1.6	8.2	0	64.3
Flight	6.8	17.3	0	100.0
Hide	0	0.3	0	2.0

The results showed significant relationships between feeding with number of people (*P* = 0.022) and anthropogenic activities (*P* = 0.0580). Resting presented a trend with a number of people (*P* = 0.08) and human activities (*P* = 0.057). Travel showed a trend with number of people (*P* = 0.07) (table 2).

Table 2. Mean±SD of percentages of activity budget of chimpanzees according to the number of people present and human activity at Dindéfélo. Different lowercase letters indicate significant differences between numbers of people (*P* < 0.005).

	0-3 people	4-30 people	31-250 people
Feeding	21.7±25.3[a]	18.9±24.8[a]	0±0[b]
Resting	9.2±15.9	20.7±25.0	85.4±22.0
Travel	58.9±32.1	49.8±30.7	14.5±22.0
	Investigation	**Washing clothes in the river**	**Tourism**
Feeding	23.0±26.8[a]	15.9±16.4[a,b]	3.5±6.0[b]
Resting	14.6±21.2	22.9±26.2	30.1±40.7
Travel	51.3±31.9	56.4±28.1	52.2±38.7

Regarding the “flight” variables, "threaten" and "hide" were eliminated because the results showed low frequencies and high variability. The statistics were performed with the rest of the variables (Table 1). “Monitor” presents a trend with year (*P* = 0.057). ”Flight” presented significant relationships with year (*P* = 0.005) (Table 3). In 2015, overall mean (± SE) of percentages of "flight" was higher in high anthropogenic activity zone (13.5 +/- 25.9 percentages of flight) than in the zone of restricted access to people

(7.9 +/- 10.3 percentages of flight). The overall mean (± SE) of percentages of "stealthy retreat" (22.5±12.5) and "flight" (1.2±3.5) decreased in July.

Table 3. Mean±SD of percentages of response categories of flight of chimpanzees according to years of study at Dindéfélo. Different lowercase letters indicate significant differences between years of study ($P < 0.005$).

YEAR	2014	2015
Ignore	50.8±29.3	30.8±28.6
Monitor	15.0±14.7	6.6±11.1
Stealthy retreat	35.1±30.9	35.0±5.3
Flight	0.3±1.8[a]	11.1±21.3[b]

The reproductive state did not have significant relationships with the dependent variables. The average of party size was 26 individuals. In the dry season the average of the party size was 33.34 chimpanzees and in the wet season 48 individuals.

As for cortisol, descriptive statistics were performed, mean FCM levels (± SE) at Dindéfélo (12.9±12.6 ng/100 mg) (table 4) and relationships with the flight categories. There were no significant relationships between FCM levels and the different flight behaviours (Table 5).

Table 4. Mean±SD and (range) of faecal cortisol metabolites level (ng/ 100 mg dry faeces) of chimpanzees sampled according to the month number, temperatures and year at Dindéfélo.

Month number	Temperatures	Year	Mean±SD (range)
4 April (N=19)	High	2014	6.3±2.8 (2.1, 13.6)
5 May (N=3)	High	2014	31.3±13.4 (17.0, 43.5)
6 June (N=19)	High	2014	27.5± 27.1 (4.0, 96.8)
7July (N=4)	High/Soft	2014	3.2±1.4 (2.1, 5.3)
9 September (N=8)	Soft	2015	43.4±31.5 (22.5, 117.9)
10 October (N=10)	Soft	2015	27.9±16.3 (8.1, 53.9)
11 November (N=8)	Soft	2015	47.9±40.8 (8.8, 138.0)
12 December (N=2)	Soft	2015	27.7±5.4 (23.8, 31.5)

Table 5. Spearman correlation coefficients and *P* valour of faecal cortisol metabolites (FCM, ng/100 mg dry faeces) of chimpanzees according to response categories of flight at Dindéfélo.

FCM (ng/100 mg)	Spearman Correlation Coefficients	*P* < 0.005
Ignore	-0.09	0.72
Monitor	-0.20	0.43
Stealthy retreat	0.06	0.81
Threaten	-0.31	0.23
Flight	.	.
Hide	0.41	0.10

The relationships between FCM and independent variables (number of people, human activity and study zone) were not significant.

4. Discussion

Chimpanzees of Dindéfélo presented a greater activity of traveling, then feeding and finally resting which contrasts with the activity budget of the chimpanzees of Fongoli: resting, feeding and traveling [Pruetz and Bertolani, 2009] or the chimpanzees of Uganda with feeding, resting and traveling [Carlitz et al., 2016]. In Senegal, during the hottest times of the day, these primates rested more, travelled less and selected gallery forests. They travelled more in earlier hours of the day that were cooler towards points with limited availability of resources (water and food) [Pruetz and Bertolani, 2009].

Feeding decreased significantly with greater the number of humans present. With a high human presence, no feeding activity was recorded during the study period. In the same line, also it has been found interruptions in the chimpanzee activity budget for human disturbances (foraging, feeding) [McLennan and Hill, 2010; Rangel-Negrín et al, 2014; Arroyo-Rodríguez and Dias, 2010]. In the same way, there were significant relationships between feeding and human activity because each human activity coincides with the number of people previously described, that is, in research the maximum of the team was 3 people. When women washing clothes in the forest river, there were usually an average of 30 people and when tourism visited in the dry season there were hundreds of people in a day. Thus, the feeding of chimpanzees also decreased significantly with anthropogenic activities with a greater number of people.

There was a tendency to increase resting and decrease travel in front of large groups of people. It was observed with high influx of tourists that the chimpanzees remained still in

an average area of the slope of the gallery forest, hidden by the dense vegetation, different to the rest when they were relaxed without an influx of tourists. Recently it have been found the neural system in charge of some survival behaviours in animals, including humans. When there is a threat, the behaviour of fight or flight is usually given if there is way out. But if the stressor is inescapable (proximity to or capture by a predator) is given passive coping strategies like quiescence, recovery or freezing. These behaviours preparing the animal to react or escape when opportunity arises [Koutsikou et al, 2017].

Regarding the response categories of flight**,** the most frequent behaviour was "stealthy retreat" followed by "ignore". Then the "monitor" and "flight" follow. The chimpanzees of Dindéfélo are semi-habituated, which would explain the dichotomy between retreating and ignoring. In the two years of study, the presence of offspring was observed, which would explain a greater number of retreats of chimpanzees in the presence of humans. In contrast, it has been found that the most frequent behaviour of chimpanzees in Uganda in the presence of researchers was "ignore" and then "monitor". To a lesser extent "stealthy retreat" and "threaten". "Flight" and "hide" were eliminated due to lack of data [McLennan and Hill, 2010].

Significant relationships between "flight" and years of study were found. In 2015 the number of flights was higher than in 2014. This could be explained, on the one hand, because in 2015 chimpanzees flighted in areas with high anthropogenic activity and tourism was exorbitant in dry season. Other studies have been found a flight response by chimpanzees when they encountered humans [McLennan and Hill, 2010] and increased primate stress with tourism [Maréchal et al, 2011; Muehlenbein et al., 2012]. Also in 2015, four adult male chimpanzees from Nandoumary site were visiting Dindéfélo agonistically until there was a war. After the females remained with the invading chimps and the alpha male was not observed again. Other investigations have also found these behaviours in the face of silent stalking and persecution of strange groups of chimpanzees during intergroup territorial encounters [Boesch and Boesch-Achermann, 2000; McLennan and Hill, 2010]. It would be necessary more long-term research because in field studies arise variables that cannot be controlled as visits of extra group individuals.

There was a tendency between "monitor" and years of study. In 2014 there was more "monitor" than in 2015. Also in the area with high human activity chimpanzees "monitored" more than in the area not accessible to humans. The increase in monitor in the presence of higher visitor presence has been described in more species such as

gorillas (*Gorilla gorilla grilla*) [Carder and Semple, 2008; Clark et al., 2012]. It could be explained by fear of danger or curiosity about human presence [Salas et al., 2017].

More "flights" were given in the zone of human activity than in the zone restricted to people. The "stealthy retreat" and "flight" decreased in July when the rain is plentiful and the forests were empty of people because they already had access to water outside the forest. This contrasts with other study in which it has been found that "stealthy retreat" was the least frequent against "ignore". The visual proximity of local people did not influence the encounter with chimpanzees. And "stealthy retreat" was diminished throughout the months of study that explain it as a habituation process to researchers [McLennan and Hill, 2010].

Although the “threats” were eliminated due to the scarce data obtained, it was interesting to observe the difference in response among resident chimpanzees that did not threaten the present humans, they "stealthy retreated", versus foreigner chimpanzees, not habituated to people, they threatened people and pushed stones. Behaviour not observed before and local people were alert. It was a complicated situation in the second year of study and that would justify the control of the number of people who access the small gallery forest to prevent conflicts. These results of resident chimpanzees did not threaten local people contrast with other investigations where there were conflicts of crop feeding or attacks on people [Costa et al, 2017; Hill, 2017; McLennan and Hill, 2012].

The average party size of chimpanzees in Dindéfélo was 26 individuals (n = 24 months), larger than the party size of the chimpanzees of Fongoli with 15 individuals (n = 17 months). However, it does coincide that in the dry season, the average of the party size was smaller than in the wet season. Chimpanzees at Dindéfélo exhibited characteristic fission-fusion social system [Pruetz and Bertolani, 2009].

As for FCM through the months of the study, there were high peaks in May and June that coincide with a high anthropogenic activity (tourism, washing in the river, forest fires to open crops, collection of forest fruits, among others) [Aguilar-Melo et al., 2013; French et al., 2010; Maréchal et al., 2011; Ramón et al., 2017; Shutt et al., 2014; Vanlangendonck et al., 2015]. In May 2015, 300 tourists were counted in 30 minutes. Also in June a mating encounter was observed for several days [Balestri et al., 2014; Takeshita et al., 2014].

Other higher peaks of cortisol were in September and November. In September they cut down a large area within a highly restricted area, being a chimpanzee area, to build a

water reservoir in Dindéfélo to supply running water to the village and nearby ones [McLennan and Hill, 2010; Rimbach et al., 2014]. In addition, a confrontation took place between the four male adult chimpanzees against the resident group [Franch et al., 2017]. There are numerous studies that support increases in cortisol with aggressive behaviour in primates [Muller and Wrangham, 2004; Rangel-Negrín et al., 2014; Yamanashi et al., 2016]. It has been found these increases in cortisol associated with agonistic interactions more frequently in those groups of primates that lived in smaller habitats [Gómez-Espinosa et al., 2013]. In November the chimpanzees had to travel to find the seasonal fruit, bhohé *(Adansonia digitata)* [Bertolani and Pruetz, 2011; Carlitz et al., 2016; Rangel-Negrín et al., 2014].

On the other hand, in April, the low peaks of cortisol coincided with chimpanzees were in a zone restricted to humans. In July the rains started and people did not go to the forest. In December, the chimpanzees were in the area of *A. digitata* and did not travel any more that month.

The highest average within the categories of flight was in "stealthy retreat" although there were no significant differences. Cortisol levels were higher in the zone of anthropogenic activity than in the area restricted to humans but there were no significant relationships. It is interesting that the value of stress was almost double with small groups of people than with large ones, although it was not significant either. More studies would be necessary to study if the researchers could be a stress factor for the animals.

It would be necessary to control the number of people accessing the natural reserve to preserve the basic activities of chimpanzees such as feeding, resting and travel. Ecotourism would be helpful as a control measure and build public washhouses in the villages so that the locals do not have to go to the forest river and thus achieve a sustainable coexistence in this complex Anthropocene era.

5. Conclusion

In conclusion, feeding of chimpanzees was altered when a high number of people were present in the forest, like the big groups of tourists. Flight was highest in a year in which chimpanzees spent more time in the anthropogenic zone and when the resident group suffered agonistic interactions of invading chimpanzees. FCM levels seem to be associated with high peaks of tourism, attack by invading chimpanzees and traveling to get food but the effect was not significant. There were no significant relationships

between flight and FCM. It is important to control the number of people accessing the Reserve to improve the welfare and conservation of chimpanzees and build washhouses for local people to improve sustainable coexistence in this complex period of the Anthropocene.

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7. Author Contributions

Conceived and designed the experiments: MA ML-B XM. Performed the experiments: MA LP. Analysed the data: DT MA. Contributed reagents/materials/analysis tools: MA ML-B. Wrote the paper: MA DT ML-B XM.

8. References

Aguilar-Melo AR, Andresen E, Cristóbal-Azkarate J, Arroyo-Rodríguez V, Chavira R, Schondube J, Serio-Silva JC, Cuarón Ad. Behavioral and Physiological Responses to Subgroup Size and Number of People in Howler Monkeys Inhabiting a Forest Fragment Used for Nature-Based Tourism. American Journal of Primatology. 2013. doi: 10.1002/ajp.22172.

Aronsen GP, Beuerlein MM, Watts DP, Bribiescas RG. Redtail and red colobus monkeys show intersite urinary cortisol concentration variation in Kibale National Park, Uganda. Conserv Physiol. 2015; 3(1): cov006.

Arroyo-Rodríguez V, Dias PAD. Effects of habitat fragmentation and disturbance on howler monkeys: a review. Am J Primatol. 2010; 72: 1–16.

Balestri M, Barresi M, Campera M, Serra V, Ramanamanjato JB. Habitat Degradation and Seasonality Affect Physiological Stress Levels of Eulemur collaris in Littoral Forest

Fragments. PLoS ONE. 2014. 9(9): e107698. doi:10.1371/journal.pone.0107698.

Barja I, Silván G, Rosellini S, Piñeiro A, Gonzáles-Gil A, Camacho L, Illera J.C. Stress physiological responses to tourist pressure in a wild population of European pine marten. J. Ster. Biochem. Mol. Biol. 2007; 104, 136–142.

Behie AM, Pavelka MS, Chapman CA. Sources of variation in fecal cortisol levels in howler monkeys in Belize. Am J Primatol. 2010; 72(7):600–6. doi: 10.1002/ajp.20813 PMID: 20166191.

Bertolani P, Boesch C. Habituation of wild chimpanzees *(Pan troglodytes)* of the South Group at Taï Forest, Côte d'Ivoire: empirical measure of progress. Folia Primatologica. 2008; 79:162–171.

Bertolani P and Pruetz JD. Seed Reingestion in Savannah Chimpanzees *(Pan troglodytes verus)* at Fongoli, Senegal. Int J Primatol. 2011. 32:1123–1132.Doi: 10.1007/s10764-011-9528-5.

Bishop N, Hrdy SB, Teas J, Moore J. Measures of human influence in habitats of South Asian monkeys. International Journal of Primatology. 1981; 2: 153-167. doi:10.1007/BF02693446.

Boesch C. Social grouping in Tai chimpanzees. In: McGrew W.C., Marchant L.F., Nishida T. (eds), Great Ape Societies. Cambridge University Press, Cambridge, 1996; pp. 101–113.

Butchart SHM. Global Biodiversity : Indicators of. Science. 2010; (80). 1164, 1164–1169. doi:10.1126/science.1187512.

Carlitz EHD, Miller R, Kirschbaum C, Gao W, Hänni DC, Van Schaik CP. Measuring hair cortisol concentrations to assess the effect of anthropogenic impacts on wild chimpanzees *(Pan troglodytes).* PLoS ONE. 2016; 11(4) e0151870 11. doi:10.1371/journal.pone.0151870.

Castles DL, Whitten A, Aureli F. Social anxiety, relationships and selfdirected behaviour among wild female olive baboons *Papio Anubis*. Anim. Behav. 1999; 58, 1207–1215.

Charbonnel N, Chaval Y, Berthier K. Stress and demographic decline: a potential effect mediated by impairment of reproduction and immune function in fluctuating vole populations. Physiol. Biochem. Zool. 2008; 81, 63–73.

Colquhoun IC. Primates in the forest: Sakalava ethnoprimatology and synecological relations with black lemurs at Ambato Massif, Madagascar. In: Paterson JD, Wallis J,

editors. Commensalism and conflict: the humanprimate interface. Norman, OK: American Society of Primatologists. 2005; p 41–59.

Cooke SJ, Blumstein DT, Buchholz R, Caro T, Fernández-Juricic E, Franklin CE, Metcalfe J, O'Connor CM, St. Clair CC, Sutherland WJ, Wikelski M. Physiology, Behavior, and Conservation. Physiol. Biochem. Zool. 2014; 87, 1–14. doi:10.1086/671165.

Costa S, Casanova C, Lee P. What Does Conservation Mean for Women? the Case of the Cantanhez Forest National Park. Conservation and Society. 2017; 15(2): 168-178. DOI: 10.4103/cs.cs_14_91.

Deschner T, Heistermann M, Hodges K, Boesch C. Timing and probability of ovulation in relation to sex skin swelling in wild West African chimpanzees, *Pan troglodytes verus*, Anim Behav. 2003; vol. 66. pg. 551-560.

Edwards MS, Ullrey DE. Effect of dietary fiber concentration on apparent digestibility and digesta passage in non-human primates. II. Hindgut- and foregut-fermenting folivores. Zoo Biol. 1999; 18: 537–549.

Ellenberg U, Setiawan AN, Cree A, Houston DM, Seddon PJ. Elevated hormonal stress response and reduced reproductive output in yellow-eyed penguins exposed to unregulated tourism. Gen. Comp. Endocrinol. 2007; 152, 54–63.

Emery Thompson M. Reproductive endocrinology of wild female chimpanzees *(Pan troglodytes schweinfurthii):* methodological considerations and the role of hormones in sex and conception. Am J Primatol. 2005; vol. 67; pg. 137-158.

Franch L, Llorente M, Pachecho L. Relationship Strategists: Social Networks Analysis of Chimpanzees *(Pan troglodytes verus)* in West Africa. Communication. VI Iberian Primatological Conference. 2017. University of Burgos, Spain.

French SS, DeNardo DF, Greives TJ, Strand CR, Demas GE. Human disturbance alters endocrine and immune responses in the Galapagos marine iguana *(Amblyrhynchus cristatus).* Horm. Behav. 2010. 58, 792–799.

Grieser Johns B. Responses of chimpanzees to habituation and tourism in the Kibale Forest, Uganda. Biological Conservation. 1996; 78:257–262.

Gómez-Espinosa E, Rangel-Negrín A, Chavira R, Canales-Espinosa D, Américo P, Dias D. The Effect of Energetic and Psychosocial Stressors on Glucocorticoids in Mantled Howler Monkeys *(Alouatta palliata).* Am J Primatol. 2014 Apr;76(4):362-73. doi:

10.1002/ajp.22240. Epub 2013 Nov 26.

Goodall J. The chimpanzees of Gombe: patterns of behavior. Cambridge (MA) Harvard University Press. 1986.

Hill CM. Primate conservation and local communities—ethical issues and debates. American Anthropologist. 2002; 104:1184–1194.

Hill CM. Primate Crop Feeding Behavior, Crop Protection, and Conservation. International Journal of Primatology. 2017; DOI 10.1007/s10764-017-9951-3.

Hill CM, Webber AD. Perceptions of nonhuman primates in human–wildlife conflict scenarios. Am J Primatol. 2010; 72(10):919–24. doi: 10.1002/ajp.20845 PMID: 20806339.

Hockings KJ. Living at the interface Human–chimpanzee competition, coexistence and conflict in Africa. Interact Stud. 2009; Jul 1; 10(2):183–205.

Hockings KJ, Anderson JR, Matsuzawa T. Socioecological adaptations by chimpanzees, *Pan troglodytes verus*, inhabiting an anthropogenically impacted habitat. Anim Behav. 2012; 83(3):801–10.

Hockings K, Humle T. Best practice guidelines for the prevention and mitigation of conflict between humans and great apes. Gland, Switzerland: IUCN/SSC Primate Specialist Group. 2009.

Hockings KJ, McLennan MR. From forest to farm: systematic review of cultivar feeding by chimpanzees—management implications for wildlife in anthropogenic landscapes. PLoS One. 2012; 7(4): e33391. doi: 10.1371/journal.pone.0033391 PMID: 22509256

Hockings KJ, McLennan MR, Carvalho S, Ancrenaz M, Bobe R, Byrne RW, et al. Apes in the Anthropocene: flexibility and survival. Trends Ecol Evol. 2015; 30(4):215–22. doi: 10.1016/j.tree.2015.02.002 PMID: 25766059.

Hockings KJ, Sousa C. Human-chimpanzee sympatry and interactions in Cantanhez National Park, Guinea-Bissau: current research and future directions. Primate Conserv. 2013; 26(1):57–65.

Humle, T., Boesch, C., Campbell, G., Junker, J., Koops, K., Kuehl, H. & Sop, T. 2016. *Pan troglodytes ssp. verus*. The IUCN Red List of Threatened Species 2016: e.T15935A102327574.http://dx.doi.org/10.2305/IUCN.UK.20162.RLTS.T15935A17989872.en. Downloaded on 12 August 2018.

Humle T, Matsuzawa T. Oil palm use by adjacent communities of chimpanzees at

Bossou and Nimba Mountains, West Africa. Int J Primatol. 2004; 25(3):551 81.

Hvenegaard GT. Economic aspects of primate tourism associated with primate conservation. In: Primate Tourism: A Tool for Conservation? Cambridge: Cambridge University Press; 2014. p. 259–77.

Jaimez NA, Bribiescas RG, Aronsen GP, Anestis SA, Watts DP. Urinary cortisol levels of gray-cheeked mangabeys are higher in disturbed compared to undisturbed forest areas in Kibale National Park, Uganda. Anim Conserv. 2012; 15(3):242–7.

Kormos, R., C. Boesch, M. I. Bakarr and T. M. Butynski. West African Chimpanzees. Status Survey and Conservation Action Plan. IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland, and Cambridge, UK. 2003.

Koutsikou S, Apps R, Lumb BM. Top down control of spinal sensorimotor circuits essential for survival. J Physiol. 2017; 595. 13 pp 4151–4158. DOI: 10.1016/j.clinph.2017.07.199.

Maestripieri D, Schino G, Aureli F, Troisi A. A modest proposal: displacement activities as an indicator of emotions in primates. Anim. Behav. 1992; 44, 967–979.

Maréchal L, Semple S, Majolo B, Qarro M, Heistermann M, MacLarnon A. Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques. Biol Conserv. 2011; Sep; 144(9):2188– 93.

Martínez-Mota R, Valdespino C, Sánchez-Ramos MA, Serio-Silva JC. Effects of forest fragmentation on the physiological stress response of black howler monkeys. Anim Conserv. 2007; 10(3):374–9.

McLennan MR. Beleaguered chimpanzees in the agricultural District of Hoima, Western Uganda. Primate Conservation. 2008; 23:45–54.

McLennan MR. Chimpanzee Responses to Researchers in a Disturbed Forest-Farm Mosaic at Bulindi, Western Uganda. American Journal of Primatology. 2010; 72:907–918. DOI: 10.1002/ajp.20839 • Source: PubMed.

McLennan MR, Hill CM. Chimpanzee responses to researchers in a disturbed forest–farm mosaic at Bulindi, western Uganda. Am J Primatol. 2010; 72:907–918.

McLennan MR, Hill CM. Troublesome neighbours: Changing attitudes towards chimpanzees *(Pan troglodytes)* in a human-dominated landscape in Uganda. J. Nat. Conserv. 2012; 20: 219–227. DOI:10.1016/j.jnc.2012.03.002.

Morgan D, Sanz C. Naïve encounters with chimpanzees in the Goualougo Triangle,

Republic of Congo. International Journal of Primatology. 2003; 24:369–381.

Mormède P, Andanson S, Aupérin B, Beerda B, Guémené D, Malmkvist J, Manteca X, Manteuffel G, Prunet P, van Reenen C, Richard S and Veissier I. Exploration of the hypothalamic-pituitary-adrenal function as a tool to evaluate animal welfare. Physiology and Behavior. 2007. 92: 317-339.

Muehlenbein MP, Ancrenaz M, Sakong R, Ambu L, Prall S. Ape conservation physiology: fecal glucocorticoid responses in wild Pongo pigmaeus morio following human visitation. PLoS ONE 7. 2012; e33357.

Muehlenbein MP, Wallis J. Considering risks of pathogen transmission associated with primate-based tourism. In: Primate Tourism: A Tool for Conservation? Cambridge; New York: Cambridge University Press; 2014. p. 278–87.

Muller MN, Wrangham RW. Dominance, cortisol and stress in wild chimpanzees (Pan troglodytes schweinfurthii). Behavioral Ecology and Sociobiology. 2004; 55(4):332-340. doi:10.1007/s00265-003-0713-1.

Murray CM, Lonsdorf EV, Eberly LE, Pusey AE. Reproductive energetics in free-living female chimpanzees *(Pan troglodytes schweinfurthii).* Behavioral Ecology. 2009; 20, 6, 1211–1216. doi.org/10.1093/beheco/arp114.

Pacheco L, Fraixedas S, Fernández-Llamazares Á, Estela N, Mominee R, Guallar F. Perspectives on sustainable resource conservation in community nature reserves: A case study from Senegal. Sustainability. 2012; 4, 3158–3179. doi:10.3390/su4113158.

Pruetz JD. Competition between savanna chimpanzees and humans in southeastern Senegal. American Journal of Physical Antrophology. 2002; 34: 128.

Pruetz JD. Competition Between Chimpanzees and Humans: The Effects of Harvesting Non-timber Forest Products. In book: Ethnoprimatology, 2016; pp.157-177. DOI: 10.1007/978-3-319-30469-4_9.

Pruetz J, Bertolani P. Chimpanzee *(Pan troglodytes verus)* Behavioral Responses to Stresses Associated with Living in a Savannah-Mosaic Environment: Implications for Hominin Adaptations to Open Habitats. PaleoAnthropology. 2009; 252–262. doi:10.4207/PA.2009.ART33.

Ramón M, Llana M, Estela N, Pacheco L, Hockings K, Hill C. The fruit of discord? *Saba senegalensis* use by chimpanzees and local people in Senegal. Poster. 7th European Federation for Primatology Meeting. 21-25 August 2017. University of Strasbourg, France.

Rangel-Negrín A, Coyohua-Fuentes A, Chavira R, Canales-Espinosa D, Dias PAD. Primates living outside protected habitats are more stressed: The case of black howler monkeys in the Yucatán Peninsula. PLoS ONE. 2014; 6; 9(11):e112329. doi: 10.1371/journal.pone.0112329 PMID: 25375243.

Rimbach R, Link A, Heistermann M, Gómez-Posada C, Galvis N, Heymann EW. Effects of logging, hunting, and forest fragment size on physiological stress levels of two sympatric ate line primates in Colombia. Conserv Physiol. 2013; 1(1):cot031.

Romero LM, Wikelski M. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. P.N.S.A. 2001; 13, 7366–7370.

Salas M. Assessment of Welfare in Captive Wild Ungulates. Thesis Department of Animal and Food Science. Autonomous University of Barcelona. 2017.

Schino G.Reconciliation in domestic goats. Behaviour. 1998; 135, 1–14.

Schino G, Perretta G, Taglioni A, Monaco V, Troisi A. Primate displacement activities as an ethopharmacological model of anxiety. Anxiety. 1996; 2, 186–191.

Sheriff MJ, Krebs CJ, Boonstra R. Assessing stress in animal populations: Do fecal and plasma glucocorticoids tell the same story? Gen. Comp. Endocrinol. 2010; 166, 614–619.

Shutt K, Heistermann M, Kasim A, Todd A, Kalousova B, Profosouva I. Effects of habituation, research and ecotourism on faecal glucocorticoid metabolites in wild western lowland gorillas: Implications for conservation management. Biol Conserv. 2014; 172:72–9.

Takeshita RS, Bercovitch FB, Huffman MA, Mouri K, Garcia C, Rigaill L, Shimizu K. Environmental, biological, and social factors influencing fecal adrenal steroid concentrations in female Japanese macaques *(Macaca fuscata).* Am J Primatol. 2014 Nov;76(11):1084-93. doi: 10.1002/ajp.22295. Epub 2014 May 16.

Tutin CEG, Fernandez M. Responses of wild chimpanzees and gorillas to the arrival of primatologists: behavior observed during habituation. In: Box HO, editor. Primate responses to environmental change. London: Chapman & Hall. P. 1991; 187–197.

van Lavieren E, Wich SA. Decline of the endangered Barbary macaque *Macaca sylvanus* in the cedar forest of the Middle Atlas Mountains, Morocco. Oryx. 2010; 44:133–138.

Vanlangendonck N, Nuñez G, Chaves A, Gutiérrez-Espeleta GA. New Route of Investigation for Understanding the Impact of Human Activities on the Physiology of Non-Human Primates. J Primatol. 2015; 4(123):2.

Wittig RM, Crockford C, Weltring A, Deschner T, Zuberbühler K. Single Aggressive Interactions Increase Urinary Glucocorticoid Levels in Wild Male Chimpanzees. PLoS ONE. 2015; 10(2):e0118695. doi:10.1371/journal.pone.0118695.

Wittig RM, Crockford C, Weltring A, Langergraber KE, Deschner T, Zuberbühler K. Social support reduces stress hormone levels in wild chimpanzees across stressful events and everyday affiliations. Nature. 2016; Commun. 7, 13361 doi: 10.1038/ncomms13361 (2016).

Yamanashi Y, Teramoto M, Morimura N, Hirata S, Inoue-Murayama M, Idani G. Effects of Relocation and Individual and Environmental Factors on the Long-Term Stress Levels in Captive Chimpanzees *(Pan troglodytes):* Monitoring Hair Cortisol and Behaviors. PLoS One. 2016 Jul 27; 11(7):e0160029. doi: 10.1371/journal.pone.0160029. eCollection 2016.

DISCUSIÓN GENERAL

La conservación de esta especie en peligro crítico de extinción es un reto complejo y global que requiere un enfoque multidimensional. En los capítulos 1, 2 y 3 de esta tesis se ha estudiado diferentes aspectos para mejorar la gestión de conservación de chimpancés en la Reserva, concretamente, las percepciones locales y las respuestas fisiológicas y conductuales de *P.t. verus* a la presencia humana.

1. Las percepciones locales para mejorar la gestión de conservación de chimpancés en la Reserva

1.1. Características de la población local

Por un lado, es importante tener en cuenta las percepciones de las personas que habitan la Reserva para mejorar la gestión de conservación de los chimpancés en libertad y conseguir una coexistencia sostenible. Las características de la población humana estudiada son: una economía de subsistencia, baja participación en educación elemental, colaboración de diversos proyectos de ONGs (como *Trees for the future* para ayudar a abrir campos de cultivo más productivos y sostenibles) y el sincretismo del islam con creencias tradicionales animistas [Kormos et al., 2003]. Estas características coinciden con las de otras etnias estudiadas tanto en países africanos como del resto de continentes tropicales. En países del Neo Trópico, África y Sudeste Asiático se han encontrado etnias con altos niveles de pobreza, rápido crecimiento de población y elevada explotación de materias primas, con lo que aumenta la deforestación, extinción de especies y las desigualdades económicas. Esto constituye en buena medida el actual reto de la conservación de la biodiversidad [Estrada, 2017].

1.2. Reacción de la población local frente a los chimpancés

Según las entrevistas realizadas en la investigación, más de la mitad de los entrevistados sentían miedo al ver a los chimpancés. Casi tres cuartas partes pensaban que los chimpancés les podían atacar. Sin embargo, la mayoría no conoce a personas que hayan sido atacadas por un chimpancé. Hay más encuentros con los chimpancés en época seca, cuando los recursos naturales son más escasos. Estas percepciones locales sobre los chimpancés en la Reserva coinciden con las de otros países como Uganda [McLennan and Hill, 2012; Webber and Hill, 2014] y Guinea Bissau [Costa et al., 2013; Sousa et al., 2014, 2017].

1.3. Competencia entre humanos y chimpancés

La gran mayoría de entrevistados utilizaban el agua del rio y la mitad de ellos argumentaban que lo hacían por tradición. El agua es un recurso por el que humanos y vida salvaje competían en Senegal [Kormos, 2003: Pacheco et al., 2012] y Guinea [Hockings and Humle, 2009]. Casi tres cuartas partes de los entrevistados recordaban que había más árboles hace treinta años que en los años de estudio pero esta idea contrastó con el pensamiento de que el bosque estará siempre y no hay problema de que los recursos se agoten. Estas creencias también se han encontrado en locales de Uganda y Guinea-Bissau [McLennan, 2008; Watkins, 2009; McLennan and Hill, 2012; Casanova et al., 2014].

En la Reserva, según las percepciones de los locales, no había problemas con los chimpancés en los campos de cultivo, la miel de las colmenas, ni con los frutos del bosque. Sin embargo, varias investigaciones han encontrado una competencia por frutos como el *Saba sengalensis* debido a la gran extracción para comercio nacional [Hockings and Humle, 2009; Pacheco et al., 2012; Ramón et al., 2017; Waller and Pruetz, 2016]. Sería necesario realizar estudios para investigar por qué los chimpancés en la Reserva no comen de los campos de cultivo y aportar luz para otros países que sufren este problema.

La población local pareció consciente del problema que suponen los incendios pero dicen que tenían que hacerlo para poder comer. El primer problema para la población local fue la falta de agua. En segundo lugar, la falta de recursos básicos como comida, medicamentos, material escolar, entre otros. Y el tercer problema comentado por los locales fue la prohibición de la tala en áreas protegidas. Esta información permitió diseñar líneas de actuación para mejorar la gestión de conservación de chimpancés en la Reserva y crear proyectos como mejorar el lavadero de Dindéfelo, construir pozos profundos de agua en Nandoumary, proyecto agroforestal, reciclaje de plásticos para crear telas, formación medioambiental, becas escolares, ecoturismo, planificación familiar, zonificación, protección y ampliación de la Reserva, entre otros.

Muchos de los entrevistados comentaron que no había problemas, lo que es destacable porque se observó que la actitud de los Peul, en general, es amable y evitan conflictos. Cuando se consigue una confianza con el tiempo entonces algunos contaron algún problema. Parece una cuestión cultural y es importante tenerlo en cuenta. Por ello es necesario contar con información objetiva sobre las conductas de esta etnia como el número de toneladas de frutos del bosque recogidos para compararlo con lo que ellos cuentan. Sería necesario realizar más estudios sobre el comportamiento de los Peul

cuando se encuentran con los chimpancés, del número de personas al día en el río del bosque, de la cantidad de basura (plásticos, telas, residuos orgánicos) en el bosque, de las hectáreas de los campos de cultivos dentro de la Reserva y su gestión, de los incendios dentro de la Reserva, entre otros.

1.4. Relación entre la educación, las creencias tradicionales y la participación en proyectos medioambientales con la actitud hacia los chimpancés

Se encontró una relación significativa entre no ir al colegio y pensar que los chimpancés no atacan, lo que podría ser explicado por la experiencia en la Reserva de ir al bosque y ver como los chimpancés huyen al ver a los humanos. Gadd [2005] estudió las actitudes locales de la conservación del elefante en Kenia y tuvo en cuenta la educación y la riqueza de la población local. No encontró correlaciones positivas entre la educación y actitudes positivas hacia la conservación del elefante [Gadd, 2005]. Sin embargo, un estudio en Tanzania encontró que los estudiantes con mayor conocimiento en vida salvaje eran más defensores de la protección de parques nacionales [Harcourt et al., 1986]. En la misma línea, en Botsuana las personas con escolaridad eran más propensas a ver el beneficio de mantener los elefantes a nivel local y nacional [Gadd, 2001]. En la Reserva sería necesario estudiar si en el colegio enseñan contenidos medioambientales y sobre los chimpancés y si estos conocimientos guardan relación con la protección de estos animales.

Por otro lado, las personas que estaban participando en la formación medioambiental de *Trees for the future* conocían mejor el número de incendios y comportamiento de chimpancés que aquellos que no estaban en la formación. Esto coincide con resultados de otros proyectos de concienciación medioambiental y chimpancés, como en Costa de Marfil, con los que los niños incrementaron su concienciación y actitud positiva hacia la naturaleza [Borchers et al., 2014].

Finalmente, se encontraron relaciones significativas entre creencias tradicionales y percepciones locales sobre los chimpancés. Por un lado, hay diversas creencias donde se relaciona al chimpancé con mala suerte y muerte. De manera que los Peul manifestaron miedo y respeto hacia estos primates. Este miedo también se encontró, en parte, en Guinea-Bissau y Uganda debido a la frecuencia de encuentros entre humanos y chimpancés [Costa et al., 2013; McLennan and Hill, 2012]. Pero además se encontró una ambivalencia en la actitud de los locales porque, por otro lado,

manifestaron, en Segou, que los chimpancés se parecen a los humanos. Una de las razones fue porque solo cogen los frutos que necesitan, idea que también se encontró en Uganda. Otra historia fue que antaño fueron humanos castigados por Dios por perezosos, la misma versión que en Guinea-Bissau [Sousa et al., 2014]. Estas creencias se relacionan con una actitud positiva hacia los chimpancés. Esta ambivalencia finaliza cuando hay problemas de ataques de chimpancés a humanos o alimentación en campos de cultivo y los humanos pasan directamente a matarlos [McLennan and Hill, 2012]. Sin embargo, si los chimpancés protegen los campos de cultivo de otras especies como los babuinos la coexistencia es viable [Costa et al., 2013].

Las personas locales con una economía de subsistencia tenían que ir al bosque por recursos básicos como agua, madera y frutos por lo que coincidían con los chimpancés y sentían miedo. Un miedo relacionado con creencias tradicionales sobre la mala suerte que traían los chimpancés. Asimismo los chimpancés huían o amenazaban a los humanos en el bosque. Estas actividades antropogénicas se tradujeron en elevaciones en los metabolitos de cortisol fecal de los chimpancés y, a nivel conductual, disminuyó su alimentación de forma significativa según los resultados encontrados. Son necesarios proyectos (becas escolares, educación medioambiental, proyecto de reciclaje, empleo local) para poder positivar las percepciones locales sobre los chimpancés y mejorar la coexistencia entre humanos y primates.

2. Indicadores fisiológicos de los chimpancés en la Reserva.

Los resultados de los metabolitos de cortisol fecal (MCF) y hormona tiroidea (T3) permitieron vislumbrar más áreas de investigación necesarias para mejorar la gestión de conservación de los *P.t. verus* en la RNCD.

Hubo aumentos de MCF y T3 en el segundo trimestre del 2014 y casi se duplicaron en el último cuatrimestre del 2015. El segundo trimestre del primer año de estudio coincidió con las temperaturas más altas, sin lluvias, escasez de agua y frutos, incendios provocados por locales para abrir nuevos campos de cultivos [Pruetz, 2009, 2011], máxima presencia de personas en los ríos de los bosques y cientos de turistas que acudían a la cascada para refrescarse [Pacheco et al., 2012]. En junio, locales y chimpancés compitieron por el fruto de temporada *(S. senegalensis)* [Pruetz, 2011; Ramón et al., 2017]. Además fue observado un encuentro amistoso entre grupos de chimpancés con muchas hembras en estro.

En julio, FCM y T3 se desplomaron. Llegaron las lluvias [Pruetz, 2009] y los bosques se quedaron libres de personas porque ya tenían agua fuera del bosque. Sin embargo, el alimento de temporada de los chimpancés *(S. senegalensis)* empezó a disminuir [Wasser et al., 2011, 2017; Cristóbal-Azkarate et al., 2016].

En el último cuatrimestre del 2015, FCM y T3 alcanzaron sus valores máximos. En contra de lo esperado, comenzaron la construcción de un depósito de agua en Dindéfélo para abastecer de agua corriente a varios pueblos de la Reserva. Se taló en zona altamente protegida por ser zona de chimpancés. También en septiembre, tuvo lugar una interacción agonística de 4 machos adultos de Nandoumary contra los chimpancés de Dindéfélo [Gómez-Espinosa et al., 2013; Muller and Wrangham, 2004; Rangel-Negrín et al., 2014; Yamanashi et al., 2016].

En noviembre, hubo baja disponibilidad de alimento y los chimpancés comenzaron sus viajes a zonas donde empieza a salir el Bhohé *(Adansonia digitata*) [Bertolani and Pruetz, 2011; McGrew et al., 1988], de baja actividad antropogénica, en la zona de Nandoumary, lo que podría explicar la disminución de T3 y MCF. En diciembre, *A. digitata* está madura lo que explicaría los aumentos de T3 pero varios grupos de chimpancés coincidieron en la misma zona para alimentarse lo que podría relacionarse con los aumentos de MCF [Behie, 2010, Rangel-Negrín et al., 2014].

Así pues, parece que los niveles de MCF aumentaron en meses con mayor actividad antropogénica pero también debido a la falta de disponibilidad de alimentos o dinámicas sociales de los chimpancés como la temporada de apareamiento, interacciones agonísticas o competencia por la comida entre grupos. Por lo tanto, sería necesario construir lavaderos públicos, pozos de agua en las aldeas, control del número de personas que acceden a las áreas protegidas de la Reserva para mejorar la conservación de los chimpancés y lograr una coexistencia sostenible.

Asimismo T3 correlacionó con la disponibilidad de alimento en función de la estación del año. En la estación seca los niveles de T3 aumentaron cuando el fruto de temporada estuvo maduro pero en la estación de lluvias la disponibilidad de alimentos aumentó y los valores de T3 también. Estos resultados también coincidieron con los cambios de temperatura. En estación seca con elevadas temperaturas, la T3 se mantuvo más baja que en época de lluvias con temperaturas más bajas que la T3 aumentó [Silva 2003, 2006]. Serían necesarios más estudios de la hormona tiroidea en chimpancés en libertad sobre métodos de recolección y almacenamiento de muestras y efectos de otras variables.

Es necesario la reforestación de *A. digitata* en diferentes zonas de la Reserva. La falta de este fruto en diferentes lugares de la Reserva podría ser explicado por la creencia tradicional local de que si hay muchos *A. digitata* juntas atraen al diablo. Los locales de Dindéfélo explicaron que años atrás había más árboles con este fruto pero los habían ido talando. Con lo que sería importante también un proyecto de educación ambiental para combatir este problema. De manera que es importante tener en cuenta las respuestas fisiológicas de los chimpancés y las percepciones locales para conseguir una coexistencia sostenible en la Reserva.

3. Respuestas conductuales de chimpancés en libertad a actividades antropogénicas en Dindéfélo y otros factores para la conservación de la biodiversidad.

El comportamiento encontrado con más frecuencia fue desplazarse seguido de alimentarse y finalmente descansar. La alimentación disminuyó al aumentar el número de personas presentes, como los grandes grupos de turistas [McLennan and Hill, 2010; Rangel-Negrín et al, 2014; Arroyo-Rodríguez and Días, 2010]. Las huidas de los chimpancés fueron mayores en 2015 que en 2014, lo que se podría explicar porque en 2015 las huidas fueron mayores en zona de alta actividad antropogénica que en la zona no accesible a humanos [McLennan and Hill, 2010; Maréchal et al, 2011; Muehlenbein et al., 2012] y por las interacciones agonísticas de 4 machos adultos de Nandoumary hacia los residentes [Boesch and Boesch-Achermann, 2000; McLennan and Hill, 2012]. Serían necesarios más estudios a largo plazo debido a este tipo de variables que no se pueden controlar en campo.

Los aumentos de metabolitos de cortisol fecal en Dindéfélo podían estar relacionados con actividades antropogénicas (turismo desorbitado, construcción de depósito de agua en zona protegida) y dinámicas propias de la especie (temporada de apareamiento, interacciones agonísticas entre grupos, desplazamientos en busca de alimento o competición por la comida entre grupos). Sin embargo, no se encontraron relaciones significativas entre las huidas de los chimpancés y los MCF. Aun así, es interesante que los niveles de MCF sean casi el doble con grupos pequeños de personas que con grandes grupos, aunque no sea significativo. Serían necesarios más estudios para valorar si los investigadores podrían ser un factor de estrés para los primates.

Es importante controlar el número de personas que acceden a los bosques para proteger las áreas de la Reserva y preservar las actividades básicas de los chimpancés,

como la alimentación, descanso y desplazamientos. Es fundamental ampliar las áreas protegidas y acciones para respetar su protección. El ecoturismo sería útil como una medida de control y construir lavaderos públicos en los pueblos para que los locales no tengan que ir al río del bosque y así lograr una coexistencia sostenible en esta compleja era del Antropoceno.

Una vez más, con las respuestas conductuales y fisiológicas de los chimpancés de Dindéfélo, se ha encontrado relación con actividades antropogénicas pero también con dinámicas propias de la especie. Chimpancés y humanos conviven en el mismo espacio y tiempo con sus propias variables que interaccionan entre sí. El comportamiento de los chimpancés estaría relacionado con actividades antropogénicas, disponibilidad de alimento, temporada de apareamiento, interacciones agonísticas con otros grupos, entre otros. La percepción de los humanos estaría influida por la educación recibida, participación en proyectos medioambientales y creencias tradicionales, entre otros. Los humanos en busca de recursos básicos en el bosque, como agua o alimento, se vieron afectados por la presencia de chimpancés; si los humanos se asustaban de los chimpancés huían corriendo. Y a su vez, los chimpancés huían de los humanos en su búsqueda básica de agua y alimentos. De manera, que es importante tener en cuenta múltiples factores como percepciones locales, indicadores fisiológicos y conductuales de los chimpancés, entre otros, para, preservar su bienestar y mejorar la coexistencia sostenible con la población humana (Figura 7) [Gibson et al., 2011].

Figura 7. Múltiples factores correlacionan en el complejo reto de la conservación de chimpancés y coexistencia sostenible con la población humana: percepciones locales, comportamiento y fisiología de los primates.

4. Referencias

Arroyo-Rodríguez V, Dias PAD. Effects of habitat fragmentation and disturbance on howler monkeys: a review. Am J Primatol. 2010; 72: 1–16.

Behie AM, Pavelka MS, Chapman CA. Sources of variation in fecal cortisol levels in howler monkeys in Belize. Am J Primatol. 2010; 72(7):600–6. doi: 10.1002/ajp.20813 PMID: 20166191.

Bertolani P and Pruetz JD. Seed Reingestion in Savannah Chimpanzees *(Pan troglodytes verus)* at Fongoli, Senegal. Int J Primatol. 2011. 32:1123–1132. Doi: 10.1007/s10764-011-9528-5.

Boesch C, Boesch-Achermann H. The chimpanzees of the Tai Forest: behavioural ecology and evolution. Oxford University Press, Oxford. 2000.

Borchers C, Boesch C, Riedel J, Guilahoux H, Ouattara D, Randler C. Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. Int. J. Sci. Educ. 2014; Part B 4: 240–259. DOI:10.1080/21548455.2013.803632.

Casanova C, Sousa C and Costa S. Are animals and forests forever? Perceptions of wildlife at Cantanhez Forest National Park, Guinea-Bissau Republic, Memórias Environmental Anthropology. 2014; 16:69-104.

Costa S, Casanova C, Sousa C, Lee P. The Good, The Bad and The Ugly: Perceptions of Wildlife In Tombali (Guinea-Bissau, West Africa). J. Primatol. 2013; 2:1. DOI:http://dx.doi.org/10.4172/2167-6801.1000110.

Cristóbal-Azkarate J, Maréchal L, Semple S, Majolo B, MacLarnon A. Metabolic strategies in wild male Barbary macaques: evidence from faecal measurement of thyroid hormone. Biol. Lett. 2016; 12: 20160168. http://dx.doi.org/10.1098/rsbl.2016.0168.

Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E, Di Fiore A, Nekaris K, Nijman V, Heymann EW, Lambert JE, Rovero F, Barelli C, Setchell JM, Gillespie TR, Mittermeier RA, Arregoitia LV, de Guinea M, Dobrovolski SR, Shanee S, Shanee N, Boyle SA, Fuentes A, MacKinnon KC, Amato KR, Meyer ALS, Wich S, Sussman RW, Pan R, Kone I, Li B. Impending extinction crisis of the world's primates: Why primates matter. Sci. Adv. 2017; 3.

Estrada, B. E. Raboy, L. C. Oliveira, Agroecosystems and primate conservation in the tropics: A review. Am. J. Primatol. 2012; 74, 696–711.

Gadd, M.E. Final report to BotswanaDepartment ofWildlife and National Parks: 2000–2001. Eastern Botswana Elephant Project, 2001. Botswana.

Gadd M. Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environmental Conservation. 2005; 32(1): 50-63.

Gibson L, Lee TM, Koh LP, Brook BW, Gardner TA, Barlow J, Peres CA, Bradshaw CJA, Laurance WF, Lovejoy TE, Sodhi NS. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature. 2011; 478: 378–381.

Gómez-Espinosa E, Rangel-Negrín A, Chavira R, Canales-Espinosa D, Américo P, Dias D. The Effect of Energetic and Psychosocial Stressors on Glucocorticoids in Mantled Howler Monkeys *(Alouatta palliata).* Am J Primatol. 2014 Apr; 76(4):362-73. doi: 10.1002/ajp.22240. Epub 2013 Nov 26.

Harcourt AH, Pennington H & Weber AW. Public attitudes to wildlife and conservation in the Third World. Oryx. 1986; 20: 152–154.

Hockings K and Humle T. Best Practice Guidelines for the Prevention and Mitigation of Conflict between Humans and Great Apes, Survival. IUCN/SSC, 2009; Primate Specialist Group. DOI:10.2305/IUCN.CH.2009.SSC-OP.37.en

Kormos R, Boesch C, Bakar MI and Butynski T. West African Chimpanzees. Status Survey and Conservation Action Plan. IUCN/SSC Primate Specialist Group. 2003. IUCN, Gland, Switzerland and Cambridge, UK. 219.

Maréchal L, Semple S, Majolo B, Qarro M, Heistermann M, MacLarnon A. Impacts of tourism on anxiety and physiological stress levels in wild male Barbary macaques. Biol Conserv. 2011; Sep; 144(9):2188– 93.

McGrew WC, Baldwin PJ, Tutin CEG. Diet of wild chimpanzees *(Pan troglodytes verus)* at Mt. Assirik, Senegal: I. Composition. Am. J. Primatol. 1988; 16: 3: 213-226. doi.org/10.1002/ajp.1350160304.

McLennan MR. Beleaguered Chimpanzees in the Agricultural District of Hoima, Western Uganda. Primate Conserv. 2008; 23: 45–54. DOI:10.1896/052.023.0105.

McLennan MR, Hill CM. Troublesome neighbours: Changing attitudes towards chimpanzees *(Pan troglodytes)* in a human-dominated landscape in Uganda. J. Nat. Conserv. 2012; 20: 219–227. DOI:10.1016/j.jnc.2012.03.002.

Meijaard, E. Unexpected ecological resilience in Bornean orangutan and implications for pulp and paper plantation management. PLoS ONE 2010; 5, e12813.

Muehlenbein MP, Ancrenaz M, Sakong R, Ambu L, Prall S. Ape conservation physiology: fecal glucocorticoid responses in wild *Pongo pigmaeus morio* following human visitation. PLoS ONE 7. 2012; e33357.

Muller MN, Wrangham RW. Dominance, cortisol and stress in wild chimpanzees (Pan troglodytes schweinfurthii). Behavioral Ecology and Sociobiology. 2004; 55(4):332-340 doi: 10.1007/s00265-003-0713-1.

Pacheco L, Fraixedas S, Fernández-Llamazares Á, Estela N, Mominee R, Guallar F. Perspectives on sustainable resource conservation in community nature reserves: A case study from Senegal. Sustainability. 2012; 4: 3158–3179. DOI: 10.3390/su4113158.

Pruetz JD. Chimpanzees in Bandafassi Arrondissement, Southeastern Senegal: Field Surveys as a Basis for the Sustainable Community-Based Conservation. Pan Africa News. 2011; 18(2).

Pruetz J and Bertolani P. Chimpanzee *(Pan troglodytes verus)* Behavioral Responses to Stresses Associated with Living in a Savannah-Mosaic Environment: Implications for Hominin Adaptations to Open Habitats. PaleoAnthropology. 2009; 252–262. doi:10.4207/PA.2009.ART33.

Rangel-Negrín A, Coyohua-Fuentes A, Chavira R, Canales-Espinosa D, Dias PAD. Primates living outside protected habitats are more stressed: The case of black howler monkeys in the Yucatán Peninsula. PLoS ONE. 2014; Nov 6; 9(11):e112329. doi: 10.1371/journal.pone.0112329 PMID: 25375243.

Ramón M, Llana M, Estela N, Pacheco L, Hockings K, Hill C. The fruit of discord? Saba senegalensis use by chimpanzees and local people in Senegal. Poster. 7th European Federation for Primatology Meeting. 21-25 August 2017. University of Strasbourg, France.

Sousa J, Ainslie A, Hill CM. Sorcery and nature conservation. Environmental Conservation. 2017; 1-6. DOI: 10.1017/S0376892917000327.

Sousa J, Vicente L, Gippoliti S, Casanova C. Local knowledge and perceptions of chimpanzees in Cantanhez National Park, Guinea-Bissau. Am. J. Primatol. 2014; 76: 122–134. Doi:10.1002/ajp.22215.

Waller MT, Pruetz J. Competition between Chimpanzees and Humans : The Effects of Harvesting Non- timber Forest Products. Ethnoprimatology. 2016; 157–177. DOI:10.1007/978-3-319-30469-4.

Watkins CA. Natural resource use strategies in a forest-adjacent Ugandan village. Hum. Ecol. 2009; 37: 723–731. DOI:10.1007/s10745-009-9268-8.

Wasser SM, Keim JL, Taper ML and Lele SR. The influences of wolf predation, habitat loss, and human activity on caribou and moose in the Alberta oil sands. Front Ecol Environ. 2011; 9(10): 546–551, doi: 10.1890/100071.

Wasser SK, Lundin JI, Ayres K, Seely E, Giles D, Balcomb K, Hempelmann J, Parsons K, Booth R. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales *(Orcinus orca).* PLoS ONE. 2017: 12(6): e0179824. https://doi.org/10.1371/journal.pone.0179824.

Webber AD and Hill CM. Using Participatory Risk Mapping (PRM) to identify and understand people's perceptions of crop loss to animals in Uganda. PLoS One. 2014; 9(7). DOI:10.1371/journal.pone.0102912.

Yamanashi Y, Teramoto M, Morimura N, Hirata S, Inoue-Murayama M, Idani G. Effects of Relocation and Individual and Environmental Factors on the Long-Term Stress Levels in Captive Chimpanzees *(Pan troglodytes):* Monitoring Hair Cortisol and Behaviors. PLoS One. 2016 Jul 27; 11(7):e0160029. doi: 10.1371/journal.pone.0160029. eCollection 2016.

CONCLUSIONS

Specific objective 1: Study local perceptions to design a course of actions to improve the management of chimpanzee conservation in the Reserve.

1. Locals who have not received elementary education thought, to a greater extent, that chimpanzees do not attack as opposed to those who have gone to school.

2. Locals who are not participated in environmental project were more afraid of the chimpanzees, thought that the chimpanzees attack, that there were no more trees 30 years ago and that there were no fires in the Reserve, as compared to those who were participating in the project.

3. Significant relationships are found between traditional beliefs and negative local perceptions towards chimpanzees, of fear and thinking that they attack.

Specific objective 2: Measure the physiological responses (concentration of faecal cortisol metabolites and T3) of chimpanzees in the Reserve to assess the effect of anthropogenic activities.

4. Faecal cortisol metabolites (FCM) and levels of T3 vary between months but not between study areas with different levels of human activity within the Reserve. FCM levels increase in months with high greater anthropogenic activity but also when there is scarcity of food, mating activity, agonistic interactions or food competition between groups.

5. T3 is related to food availability and temperature.

6. FCM and T3 are highly correlated.

Specific objective 3: Evaluate behavioural responses of chimpanzees to assess whether anthropogenic activities influence chimpanzees welfare in a human-dominated landscape.

7. The most common behaviour patterns in chimpanzees from Dindéfélo were traveling followed by feeding and resting. Feeding time decreased as the number of people present increased.

8. Flight behaviour of chimpanzees could be related to anthropogenic activities but also to the dynamics of the species such as agonistic interactions between groups.

9. There were no significant relationships between flight behaviour and FCM. Therefore, it is suggested that both physiological and behavioural measures should be used to assess chimpanzees' response to human activity.