The influence of certification and size of palm oil plantations on terrestrial biodiversity in Indonesia and Malaysia

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Abstract

The cultivation of palm oil has many adverse social and environmental impacts. The high level of biodiversity that is native to areas where palm oil plantations occur is at risk. Various measures are taken, such as the Roundtable of Sustainable Palm Oil (RSPO). The RSPO certification is a sector governance measure that indicates which management and operations interventions have to be implemented to protect the public interest – countering negative social and environmental impacts. No research has been done on the impact of RSPO certification and the plantation size on biodiversity. The research question of this thesis is "do RSPO certification and plantation size influence the level of biodiversity of palm oil plantations in Indonesia and Malaysia?" Three open source online data sets from Global Forest Watch containing information on plantations were used. These spatial data sets were combined with Global Biodiversity Information Facility (GBIF) species observations data. From GBIF, four taxa were selected to be used in this study, known to be impacted by palm oil cultivation: birds, lizards, primates and small mammals. The majority of the GBIF observations that laid within the studied plantation data set, however, were bird observations (93.0%). Only 1.8% of the GBIF observations laid within the palm oil plantations. Data analysis indicated that there is no significant difference between RSPO and non-RSPO-certified plantations in terms of biodiversity. The obtained results imply that the measures that are taken by plantations to obtain the RSPO certificate do not affect the level of biodiversity and therefore certification does not protect the species living on plantations better when compared to plantations that are not RSPO-certified. Results also indicate that biodiversity is not influenced by the size of a plantation – small, medium or large. The proposed research was the first attempt in getting insight into the effectiveness of certification and small-scaled plantations – in other words plantation size – on biodiversity levels. It can be concluded that the effectiveness of the two measures has not been proven yet. Suggestions for further research are done, in which higher quality data sets and larger numbers of observations are of importance.

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Introduction

Agricultural activity is currently one of the greatest threats to biodiversity together with the overexploitation of natural resources (Sodhi *et al.*, 2004). In Southeast Asia, this threat has intensified over the past years due to the constant expansion of oil palm plantations to meet the increasing global demand in vegetable oil. Palm oil is a highly versatile vegetable oil which can be included in both edible and non-edible products. It has low production costs, as well as a high efficiency in comparison to other vegetable oils. Consequently, palm oil is becoming more and more popular. It is estimated that global palm oil production is increasing 9% per year and it is expected to continue to increase in order to match the demand (Carter *et al.*, 2007). Most recent numbers by Index Mundi – a data portal that gathers facts and statistics from multiple resources worldwide – indicate that Indonesia is the largest palm oil producer; in 2018 it produced approximately 36 million tons of palm oil (Index Mundi, 2018). Indonesia is followed by Malaysia, which produces 21 tons of palm oil (Index Mundi, 2018). The annual production is still increasing in Indonesia, as the estimations for 2018 are that Indonesia produced 40.5 million tons of palm oil, whereas the production in Malaysia stagnated to approximately 20.5 million tons in 2018 (Index Mundi, 2018). To make room for the cultivation of palm trees, tropical rainforest is converted into agricultural land. During the period 1990-2005, over 50% of tropical forest has changed to agricultural land use (Koh and Wilcove, 2008; Vijay *et al.*, 2016). It is expected that the increase of human population and consumption will continue and this will lead to expand the conversion of 10^9 ha of natural ecosystem into agricultural land by 2050.

The impact of this expansion of agricultural land on biodiversity has widely been studied (Fitzherbert *et al.*, 2008; Koh and Wilcove, 2008; Danielsen *et al.*, 2009; Meijaard *et al.*, 2018). Biodiversity is threatened by palm oil plantations and the main direct impact is habitat loss (Meijaard *et al.*, 2018). Habitat loss is caused by deforestation and fire prior to palm oil development. According to Gaveau et al. (2016), 76% of Borneo has been converted into industrial plantations since 1973. The rapid conversion of tropical rainforest cleared into palm oil plantation has been up to 60% in Malaysia and around 15% for Indonesia as a whole. In comparison, globally oil palm development causes no more than 0.5% of all deforestation (Meijaard *et al.*, 2018). Besides habitat loss caused by deforestation, palm oil cultivation also has indirect impact on biodiversity loss. This indirect impact is a result of the use of fertilizers and pesticides. By 2050, the concentration of nitrogen and phosphorous-driven eutrophication is expected to be 2.4-2.7 folds the base line level of 2000 (Tilman *et al.*, 2001). Especially surrounding aquatic ecosystems are vulnerable to this eutrophication and runoff of substances. These freshwater aquatic ecosystems usually have a high biodiversity, meaning they support relatively high species diversity per unit area (Dudgeon *et al.*, 2006). This high species diversity is exposed to fertilizer and pesticides from runoff of the palm oil plantations, which is an adverse consequence of the agricultural expansion of palm oil.

Indonesia and Malaysia are not only the world leading palm oil producing countries, but they are also two of the 25 biodiversity hotspots indicated by Myers et al. (2000) (Figure 1). This combination makes these two countries very susceptible to high biodiversity losses. In addition to biodiversity loss, deforestation also negatively influences climate change (Moutinho and Schwartzman, 2005; Carlson *et al.*, 2012). Palm oil cultivation also has social impacts on people. Often governments prioritize economic growth and therefore allow corporations to take the land that is owned by indigenous people for their own financial benefit (Colchester *et al.*, 2007). Rules on the management of land property are often vague or non-existing, especially in non-democratic countries or places where corruption is common. The location of plantations is also alarming; although tropical rainforest sustains many (endangered) plant and animal species, the soil is not as fertile as expected. The majority of tropical rainforest is considered to be so called wet-deserts, as the vegetation grows on extremely poor soils, which are low in minerals and nutrients and are acidic. The rich and diverse vegetation is only able to exist because of the rapid nutrient cycling that is characterizing rainforest (Anderson and Ingram, 1989). Especially when the tropical rainforest is cleared by the "slash-and-burn" method – a farming method that involves the cutting and afterwards burning of vegetation and trees in a woodland or forest to create an agricultural field, called a swidden – the total mineral nutrient stock gradually declines over time. The majority of the nutrients derive from the above-ground biomass are released and available at the first few years after clearing (Juo and Manu, 1996). This implies that large amounts of fertilizers are needed to be applied to agricultural land in order to retain the same yield after the first few years.

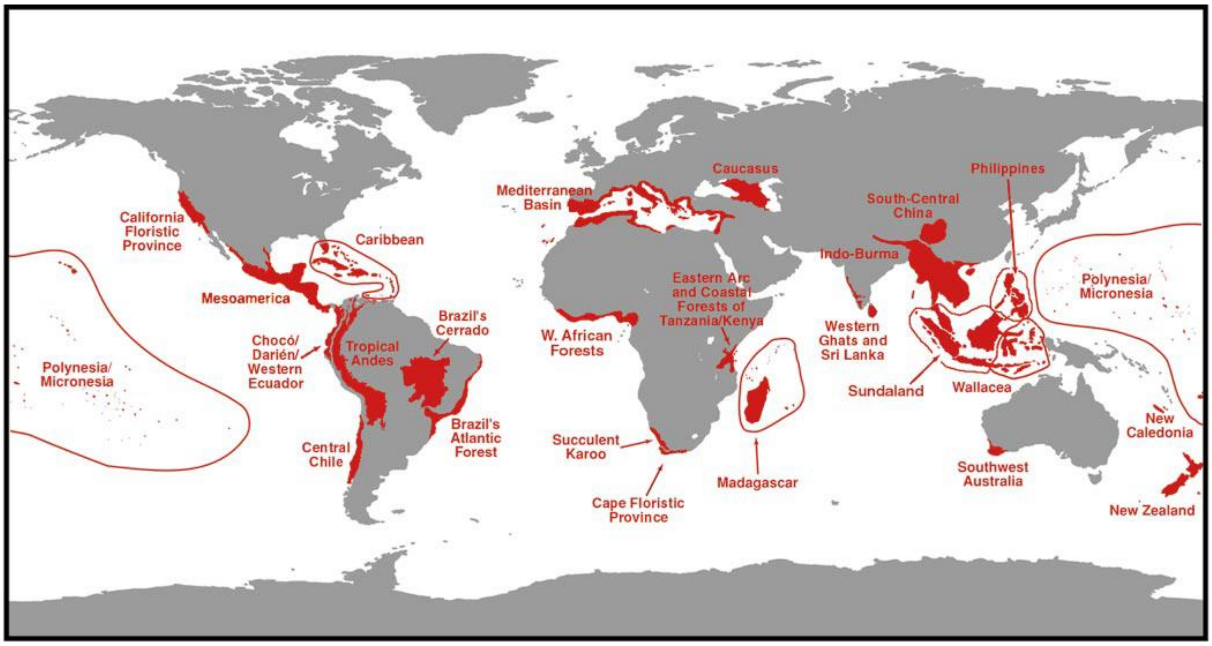

Figure 1. The 25 hotspots of biodiversity. Sundaland and Wallacea represent the hotspots in Indonesia and Malaysia (Myers *et al.*, 2000, p. 853).

Wilcove and Koh (2010) indicate four important actions that should be taken to reduce the negative impact palm oil plantation have in Southeast Asia. (1) There should be regulations to curb undesirable activities, for example by banning the conversion of forests into plantations.

(2) Financial incentives should be implemented to promote desirable behavior. (3) Financial disincentives should be implemented to discourage undesirable behavior. Consumers may have an influence on this, by putting pressure on major manufacturers and retailers to use more sustainable palm oil that does not come from plantations created at the expense of tropical rainforest. (4) Forested land that is prone to become palm plantations should be promoted to be used for alternative, more biodiversity-friendly purposes. Currently, worldwide industries and governments focus on certification of palm oil, which is an aspect related to the second and third action mentioned above.

The largest and most widely known certification system is the Roundtable on Sustainable Palm Oil (RSPO). Although this certification does already exist and is emphasized on global level by for example the European Sustainable Palm Oil, it remains a point of debate. In November 2018, a open statement was written against the RSPO, that was signed by over 100 parties such as Milieudefensie, in which it was stated that "the RSPO certification scheme allows the palm oil industry to expand while greenwashing the destruction and human rights violations it is responsible for" (World Rainforest Movement, 2018). The RSPO is also being accused of a) greenwashing by selling Green Palm Certificates; b) that the RSPO language is too weak and c) that the RSPO is ineffectual, as it lacks the power to enforce the guidelines and rules (Alexandre *et al.*, 2014). Paoli et al. (2010) also indicated four major challenges for the RSPO. One of them is the challenge of translation of boardroom corporate social responsibility (CSR) decisions – of which RSPO is part – into conservation actions on the palm oil plantation grounds itself.

The negative consequences, especially the environmental ones, of palm oil cultivation are also still of increasing concern and are not expected to stabilize any time soon. One of the reasons for this is the ongoing debate on the effectiveness of the RSPO – and certification in general as a matter of fact. Little is known about the effect it has on for example biodiversity loss and climate change. It is unclear how effective measures are on the preservation of biodiversity, as no research has been done on this topic up until now. The only research on possible differences between RSPO and non-RSPO plantations has been done by Morgans et al. (2018). The metrics that were studied in this case study in Indonesian Borneo (Kalimantan) were on three levels: environmental, social and economic. The environmental metrics were orangutan occurrence (as a unit key their presence) and fire (reduced number of fire incidents); the social metrics were poverty (reduced number of households receiving government assistance) and heath services (availability of rural health facilities); the economic metrics were yield (fresh fruit bunch (FFB) produced) and profits (share price). No significant difference was found between the non-certified and certified plantations for any of the investigated environmental and social metrics. There was however a positive economic impact of the certification: the FFB yield of the certified plantations was higher. The research concludes with "to achieve intended outcomes, RSPO principles and criteria are in need of substantial improvement and rigorous enforcement" (Morgans *et al.*, 2018, p. 1).

Besides the certification, the size a plantation might influence the level of impact too. This is related to the fourth action of Wilcove and Koh (2010) that is mentioned before: Forested land that is prone to become palm plantations should be promoted to be used for alternative, more biodiversity-friendly purposes. In line of this action, smaller sized plantations would be favourable over larger sized plantations. Therefore, for possible implementations to improve the certification system, the scale or the plantation size should also be examined. It could be that in order to protect biodiversity at palm oil plantations, a restriction on the size of a palm oil plantation is needed. Although little is known about the exact difference between smallholdings and large industrial scale plantations, there are indications that large industrial scale plantations have larger impacts (Lee *et al.*, 2014). In order to optimize the certification system in a way that it will become effective on a large scale, research on the effects on biodiversity is needed to indicate possible improvements. In this thesis, the first step towards implications for improvements is taken, as the effectiveness of certification at the palm oil plantations where this measure is in place, should be investigated first. In addition to this, there are also uncertainties about the effect that the scale of a plantation has on biodiversity and therefore this is investigated too.

Research question

The main research question is "*do RSPO certification and plantation size influence the level of biodiversity of palm oil plantations in Indonesia and Malaysia?*"

To answer this main research question, the sub questions below need to be answered.

(1) How can biodiversity be defined?
(2) How can terrestrial biodiversity be measured?
   a. Where are impacts expected to occur, i.e. what taxa are influenced the most when rainforest is converted into palm oil plantations?
   b. How can taxa be combined, i.e. in what ways is taxa aggregation possible?
   c. What data is available?
(3) How does certification influence the terrestrial biodiversity?
   a. How is certification currently organized?
   b. What (types of) certification (systems) exists?
   c. What are indicators that are measured in the assessment of the RSPO certification?
(4) Where are the palm oil plantations located?
   a. What data is available?
(5) What is the relation between palm oil plantations and terrestrial biodiversity?

Relevance

The current debate on (RSPO) certification is mainly fed by the fact that little is known about the effect it has on for example biodiversity loss and climate change. Uncertainty is one of the causes of disagreement on the effect certification has. In 2018, a large research was published: "Oil palm and biodiversity - A situation analysis by the IUCN (International Union for Conservation of Nature) Oil Palm Task Force". Many knowledge gaps were mentioned in this report. One of them indicated that "analyses to understand the effectiveness of governance initiatives for conservation, including accounting for recent changes in their setworks and implementation [are needed]" (Meijaard et al., 2018, p. 67). This research is a first attempt in investigating this knowledge gap, as this research is focused on investigating the effectiveness of two characteristics, RSPO and the plantation size, that may influence biodiversity levels. This may lead to a better understanding, which is needed to develop a better certification and monitoring system.

This research topic is related to the field of Industrial Ecology, as palm oil production is an industrial process that interacts and interferes with various ecosystems. Certification is an important tool that can be used to reduce negative impacts, but system-thinking, governance, stakeholders and a multi-level perspective are all key to succeed in reducing negative impacts of an industry on the environment. These are all aspects that are tackled in the field of Industrial Ecology and certification touches upon many of these aspects. This also implies the effectiveness of certification needs to be understood, which is the topic of this thesis.

Literature Review

The aim of this literature review is to define and operationalize biodiversity in the context of this research. More information about the RSPO certification system may also be found in this section.

Definition of biodiversity in the context of this research

There is a multitude of definitions for biodiversity (Hengeveld, 1996; DeLong, 1996). According to DeLong (1996), biodiversity can be defined in terms of species richness, species diversity, ecological diversity or native diversity. DeLong (1996) defines biodiversity as "an attribute of a site or area that consists of the variety within and among biotic communities, whether influenced by humans or not, at any spatial scale from microsites and habitat patches to the entire biosphere" (p. 745). This definition and the other definitions defined by DeLong (1996) are very complete and use an ecosystem view. However, for this research, biodiversity is measured in terms of species richness. Species richness is the number of different species represented in an ecological community, landscape or region (Colwell, 2009). When put in the context of this research, biodiversity is defined as the *total number of unique species that is found at a given location.* There are three main reasons for choosing this particular definition.

First of all, the aim of this research is to determine whether certification and size of palm oil plantations influences the biodiversity levels. The presence of species – which is included in the species richness definition – is influenced by the land use (Poschlod *et al.*, 2005; Koellner and Scholz, 2008). The cultivation of palm oil is a type of land use and therefore it is assumed that the species richness may be impacted and vary across plantations. Secondly, previous research has proven evidence that species richness is impacted when primary rainforest is converted into oil palm plantations (Foster *et al.*, 2011). According this research, biodiversity is both influenced in terms of species richness and species abundance (Figure 2). More on the relation between biodiversity and palm oil cultivation may be found in the next section of this literature review. Besides this, the data set that is used to calculate the biodiversity complies with the definition of species richness, as the data consists of spatial point observations of species. More on the used data may be found in the Methodology chapter. Thirdly, species richness, in other words the number of species, is considered to be "the simplest definition for biodiversity" (Swingland, 2001, p. 378). It is chosen to use the simplest definition for biodiversity to make this research accessible, also for laymen. Additionally, the risk of causing confusion about what biodiversity exactly is and how to measure it is avoided as much as possible by using the simplest definition.

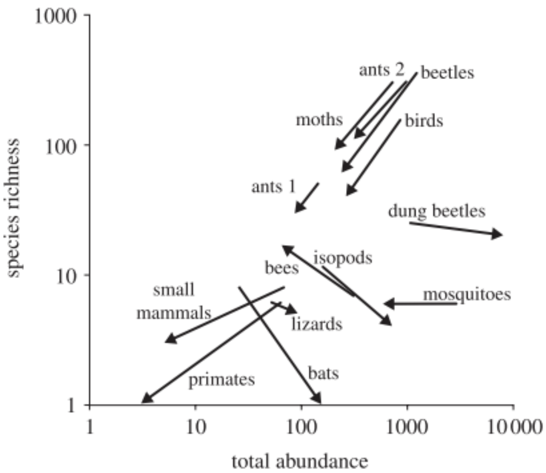

Figure 2. The impacts of converting primary rainforest into an oil palm plantation on the abundance and species richness of different taxa. Arrow tails denote primary forest communities and arrow heads oil palm communities. Where multiple oil palm plantations were surveyed, or multiple techniques were used to sample a single taxon (but where sampling effort was equivalent in both habitats), average values are used. Note that studies where collection methods differed between habitats or those that do not provide abundance data are not included (Foster *et al.*, 2011, p. 3278).

Biodiversity and palm oil cultivation

In 2005, Malaysia and Indonesia had 44% and 42% share of the palm oil production respectively (Basiron, 2007). As from 2006 onwards, Indonesia has been the largest producing country of palm oil. Over the years, a large amount of research and development has been conducted to optimize the palm oil production in terms of yield and productivity, as the demand for palm oil has grown rapidly. This is due to the increased world population and the related increase in food demand. Additionally, palm oil is also used as raw material for the production of biodiesel. Biodiesel is used to substitute fossil fuels in order to reduce non-biogenic greenhouse gas emission and thereby reduce climate change. On the one hand, the search for and growing interest in fossil fuel substitutes to possibly mitigate climate change is a positive development, but at the same time it poses new problems, such as deforestation, habitat fragmentation and corresponding biodiversity loss and competition with other crop (food) production. According to Basiron (2007), for this reason the palm oil industry players recently collaborated with other stakeholders to establish a certification system for sustainably produced palm oil, with full traceability.

Palm oil cultivation has a significant negative impact on biodiversity (Meijaard *et al.*, 2018). On a global level, at least 193 threatened species of the IUCN Red List of Threatened Species are affected by palm oil production (IUCN, 2018). The IUCN Red List of Threatened Species hold all the species within the IUCN “Critically Endangered”, “Endangered” or “Vulnerable” status – see Table 4 of the Methodology chapter for descriptions of the Red List statuses. These 193 species entail 64% of the threatened birds globally and 54% of the threatened mammals globally (IUCN, 2018). This is a substantial negative impact and is mainly caused by deforestation in order to clear land for cultivation. Deforestation has many consequences, such as habitat loss and degradation, but also less obvious impacts such as cumulative and indirect impacts. Cumulative impacts include effects on the landscape in combination with other land-use changes. In these cases the landscape changes lead to alterations in the habitat of species in a way it becomes less suitable for species to live in. An example of this could be that due to landscape alterations, the environment does not supply enough protective places to nest and consequently reproduction may become at risk. In these cases the impact of deforestation is amplified. Indirect impacts could be road building and induced in-migration (Meijaard *et al.*, 2018). Another indirect impact that influences especially the aquatic ecosystems is the runoff of fertilizers and pesticides that are used to increase the palm oil yield. All these impacts lead to a decline in species populations in the local and surrounding ecosystems and thereby the overall biodiversity of the area. It must be noted however that not all the palm oil cultivation is at the cost of biodiversity, as about 50% of the palm oil developments between 1972 and 2015 replaced shrubslands, pasturelands, cropland and other land uses. The other half of the palm oil developments was at cost of tropical rainforest and therefore significantly negatively impacted the biodiversity (Meijaard *et al.*, 2018, Appendix 3).

Fitzherbert et al. (2008) addressed the critical question "How will oil palm expansion affect biodiversity?". They concluded that the negative impact on biodiversity due to palm oil expansion will remain substantial unless governments of producing countries become better at controlling the protection of forest, logging and ensuring that plantations are located in appropriate areas. Often this is a challenge, as the governance of producing countries is in general weak. Causes for this vary but include corruption as well as other structural and complex underlying causes. These underlying causes include high poverty and therefore the focus of governments is very short term and mainly focused on economic drivers. Governance is a critical aspect, especially since it is often not the lack of willingness to comply with international sustainability – environmental, social and economic – standards, but the political and economic ability to do so (Fitzherbert *et al.*, 2008).

As stated before, it can be concluded that oil palm cultivation has a negative impact on biodiversity when compared to the natural rainforest biodiversity levels. According to Koh (2008), biodiversity within palm oil plantations may also vary. This variation in species composition may be explained by differences in local vegetation characteristics within estates. Other biotic and abiotic factors may also play a role in the variation of biodiversity within oil palm estate. Not all species are negatively impacted by the transformation of rainforest into oil palm however; some species benefit from the presence of oil palm plantations. These species are ecological generalists, such as some snakes and pigs, and profit from the high food availability at plantations. The species that suffer the most from habitat lost and fragmentation due to land clearing for agriculture are the orangutans (*Pongo).* This genus has three species: the Bornean orangutan (*P. pygmaeus*), the Sumatran orangutan (*P. abelii*) and the Tapanuli orangutan (*P. tapanuliensis*) (Nater *et al.*, 2017). Other species that are found to be severely affected by oil palm plantations are gibbons *Hylobates albibarbis* (Marshall, 2009), tigers *Panthera tigris sumatrae* (Luskin *et al.*, 2017) and certain birds species, especially forest specialized species (Sheldon *et al.,* 2010).

Certification and the Roundtable of Sustainable Palm Oil (RSPO)

Although Basiron (2007) was quite positive on the effectiveness of RSPO, it should be mentioned that his research has been written commissioned by the Malaysian Palm Oil Council. Other publications on the effectiveness of certification are less optimistic (Fitzherbert *et al.*, 2008; Rival *et al.*, 2016; Meijaards *et al.*, 2018). Currently, a number of standards to support sustainable and responsible palm oil production exists. These include certification standards for palm plant growers and are the most widely known, of which the Roundtable on Sustainable Palm Oil (RSPO) standards are the most important. According to Balch (2013), RSPO is the "world's flagship certification body for the palm oil industry". The RSPO is also considered to be the most important, as 19% of the global palm oil is RSPO-certified and according to the RSPO webpage on impacts, 40% of the world's palm oil producers are members of the RSPO. RSPO is a non-governmental institute – so, according to themselves, a not-for-profit – founded in 2004. The RSPO unites stakeholders from seven sectors of the palm industry: oil palm producers, processors or traders, retailers, consumer good manufactures, bank/investors, environmental and social non-governmental organizations (NGOs). Its vision is "RSPO will transform markets to make sustainable palm oil the norm". Its mission is to establish global standards for sustainable palm oil production and ensure stakeholder engagement, throughout the supply chain; both on a governmental as well as at the consumer level. They also provide assurances to investors and buyers. In addition to this RSPO, other initiatives exist, that are also on a voluntary base, such as the Sustainable Palm Oil Manifesto (SPOM) and the Palm Oil Innovation Group (POIG).

Mandatory national standards also exist. Indonesia has such a system, called Indonesian Sustainable Palm Oil (ISPO). Although this ISPO is mandatory, in April 2017 only 12% of Indonesia's palm oil plantations were ISPO certified (Ribka, 2017). This indicates that the government's attempt to improve sustainable palm oil production still has a long way ahead. The largest difference between the ISPO and the RSPO is their aim. The aim of the ISPO is "to improve the competitiveness of the Indonesian palm oil on the global market and contribute to the objective set by the President of the Republic of Indonesia to reduce greenhouse gases emissions and draw attention to environmental issues" (ISPO, n.d). The aim of the RSPO is to: "1) advance the production, procurement, finance and use of sustainable palm oil products; 2) develop, implement, verify, assure and periodically review credible global standards for the entire supply chain of sustainable palm oil; 3) monitor and evaluate the economic, environmental and social impacts of the uptake of sustainable palm oil in the market; 4) engage and commit all stakeholders throughout the supply chain, including governments and consumers" (RSPO, n.d.). Clearly, the scope of the aim of the RSPO is much broader than ISPO's aim. This is in line with the multi-stakeholder approach that is distinctive to the RSPO.

Schouten and Glasbergen (2011) investigated global private governance, by using the Roundtable on Sustainable Palm Oil as a case. Global private governance is defined as "forms of socio-political steering in which private actors are directly involved in regulating – in the form of standards or more general normative guidance – the behavior of a distinct group of stakeholders" (Pattberg 2006, p. 591). A remaining problem in global private governance is the equal representation of stakeholders (Schouten and Glasbergen, 2011). However, the RSPO is aware of this challenge and is investing time and energy to reduce and if possible even solve this issue. Although RSPO is considered to be a good example in which global private governance is effective by Schouten and Glasberg (2011), they also concluded that the RSPO is not – yet – able to change the whole palm oil market. Additionally, the RSPO was not able to ensure approval and consent of some external NGOs (Schouten and Glasberg, 2011). Some NGOs think RSPO is not progressive enough and measures to improve production methods and prevent expansion and deforestation of the tropical rainforest are not sufficiently strict and rigid.

Wilcove and Koh (2010) are also less optimistic about the RSPO certification. They indicate that "the success of any certification program depends on the willingness of manufactures and consumers to preferentially pick the certified product, even if they have to pay a premium for it" (p. 1005). As palm oil plantations are commercial companies, revenues are crucial for them to survive. Therefore, certification should not have any negative financial consequences. As certification costs money, the RSPO-certified palm oil is more expensive. In order to be effective, certification should either lead to higher market prices in general, but then the certification must be obligatory for all producers, which is currently, and in the near future, not the case. If the market price increases, all producers of palm oil will have the financial resources to comply with the regulations of certification and to pay for the fee for being certified. Another option would be that consumers must be willing to pay more for RSPO-certified products. A small research by Giam et al. (2016) among 251 consumers in Singapore indicated that on average people – within this sample at least – were willing to pay 8.2-9.9% more for deforestation-free palm oil-containing products compared to non-certified products. A large scale study performed on the willingness-to-pay for RSPO-certified – or deforestation-free – palm oil-containing products was not found. No study was also found that was executed in a region that is further away from the palm oil plantations. It is likely that deforestation is more of concern in regions close to where it actually occurs, such as Singapore. De Waal and Ostfeld (2017) however found that the British consumer recognition of the RSPO eco label on packages was "virtually non-existent" in comparison to for example the Fair Trade label. Ten years ago, according to a World Wildlife Fund press release in May 2009, less than 1% of certified palm oil produced in the previous half year had been sold (Butler, 2009). This indicates that customers show little interested in buying more expensive, but RSPO-certified products. The shelf life of palm oil is long however, so it is not possible to draw strong conclusions from this press release. More recent studies or press releases have not been found.

Recently, Azhar et al. (2017) identified that the attitude has changed and currently most palm oil available in global markets is sourced from large scale certified plantations. Only little is sourced from smallholders, who are typically uncertified. Azhar et al. (2017) argue however that the sourcing of sustainable palm oil should not be determined solely by commercial certification, which RSPO is. Often, the palm oil of smallholders is more biodiversity and environmental friendly, but lack certification, because of the associated costs. In general, these smallholders cultivate palm trees mixed with other crops (poly-culture agriculture), which reduces the negative impacts on biodiversity compared to large-scale mono-cultivation of palm trees. Sourcing palm oil from smallholders alleviates poverty among rural farmers, this may also promote better conservation outcomes (Azhar *et al.*, 2017). The financial stability can prevent rural migration, can ensure minimal deforestation and may minimize the gobbling of employees by large plantation owners (McCarthy and Cramb*,* 2009; Cramb and Curry*,* 2012). In addition to this, individual farmers that practice poly-culture agriculture have a greater ability to buy food compared to farmers that rely on a single crop (Fu *et al.*, 2010; Kremen *et al.,* 2012). Azhar et al. (2017) conclude that the certification process and assessment need revision and the value of smallholders should be recognized more. The possible value of smallholders – in other words smaller sized plantations – in terms of biodiversity is investigated in this thesis.

In order for a plantation to become RSPO-certified, it has to comply with the "RSPO Principles and Criteria" (P&C). Once a planation is RSPO-certified, re-assessment will occur every five years. According to Roundtable on Sustainable Palm Oil (2013), there are eight principles for palm oil farmers to become RSPO-certified:

"1) commitment to transparency;
2) compliance with applicable laws and regulations;
3) commitment to long-term economic and financial viability;
4) use of appropriate best practices and millers;
5) environmental responsibility and conservation of natural resources and biodiversity;
6) responsible consideration of employees and of individuals and communities affected by growers and millers;
7) responsible development of new plantings;
8) commitment to continuous improvement in key areas."

The fifth principle is the most interesting one for this research. Although there are interdependencies between principles, the aim is to have a clear subdivision and to evaluate them separately accordingly. RSPO (2013) elaborated on this principle by indicating six sub principles and criteria. The entire chapter on P&C number 5 of RSPO (2013) is found in Appendix A.

Summarized, RSPO demands:
5.1) indication of the environmental impacts;
5.2) High Conservation Value identification;
5.3) reduction, recycling, re-use and environmental friendly disposal of waste;
5.4) efficient use of fossil fuel and preferably renewable energy;
5.5) avoidance of the fire use, unless it has proven to be the best or only solution;
5.6) reduce pollution and emission.

In November 2018, a new report with "RSPO Principles and Criteria" guidelines (RSPO, 2018) was released. The principles are sharpened and more tangible. Another difference compared to the RSPO 2013 is the three defined impact areas: prosperity, people and planet. These three impact areas – also referred to as the three P's – are a common concept in sustainable development. According to Hammond (2005), they are the determinants of humanity's environmental or ecological footprint. By using the three P's, the RSPO does show it is aware of the important factors that play a key role towards sustainable development. The RSPO P&C 2018 is structured as following:

"**Impact Goal Prosperity:** <u>Competitive, resilient and sustainable sector</u>

Principle 1. Behave ethically and transparently

Principle 2. Operate legally and respect rights

Principle 3. Optimise productivity, efficiency, positive impacts and resilience

Impact Goal People: <u>Sustainable livelihoods and poverty reduction</u>

Principle 4. Respect community and human rights and deliver benefits

Principle 5. Support smallholder inclusion

Principle 6. Respect workers' rights and conditions

Impact Goal Planet: <u>Conserved, protected and enhanced ecosystems that provide for the next generation</u>

Principle 7. Protect, conserve and enhance ecosystems and the environment"

Although most principles are related to prosperity and people, the planet is also seen as an important impact area. The development that the planet has become a separate impact category, suggests that biodiversity, as an important element of the planet pillar, also seems to have become more of a priority in the new P&C. However, within the criteria of principle 7, biodiversity is not mentioned once. In the definition section, biodiversity is neither mentioned. A reason or explanation behind this development compared to the RSPO P&C 2013 was not found in literature or official documentation. Presumably politics – related to the uncertainties involved when quantifying biodiversity – were involved in this decision, but this assumption cannot be proven in any way. The entire Impact Goal Planet chapter of the RSPO (2018) is found in Appendix B. Summarized the RSPO demands the following to reduce the impact on the planet:

7.1) usage of Integrated Pest Management techniques;
7.2) responsible application and usage of pesticides;
7.3) reduction, recycling, re-use and environmental friendly disposal of waste;
7.4) maximization of soil fertility;
7.5) minimization of erosion and degradation of soil;
7.6) site planning incorporates soil surveys and topographic information;
7.7) preservation of peat lands;
7.8) maintenance of quality and availability of surface and groundwater;
7.9) energy efficiency, preferable renewable energy use;
7.10) reduction of pollution and (GHG) emissions;
7.11) no usage of fire;
7.12) no deforestation of High Conservation Values (HCVs) or High Carbon Stock (HCS) forests.

A comparison of the full criteria of both RSPO (2013) and RSPO (2018) that tackle the environment – and thereby the planet, including biodiversity – can be found in Table 1. The main difference is the way in which the criteria are formulated. The latest RSPO P&C have more criteria and the criteria are more concrete. The RSPO has made an attempt to make the criteria more SMART: Strategic, Measurable, Attainable, Results-oriented, and Time-bound (Doran, 1981). The criterion that concerns biodiversity, criteria 5.2 of RSPO P&C 2013 and criteria 7.12 of RSPO P&C 2018, is rephrased. "The status of rare, threatened or endangered species" within the criterion has disappeared and thereby High Conservation Values (HCV) forest might be susceptible to wrong interpretation of the meaning. In the definitions chapter of RSPO P&C 2018, HVC is extensively defined. There are six types of HCV areas mentioned, namely in terms of 1) species diversity; 2) landscape-level ecosystems, ecosystem mosaics and Intact Forest Landscapes (IFL); 3) ecosystems and habitats; 4) ecosystem services; 5) community needs; 6) cultural values. An area with high species diversity is considered to be a HCV area according the RSPO definition. However, this species diversity is only used as a criterion to determine which areas cannot be converted into palm oil plantations. The RSPO does not include anything about the species richness – the used definition of biodiversity in this research – on the palm oil plantation itself after it is converted. Biodiversity loss reduction is thereby not explicitly a criterion to be RSPO-certified. An important improvement however in the RSPO P&C 2018 compared to the RSPO P&C is the the inclusion of a roadmap towards Sustainable Palm Oil Production (Appendix C).

Table 1. Criteria of RSPO P&C 2013 with the corresponding criteria of RSPO P&C 2018 that are related to the environmental impact reduction (the “Planet” pillar).

	RSPO criteria 2013	Corresponding RSPO criteria 2018
1	Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continual improvement.	Pests, diseases, weeds and invasive introduced species are effectively managed using appropriate Integrated Pest Management (IPM) techniques. (1)
		Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield. (4)
		Practices minimise and control erosion and degradation of soils. (5)
		No new planting on peat, regardless of depth after 15 November 2018 and all peatlands are managed responsibly. (7)
2	**The status of rare, threatened or endangered species and other High Conservation Value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and operations managed to best ensure that they are maintained and/or enhanced.**	**Land clearing does not cause deforestation or damage any area required to protect or enhance High Conservation Values (HCVs) or High Carbon Stock (HCS) forest. HCVs and HCS forests in the managed area are identified and protected or enhanced. (12)**
3	Waste is reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner.	Waste is reduced, recycled, reused and disposed of in an environmentally and socially responsible manner. (3)
4	Efficiency of fossil fuel use and the use of renewable energy is optimised.	Efficiency of fossil fuel use and the use of renewable energy is optimized. (9)
5	Use of fire for preparing land or replanting is avoided, except in specific situations as identified in the ASEAN guidelines or other regional best practice.	Soil surveys and topographic information are used for site planning in the establishment of new plantings, and the results are incorporated into plans and operations. (6)
		Fire is not used for preparing land and is prevented in the managed area. (11)
6	Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.	Pesticides are used in ways that do not endanger health of workers, families, communities or the environment. (2)
		Practices maintain the quality and availability of surface and groundwater. (8)
		Plans to reduce pollution and emissions, including greenhouse gases (GHG), are developed, implemented and monitored and new developments are designed to minimise GHG emissions. (10)

Conclusions of the literature review

Meijaard et al. (2018) have investigated the link between oil palm and biodiversity. A lot of research has been done on the difference in biodiversity between natural forest and palm oil plantations (Savilaakso *et al.*, 2014). It can be concluded that oil palm plantations have lower biodiversity levels compared to tropical rainforest (the natural forest). Meijaard et al. (2018) also identified eight requirements that are key to the future success of more responsible palm oil production programs. This transition will require “scientists to create an improved evidence-base of in-situ certification effectiveness to continuously refine criteria to be more vigorous and effective in meeting environmental (and social) goals among highly variable production systems and groups of stakeholders” (p. 84). The combination of the fact that research has been done on differences between plantations and natural forests and the need for evidence of effectiveness of certification is combined in this research.

Little research has also been done on the scale of plantations. One study on bird diversity between large industrial oil plantations and smallholdings indicated that the bird assemblages are similar, but the small scaled plantations support slightly higher levels of bird species richness (Azhar *et al.*, 2011). Therefore, the possible influence of the size of the plantations on biodiversity is also studied in this research.

Methodology

In order to obtain a better understanding in the possible impact of management measures taken within palm oil cultivation on terrestrial biodiversity, a data study is being conducted. Data on two main aspects is used. (1) Spatial data on palm oil cultivation, with a particular focus on the presence of RSPO certification and the size of the plantation. (2) Spatial data on the current biodiversity levels – in other words species presence. An overlay of these two data sources will be used to answer the main question of what is the impact of RSPO certification and the size of palm oil plantations on terrestrial biodiversity. The entire code that has been executed can be found in Appendix D.

Spatial palm oil plantation data

Multiple data sets on oil palm plantations are available worldwide. As the analysis is focused on diversity within plantations, two spatial data sets were used:

(1) A data set (Global Forest Watch, 2018a) that attempts to distinguish between natural forest and various stages of plantations (not only oil palm). The data set includes all the plant species and therefore only "Oil palm" for the variable named "spec_org" in the original data set was selected. The key countries on which this data set is focused are Brazil, Cambodia, Colombia, Indonesia, Liberia, Malaysia, and Peru. As this research only concerns Malaysia and Indonesia, the plantations within this area were selected. The subset that is used in the analysis therefore only includes data on palm oil plantations within Indonesia and Malaysia. This data set indicates land use in four different categories:
"**Large industrial plantation:** single plantation units larger than 100 hectares
Mosaic of medium-sized plantation: mosaic of plantation units < 100 hectares embedded within patches of other land use
Mosaic of small-sized plantation: mosaic of plantation units < 10 hectares embedded within patches of other land use.
Clearing/very young plantation: bare ground with contextual clues suggesting it will become a plantation (shape or pattern of clearing, proximity to other plantations, distinctive road network, etc)."
This data set is used to investigate the effect of the scale, in other words the *size* of plantations on the terrestrial biodiversity.

(2) The second data set that is used is focused on certification. Availability of these types of data sets is limited, as information regarding certification and locations is often unclear and not openly available. The data sets are also on a national level, not on a global level. Therefore, a combination of multiple (two) data sets was used to investigate the effect of *RSPO certification* of oil palm plantations on terrestrial biodiversity. The combination is made up of the following separate data sets:

- RSPO Palm Oil Mills (Global Forest Watch, 2018b) → spatial points data set.
- RSPO-certified oil palm supply bases in Indonesia (Global Forest Watch, 2018c) → spatial polygons data set.

As the data sets that were used concern spatial data, the two used packages in R are "raster" (Hijmans, 2017) and "sp" (Pebesma and Bivand, 2005). The data set types are not the same and therefore, the RSPO Palm Oil Mills data set was first changed into a spatial polygons data set by adding buffers of 100 meter around each data point. This 100 m buffer was chosen as most palm oil plantations have multiple mills. This small buffer size therefore reduces the risk of overestimation of the number of RSPO plantations within the plantation size data set (1) after the overlay was made that is described in the next paragraph.

In order to make the comparison between RSPO-certified and non-RSPO-certified plantations, an overlay has been generated of the combination of the two RSPO data sets (2) and the plantation size data set (1). It is assumed in this case that all the palm oil plantations that have no overlay, in other words that do not correspond with the location of the RSPO data set, are uncertified, i.e. are non-RSPO. The plantations that were not in the plantation size data set, but were in the RSPO plantation data set were added to the total data set. The output of the steps performed above it called the complete data set (complete_data_set in R) and this is the end result of the combination of the three data sets. This complete spatial data set consists of 6,311 observations.

Biodiversity data

For this research, GBIF (Global Biodiversity Information Facility) data was used to estimate the biodiversity. GBIF provides world-wide species occurrence records. The GBIF information records spatial observations on the occurrence of a particular species. Therefore, the GBIF data set can be used to obtain a meaningful quantification of biodiversity according to the definition that is used for this research; *total number of unique species that is found at a given location.* This definition is related to the species richness at a given location.

GBIF data only provide insight in species richness – a species is present or not – and no insight in species abundance. Therefore, the specific taxa that are influenced in terms of species richness are the species that can be used for the biodiversity investigation of this research. Based on the literature review, taxa that seem sensitive to the conversion form tropical rainforest to plantation were the main focus in the analysis. Assumed is that the drivers for this sensitivity are the same as the drivers for differences within palm oil plantations. Consequently, the same taxa as Foster et al. (2011) are assumed to be representative for this research. These taxa are isopods, moths, birds, ants, beetles, bees, lizards, small mammals and primates (see Figure 2 of the literature review). Within this selection, the choice has been made to analyze those taxa for which the most data is available in GBIF and also on which indications of the total number of species present in the country are available. An example for this is the number of species of birds

present in Indonesia and Malaysia, which is 1,709 and 718 respectively according to Bird Life National. According to Profauna, there are 40 primate species in Indonesia. For Malaysia, the number is estimated to be at least 20 primate species (Badrul *et al.,* 2015). At least 10 endemic lizard species in Indonesia are indicated by the World Atlas. For Malaysia this number is at least 7 lizard species within the Beris Valley (Shahrudin *et al.,* 2011). According to Wilson and Reeder (2005) there are 85 species of small mammals in Indonesia and at least 57 species in Malaysia.
These indications are used to determine if the species richness that is found for a particular location according to the GBIF data is in the right order of magnitude. As a consequence of the lack of any certainty in the number of invertebrate species (isopods, moths, ants and beetles), these taxa were excluded for the analysis. It is also expected that the availability of species observations of invertebrates within the GBIF data set will not outweigh the lack of knowledge in an estimation of the number of invertebrate species. It is expected that as invertebrates are smaller is size and often live within soil, data on the occurrence is likely to be incomplete. Therefore, these taxa were omitted from further analysis.

Estimates of biodiversity were derived in two different ways. First, the number of different species per taxa was used as an indicator of biodiversity. For this purpose, every taxa was investigated separately. Secondly, the total biodiversity was determined according to Verones et al. (2015), in which equal weights were given to all taxonomic groups. A list of the studied taxa, including scientific name is presented in Table 2. This list only includes fauna species, as analysis of flora within palm oil plantations will be hard, as the main occurring plant species is the oil palm (*Elaeis guineensis*) itself.

Table 2. Scientific names of orders that were investigated in terms of species richness at palm oil plantations.

Taxa/Order	Scientific name
Birds	*Aves*
Lizards	*Lacertilia*
Primates	*Primates*
Small mammals[1]	*Rodentia, Scandentia and Eulipotyphla*

[1] The group of small mammals is made up of the rodents, tree shrews and the eulipotyphlans, according to the IUCN SSC Small Mammal Specialist Group classification. (Source: http://www.small-mammals.org/small-mammals-2/)

The species data from GBIF were extracted in R, using the "RGBIF" package (Chamberlain *et al.,* 2019). The taxon keys that correspond to the scientific name mentioned in Table 2 were found by using the "name_backbone" function. Results of this backbone search may be found in Table 3. The taxon keys were used to download the point data set of the taxa. The country codes that were used are "IN" and "MY", for Indonesia and Malaysia, respectively. Data sets per taxa were requested and downloaded by using the "occ_download" and "occ_download_get" functions within the applied RGBIF package.

Table 3. Corresponding taxon keys of the taxa that were investigated.

Scientific name	TaxonKey	Level	Taxa Order
Aves	212	classKey	Birds
Lacertilia	715	orderKey	Lizards
Primates	798	orderKey	Primates
Rodentia	1459	orderKey	Small mammals
Scandentia	801	orderKey	Small mammals
Eulipotyphla[2]	359	orderKey	Small mammals
Erinaceida[2]	5722	familyKey	Small mammals
Soricomorpha[2]	803	orderKey	Small mammals

[2] Order Eulipotyphla = 'Erinaceomorpha' + 'Soricomorpha', therefore all three backbone searches were performed and used for further analysis.

The four taxa were downloaded separately, but also all together, by using the code below.

```
request_all <- occ_download('taxonKey = 212,715,1459,801,359,5722,803,798',
'country = ID,MY', 'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
#              user = "cathelijnestikkers", pwd = "###", email = "###")
```

This downloaded data set has a total of 515,231 observations. As not all the information is relevant, only the variables listed below were kept in the subset that was used for the overlay with plantation information:

- speciesKey
- familyKey
- classKey
- orderKey
- year
- countryCode
- decimalLatitude
- decimalLongitude

The taxon key equals the family key, class key or order key, depending on the level of the taxon (Table 3).

Overlay spatial indicators and biodiversity

To investigate the possible effects of a spatial characterization (plantation size) and management indicator (RSPO certification) on biodiversity within oil palm plantations, a spatial overlay of the spatial data set (complete_data_set) and the biodiversity data set (gbif_all) was made. The complete_data_set is the data set that includes all the plantations – both RSPO and non-RSPO – that were used in this analysis (see section "Spatial oil palm plantation data", p. 15/16). The function below is used.

```
overlay_gbif <- over(gbif_all,complete_data_set)
```

The missing values (indicated as "NA", an abbreviation for "not available") in this data set are species data observations that do not occur within the plantations data set (i.e. complete_data_set). A data set of the not missing values (non NA's) (data set is called "GBIF_in_plantations") was created. Out of the total of 515,231 observations in the total GBIF data set, 9,061 observations fall within spatial configuration of the plantations data set. To check whether these results are plausible, both the gbif all dataset and the complete data set were exported to a shape file. In QGIS Desktop 3.0.3, the overlay was visualized. An extra layer of the outline of countries – large scale and cultural as settings – was added, downloaded from the Natural Earth Data website.

Systematic Overview

A systematic overview of the steps that have been taken to get to the spatial overlay of plantations (including information on certification and plantation size) and biodiversity data points (GBIF) is found in Figure 3.

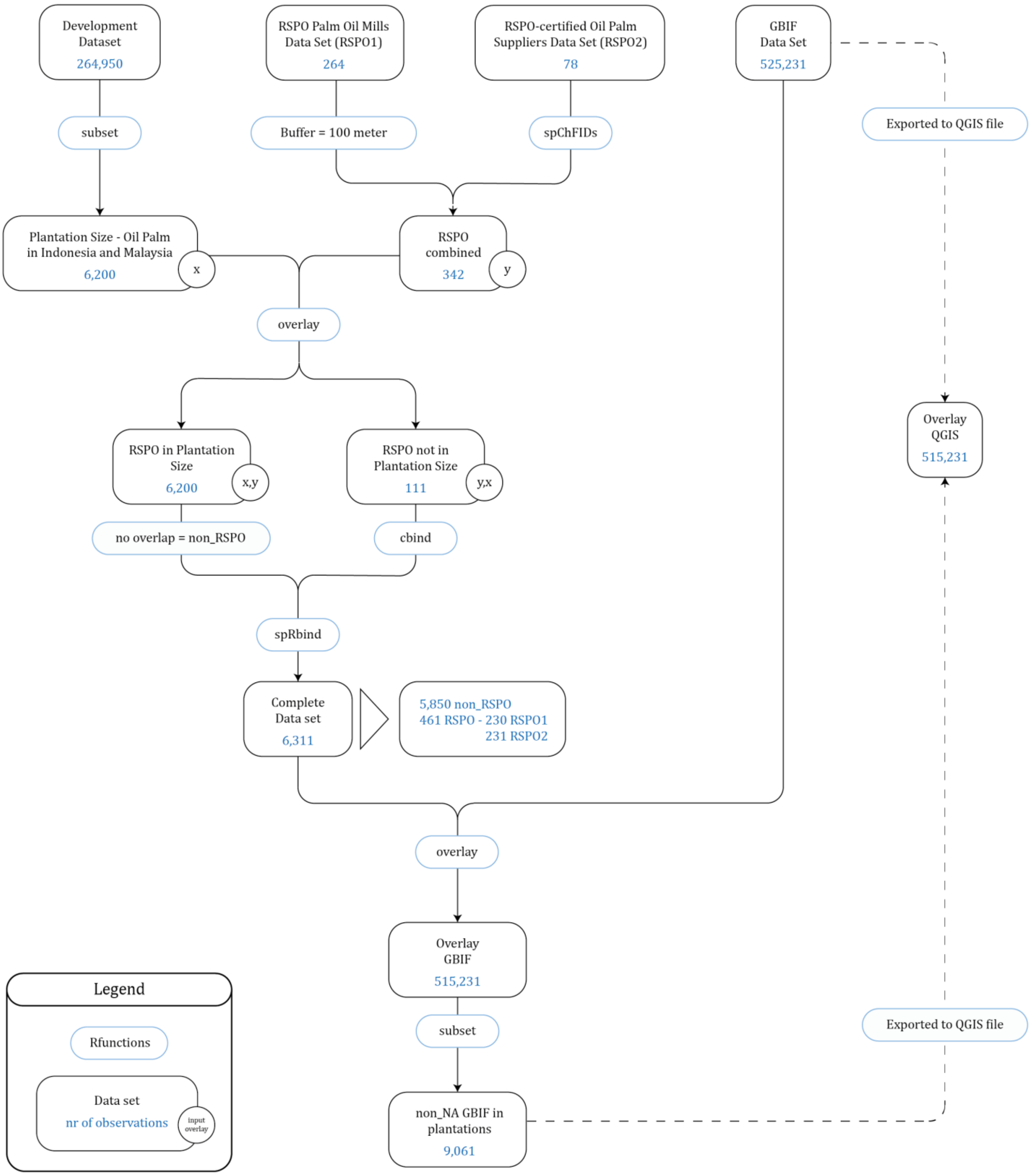

Figure 3. Overview code execution in R. The blue numbers indicate the number of elements (observations) within the data set.

Statistical analysis

The next step in the analysis was to get a response variable to perform statistical analyses in order to determine whether there is a difference between a) biodiversity in RSPO and non-RSPO plantations and b) biodiversity in plantations of different sizes. For the statistical analysis, two types of data sets were used: one data set including the information of all species of the four studied taxa (in R named "all") and four data sets per taxa (in R named "birds", "lizards", "primates" and "smallmammals"). The steps described in this section were performed in the same way for all five data sets.

The response variable was defined as **the number of different species per plantation**. This value was generated in a two-step procedure by using the "aggregate" function. The outcome of this procedure is a data set with the count of all different species keys per plantation.

1) `response_variable2 <- aggregate(GBIF_in_plantations$objectid, list(GBIF_in_plantations$objectid, GBIF_in_plantations$speciesKey), FUN = "length")`
2) `response_variable_2.2 <-aggregate(response_variable2$Group.1, list(response_variable2$Group.1), FUN= "length").`

The variable is called response_variable2, because at first, the response variable that was used did not take the species key into account, and aggregated all individual observations.

While performing the aggregations, the certification and plantation size information was lost and therefore another step was taken to add this information to the response variable data set. The response variable data set and the original "GBIF_in_plantations" data set were merged (see code below; NB "developmental_stage" in the code refers to the plantation size).

```
total_spp_per_location_incl1 <- merge(response_variable,
unique(GBIF_in_plantations[,c("objectid",
"certification","developmental_stage")]),
                                 by="objectid")
```

The distribution of the response variable data set was checked. Generating histograms by using the "hist" function, revealed that the response variable was not normally distributed. Therefore, a log transformation to the species count (= response variable) was performed by using the "log10" function. One last step was taken to obtain the final data set that was used to perform the final step of the statistical test. A large number of plantations only had a species count of 1, meaning there would only occur one species at the given plantation. As it is not realistic that only one species of a given taxa occurs at a plantation, all the observations that had species count=1 were excluded from the data sets for further analyses.

The statistical test that was used in the analysis to investigate whether there are differences between certification and plantation size is an ANOVA. ANOVA stands for "analysis of variance". It is a collection of statistical models, with certain associated estimation procedures, that can be used to analyze differences in a sample among group means. One of the estimations is the variation among and between groups. This particular test was chosen, as it was aimed to investigate whether the number of species occurring at different types of plantations differs. If the outcome of the ANOVA is significant (p-level < 0.05), the difference cannot only explained by random variance and therefore the difference in the means of the sample between the groups can be attributed to the factor used for the ANOVA. The factor levels in this analysis were "certification" and "plantation size". In ANOVAs the interaction between two (or more) factors can also be investigated. The ANOVAs were performed on the five data sets, by using the "lm" function within the "stats" package (R Core Team, 2018). Boxplots were generated using the "boxplot" function.

To generate less basic figures, the program IBM SPSS Statistics 25 was used. The data sets including the response variable were exported to an Excel file with the "write.xlsx" function within the "xlsx" package (Dragulescu and Arendt, 2018).

Assumptions

Summarized the following assumptions are made during the code execution:

- The circumferences of RSPO palm oil mills that are used to determine whether they have an overlap with the plantation size data set is 100 m;
- Plantations in the plantation size data set that do not correspond to the location of the RSPO combined data set are non-RSPO-certified;
- Data obtained from the GBIF package is complete and observations are also done at private premises, such as plantations;
- The four taxa indicated in Table 2 are included in the analysis and therefore it is assumed that these four taxa are representative for the differences in biodiversity, which is the outcome of the analysis;
- It is not realistic that only one species of a given taxa occurs at a plantation.

Species occurrence analysis

To investigate whether there are large differences in the species identities of the species that occur at the different types of plantations, an additional analysis was performed. For this analysis, only certification was taken into account as factor. Per taxa, a data set with all species that occur within the "GBIF_in_plantation" data set was generated and exported to Excel. The information in the exported data sets was the species key and certification (RSPO or non-RSPO). By using the function Pivot Table in Microsoft Excel 2010, an analysis of the occurrence per species key in both types of plantations was performed. In the pivot table function, "certification" was added as column label, "speciesKey" as row label and the sum of frequency as value.

As there was a large difference between the number of data points within RSPO plantations and non-RSPO plantations (see Table 5 in the Results section), the obtained data in the pivot table was first normalized. This was to avoid biases towards the non-RSPO data, as the species occurrence data analysis should investigate whether a particular species has a preference for a type of plantation (RSPO or non-RSPO). The number of presences for species *i* in RSPO plantations (*x)* was divided by the total number of RSPO plantations. The value (Y_1) obtained is the fraction of RSPO plantations occupied by species *i.* Consequently the same was done for the number of presences for species *i* in non-RSPO plantations (*y)*. This number is divided by the total number of non-RSPO plantations. The value (Y_2) obtained is the fraction of non-RSPO plantations occupied by species *i.* The value of interest, the relative preference of species *i* for RSPO plantations versus non-RSPO plantations, was calculated by subtracting non-RSPO plantations occupied by species *i* from RSPO plantations occupied by species *i* (Y_1-Y_2). As a final step the species keys were looked up in the GBIF data set and the corresponding scientific names were obtained. The obtained scientific names were looked up in to the IUCN Red List, to check the Red List status of the species. This status is obtained to get insight in the distribution of the various Red List statuses along the relative preference for RSPO plantations among species. It might be that the Red List species have a higher preference for the RSPO plantations, indicating that RSPO plantations might be more beneficial for Red List species to live in. The species occurrence analysis has been done for all four species categories separately. The IUCN Red List status are described in Table 4, in which the concerns are from the lowest to the highest.

Table 4. The nine IUCN Red List catergories including explanation (Dublin, 2013).

Red List Abbrivation	Red List category	Explanation of Red List category (Dublin, 2013)
NE	Not Evaluated	"A category used to include any of the nearly 1.6 million species described by science but not assessed by the IUCN."
DD	Data Deficient	"A condition applied to species in which the amount of available data related to its risk of extinction is lacking in some way. Consequently, a complete assessment cannot be performed. Thus, unlike the other categories in this list, this category does not describe the conservation status of a species."
LC	Least Concern	"A category containing species that are pervasive and abundant after careful assessment."
NT	Near Threatened	"A designation applied to species that are close to becoming threatened or may meet the criteria for threatened status in the near future."
VU	Vulnerable	"A category containing those species that possess a very high risk of extinction as a result of rapid population declines of 30 to more than 50 percent over the previous 10 years (or three generations), a current population size of fewer than 1,000 individuals, or other factors."
EN	Endangered	"A designation applied to species that possess a very high risk of extinction as a result of rapid population declines of 50 to more than 70 percent over the previous 10 years (or three generations), a current population size of fewer than 250 individuals, or other factors."
CR	Critically Endangered	"A category containing those species that possess an extremely high risk of extinction as a result of rapid population declines of 80 to more than 90 percent over the previous 10 years (or three generations), a current population size of fewer than 50 individuals, or other factors."
EW	Extinct in the Wild	"A category containing those species whose members survive only in captivity or as artificially supported populations far outside their historical geographic range."
EX	Extint	"A designation applied to species in which the last individual has died or where systematic and time-appropriate surveys have been unable to log even a single individual."

Results

The distribution of the GBIF species observations

The frequency of data points within the overlay of the spatial data set of plantations and the biodiversity GBIF data set is displayed in Table 5 (certification) and Table 6 (plantation size). It can be concluded that the data set is not balanced either in terms of certification or of plantation size, but there are observations in all categories except in the clearing/very young plantations. The unbalance is not insurmountable and therefore no extra measures were taken before further analysis. In reality, the majority of palm oil planation is large-scaled within the studied region (Austin *et al.,* 2017). In the selected data set, the majority of the GBIF species data lies within the "Large industrial plantations" and "non-RSPO" certified plantations. In total there were 515,231 GBIF data points within Indonesia and Malaysia in the species categories that are studied (Table 7). Of these 515,231 observations, 9,061 observations lay within the boundaries of the plantations (Figure 4). The total species data set was used for this study, but also data sets on the four species categories separately. The majority (93%) of the observations are within the bird category (Table 7).

Table 5. Frequency of species observations (GBIF data points) in certification categories.

Category	Number of data points
Non-RSPO	6,785
RSPO (Global Forest Watch, 2018b and 2018c combined)	2,276
<NA>	506,170

Table 6. Frequency of species observations (GBIF data points) in plantation size categories.

Category	Number of data points
Large industrial plantation	7,271
Mosaic of medium-sized plantation	1,272
Mosaic of small-sized plantation	518
Clearing/very young plantation	0
<NA>	506,170

Table 7. The number of observations per taxa that lay within the investigated plantations.

Taxa/Order	Number of observations	Percentage of total observations (%)
Birds	*8,425*	*92.98*
Lizards	*72*	*0.79*
Primates	*42*	*0.46*
Small mammals	*120*	*1.32*

The distribution of species that is presented in Table 7 suggests that only for birds meaningful results may be obtained and interpreted. The numbers of observations within the other taxa are small and therefore are more likely to have biased results.

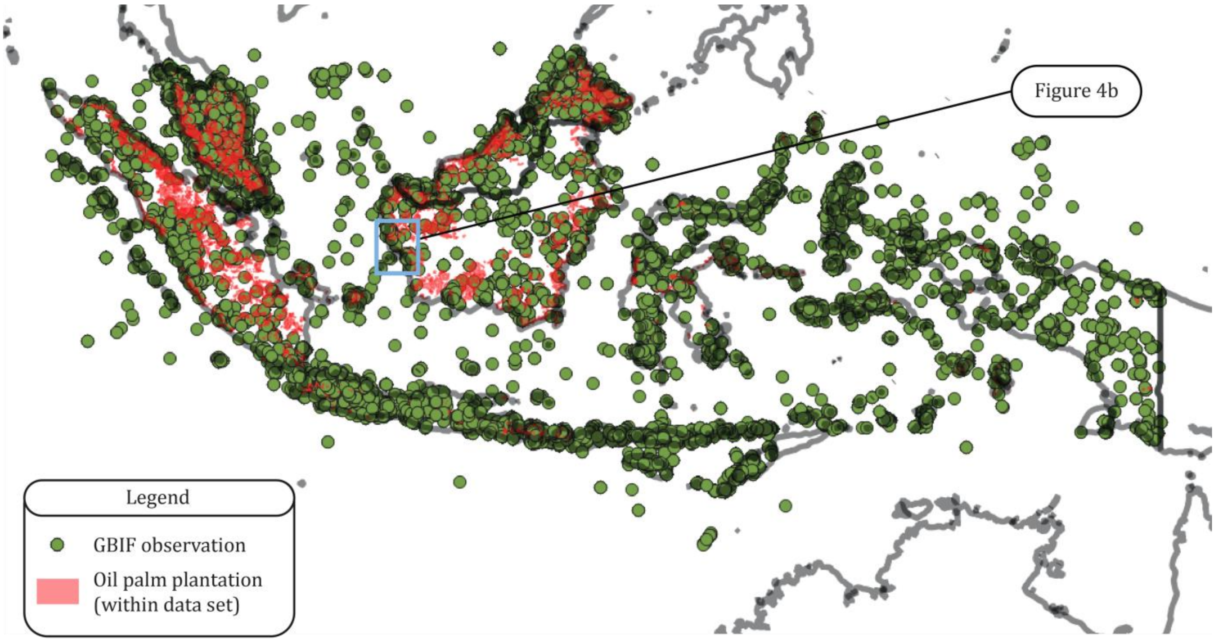

Figure 4a. Overlay in QGIS. Green dots represent GBIF observations; the red area represents the plantations that are included in the data set (both RSPO and non-RSPO).

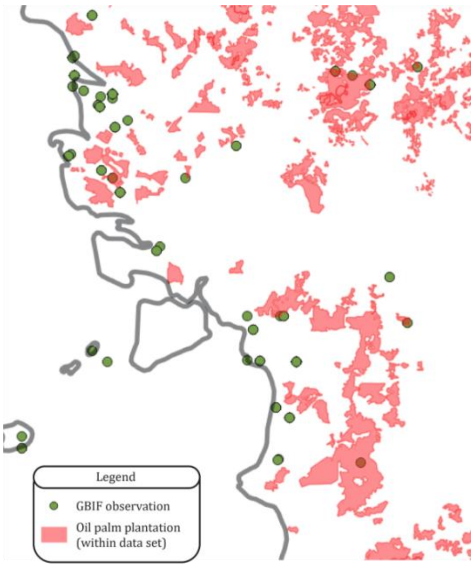

Figure 4b. Zoom-in of the blue area indicated in Figure 4a. GBIF observations that fall within the palm oil plantations are visible, as well as GBIF observations that fall outside of the studied plantations. The latter were excluded from the analysis.

The distribution of species across the studied plantations

Histograms of the response variable – species count per plantation – are presented in Figure 5. As seen in the histograms, the response variable is not normally distributed and therefore a log transformation was performed before ANOVAs were conducted. The histograms after the log transformation are found in Appendix E. The number of plantations that had a species count of >1 in the five data sets is listed in Table 8. The characteristics (certification and plantation size) of these plantations are also mentioned. More information on descriptive results of the species count is found in Appendix F.

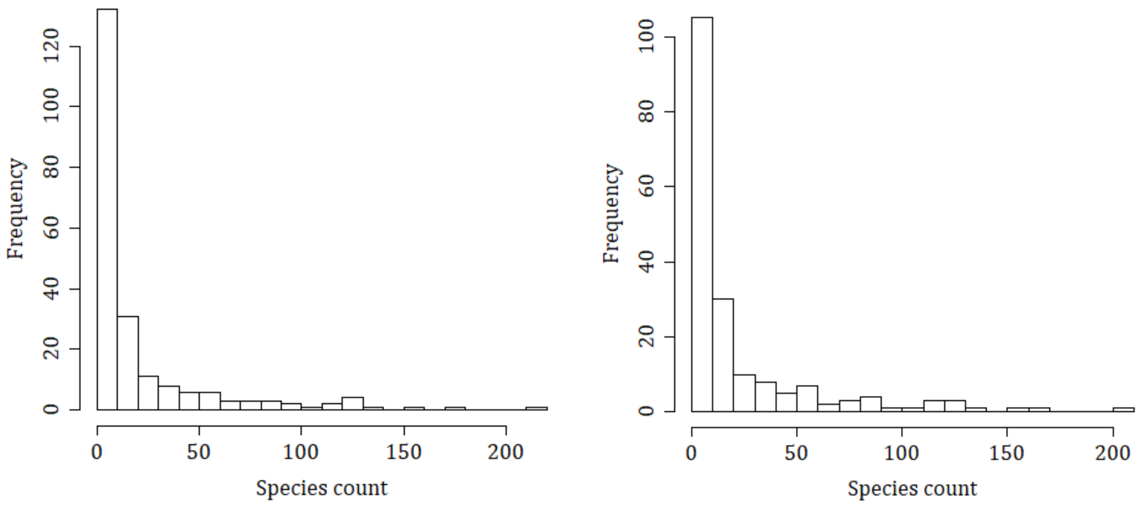

Figure 5ab. Histogram of distribution of species count per plantation of **a.**(left) all species combined and **b.**(right) bird species.

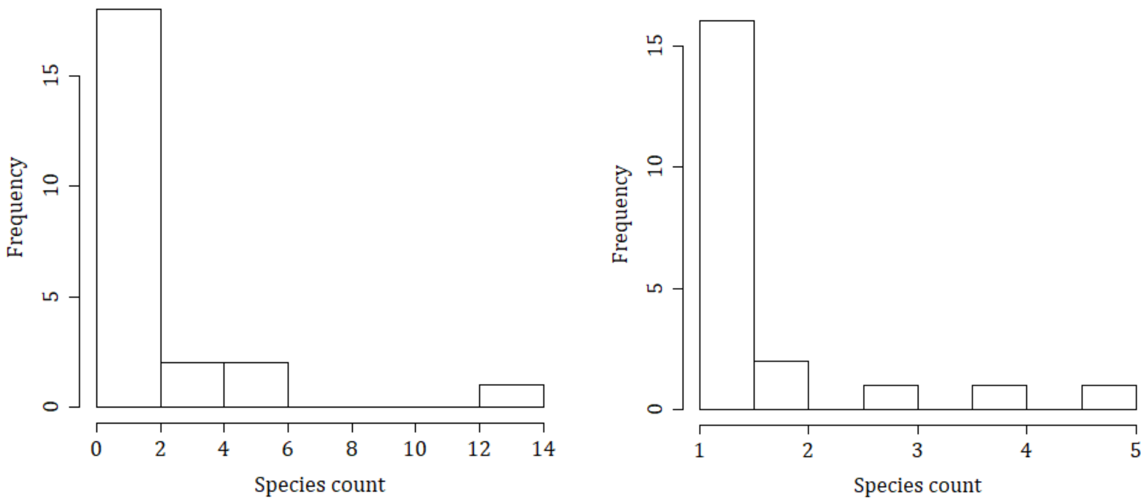

Figure 5cd. Histogram of distribution of species count per plantation of **c.**(left) lizard species and **d.**(right) primate species.

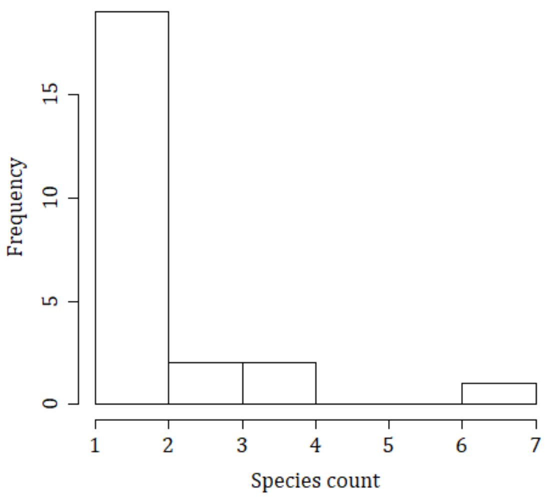

Figure 5e. Histogram of distribution of species count per plantation of small mammal species.

Table 8. Descriptive frequencies analyses – number of plantations that have a species count >1, including certification and plantation size information.

Taxa	Number of plantations	Certification		Plantation size		Mean speciescount
All	161	non-RSPO	137	Large	117	27.15
		RSPO	24	Medium	23	
				Small	21	
Birds	146	non-RSPO	123	Large	106	28.51
		RSPO	23	Medium	21	
				Small	19	
Lizards	9	non-RSPO	9	Large	5	4.44
		RSPO	0	Medium	1	
				Small	3	
Primates	5	non-RSPO	1	Large	5	3.20
		RSPO	4	Medium	0	
				Small	0	
Small mammals	6	non-RSPO	4	Large	5	3.83
		RSPO	2	Medium	1	
				Small	0	

Table 8 suggests that in general, according this research's approach, most GBIF observations are done within the non-RSPO plantations and the large, industrial scaled plantations (which is in accordance of the availability in the plantations data set). The only exception of this is the primate category. More GBIF observations were done within RSPO-certified plantations – 4 RSPO plantations have observations of primates versus 1 non-RSPO-certified plantation where primate species were recorded.

The differences in biodiversity levels between the various types of plantations

To investigate whether the suggested findings according the descriptive frequencies results (Table 8) are significant, ANOVAs were performed. The difference between the certification (RSPO or non-RSPO) and the size of plantations, if possible, was tested. The interaction between the two factors was also included, but there were too many data gaps to calculate this interaction (Table 9). The p-values of the various ANOVA tests are presented in Table 9. The full ANOVA tables can be found in Appendix G. It can be concluded that there are no significant differences in species richness between the various plantation types considered, as no p-value is <0.05 (level of significance). For primates and lizards, the data sets contained too little information to perform an ANOVA, indicated with NA (= "not available"). This can be explained by the information in Table 8. According to the GBIF observations, lizards were only observed in non-RSPO plantations. There are only primate observations in large industrial plantations and none in the other plantation types. This can also be seen in the corresponding boxplots (Figure 8a and Figure 9b).

Table 9. Summary of p-values of ANOVAs performed on data set. The response variable is number of species observations per plantation ("speciescount").

	all spp	birds	Lizards	Primates	small mammals
certification	0.1937	0.4602	NA	0.3375	0.9389
plantation size	0.7705	0.6702	0.7334	NA	0.8348
certification*plantation size	NA	NA	NA	NA	NA

The boxplots of the total data set, that includes all the species (Figure 6), indicate that the distribution of the response variable "speciescount" is more spread for the certification data than the plantation size data. This corresponds to the lower p-value for certification found in Table 9. The distribution for the plantation size is quite similar for all three categories. The black line in the middle of the blue boxes indicates the mean species count. This mean score for both factors (certification and plantation size), hardly differs for the different categories indicated at the x-axis. This is in line with the insignificant result found in the ANOVA (Table 9). It can be concluded that there is no significant difference in mean species count, and thereby in total biodiversity, between RSPO-certified and non-RSPO-certified plantations. The same holds for the size of a plantation. Noticable are the outliers, that occur in the non-RSPO category, the large industrial plantations and the medium-sized plantations.

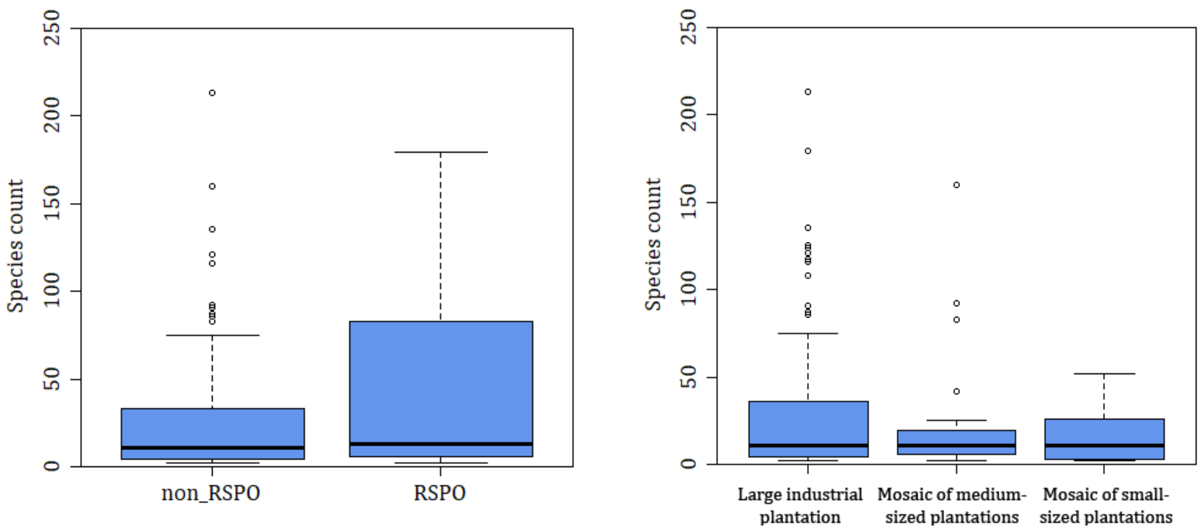

Figure 6ab. Boxplots of total data set. **a.**(left) species count by certification and **b.**(right) species count by plantation size.

The boxplots for the bird species (Figure 7), also indicate that the mean species count, and thereby biodiversity, hardly differs between RSPO and non-RSPO-certified plantations. The plantation size neither influences the biodiversity. The distribution of the response variable is larger for RSPO plantations than for non-RSPO plantations, but is not significant (Table 9). Outliers are again present.

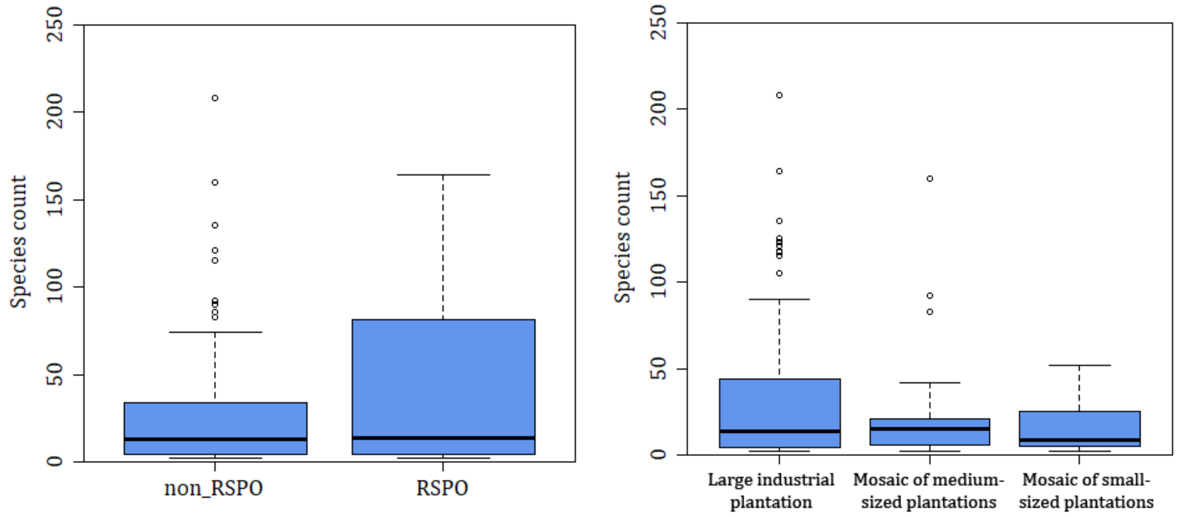

Figure 7ab. Boxplots of bird species. **a.**(left) species count by certification and **b.**(right) species count by plantation size.

The boxplots for lizards (Figure 8) indicate that there are no observations at RSPO-certified plantations and this corresponds to the inability to perform an ANOVA with certification as a factor (Table 9). Only one observation is done for medium-sized plantation, which is also visible in Table 8. The distribution of biodiversity in the small-sized plantation is wider. The lower whisker equals the mean, however, which suggests there are many plantations with low species numbers. One outlier is present when looking at the observations within the certification category.

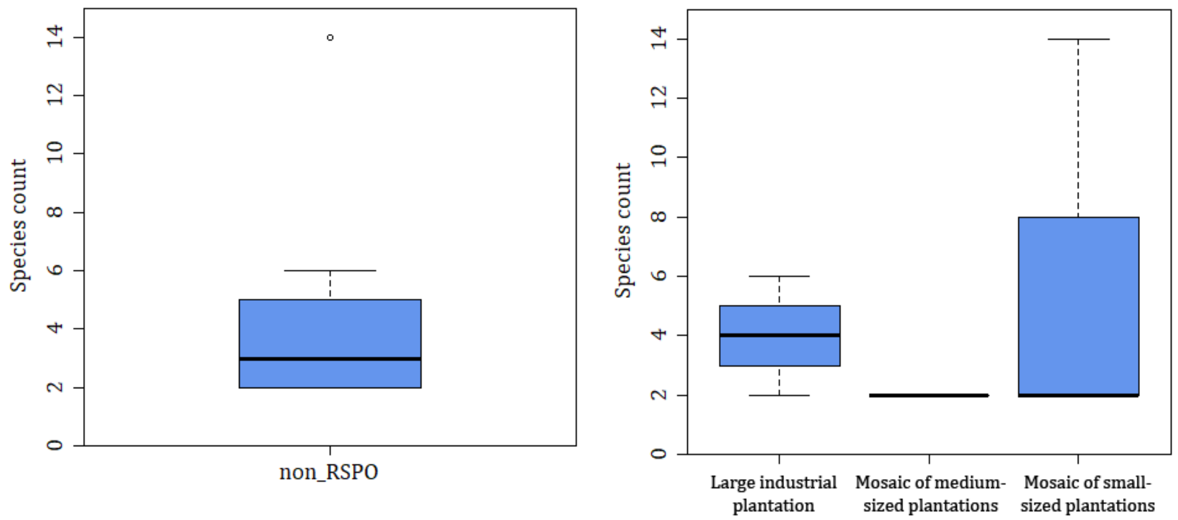

Figure 8ab. Boxplots of lizard species. **a.**(left) species count by certification and **b.**(right) species count by plantation size.

The boxplots of the primate species (Figure 9), indicate that observations are only done within one non-RSPO plantation (i.e. one data point), also indicated in Table 8. The mean biodiversity differs for this reason between RSPO and non-RSPO-certified plantations, but this result is not significant due to the low number of data points. An ANOVA for the plantation size could not be performed, as observations are only done within large industrial plantations (Figure 9b).

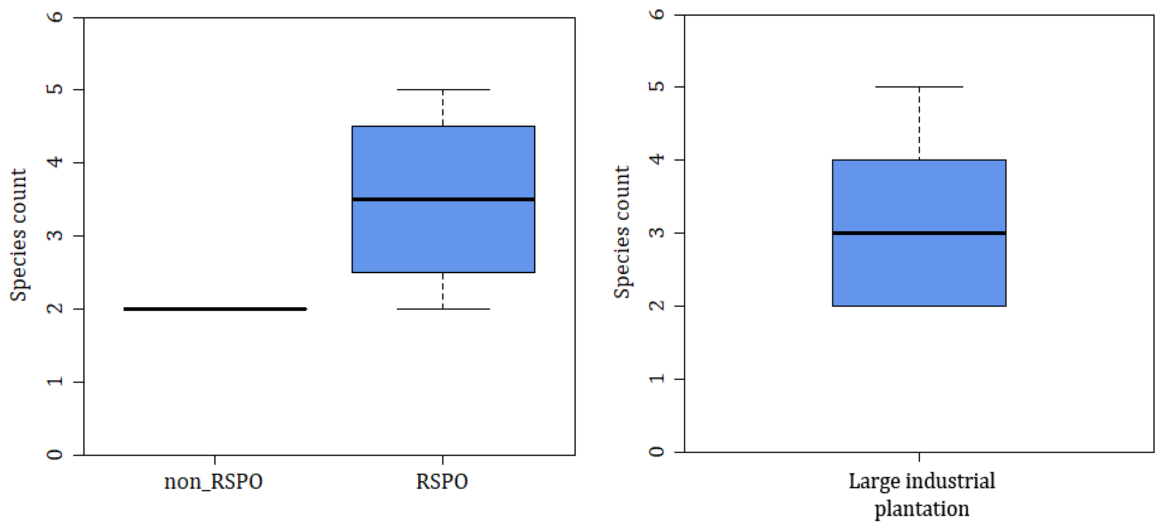

Figure 9ab. Boxplots of primate species. **a.**(left) species count by certification and **b.**(right) species count by plantation size.

The mean species count, representing biodiversity, for small mammals (Figure 10) is about equal across the two certification categories. In the plantation size analysis, observations were only done in large and medium-sized plantations. The mean species count differs, but this difference is again explained by the fact that observations were only done within one medium-sized plantation, and are therefore not significant (Table 9).

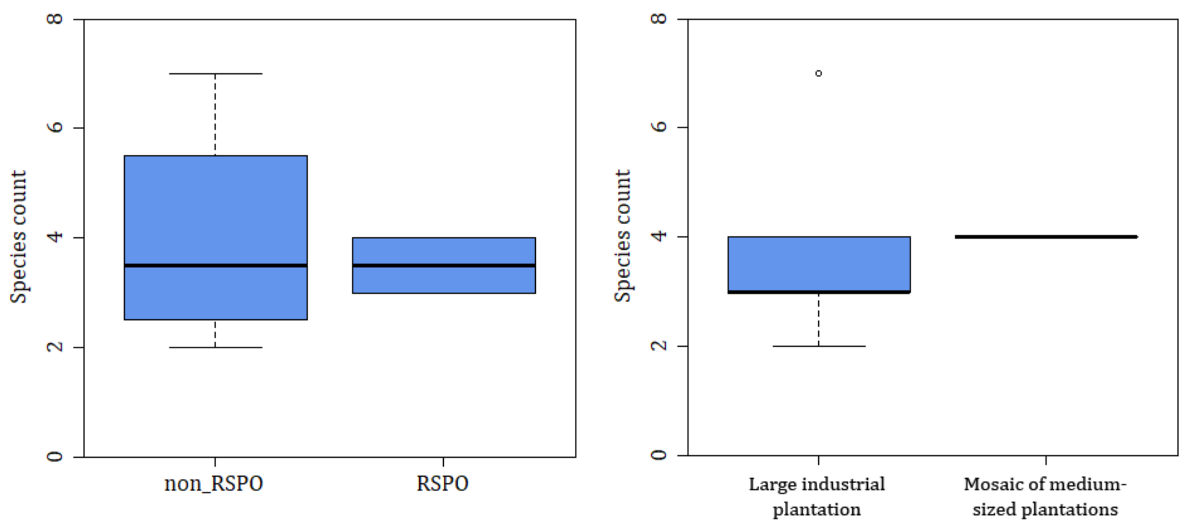

Figure 10ab. Boxplots of small mammal species. **a.**(left) species count by RSPO and **b.**(right) species count by plantation size.

Species occurrence analysis

The relative preference of bird species in RSPO plantations versus non-RSPO plantations (Figure 11) is both positive as well as negative. The positive values are more frequent, meaning that more bird species have a relative preference towards the RSPO plantations. Of the bird species that occur within the studied plantations, none of the bird species fall within the IUCN Red List "Vulnerable" category, six of the species fall within the IUCN Red List "Endangered" category and three of the species fall within the "Critically Endangered" IUCN Red List category. These species however are not at the tails of the diagram. The bird species that have the highest positive relative preference for RSPO plantations versus non-RSPO plantations (Figure 12) and have the lowest negative preference for RPSO plantations versus non-RSPO plantations (Figure 13) – meaning these have a higher preference for non-RSPO plantations according to the analysis – all fall within the "Least Concern" IUCN Red List category. These species are also all of a different bird guild, which are groups of species in a community that exploit the same set of resources in a similar manner, but are not necessarily closely related. The maximum value of the relative preference for RSPO plantations is higher than the relative preference for the non-RSPO plantations. This implies that the preference of bird species for RSPO plantations is clearer – and therefore more noticeable – than for non-RSPO plantations.

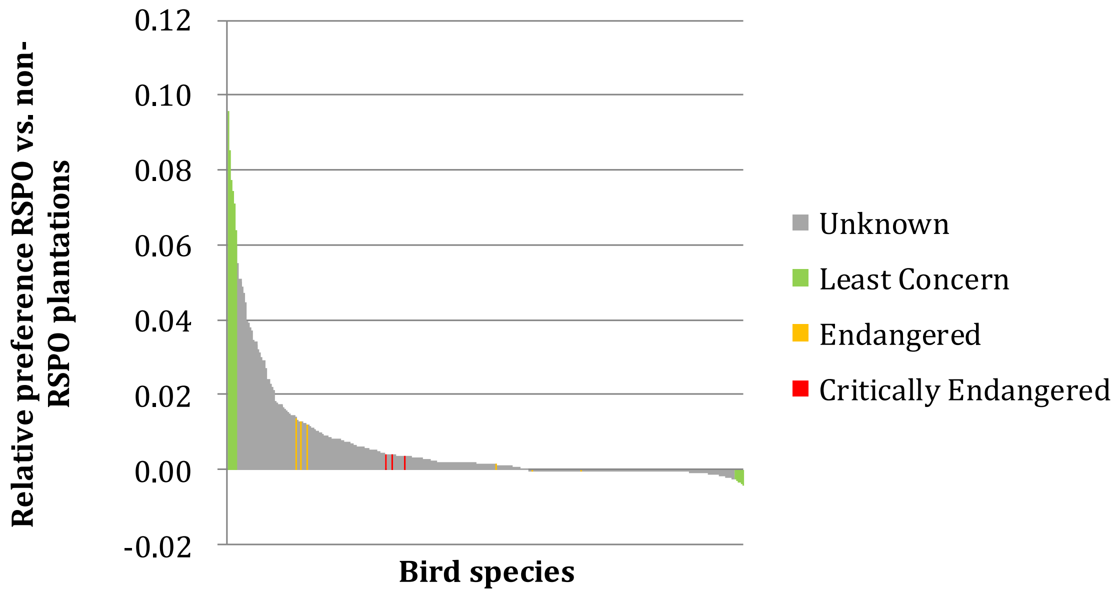

Figure 11. Total overview of relative preference of bird species in RSPO versus non-RSPO plantations. IUCN Red List "Endangered" and "Critically Endangered" species are indicated by orange and red. The ten bird species with the highest and lowest relative preference for RSPO plantations were looked up in the Red List status manually and all had the "Least Concern" status. "Unknown" species were not looked up in the Red List, but do not have the "Vulnerable", "Endangered" or "Critically Endangered" status.

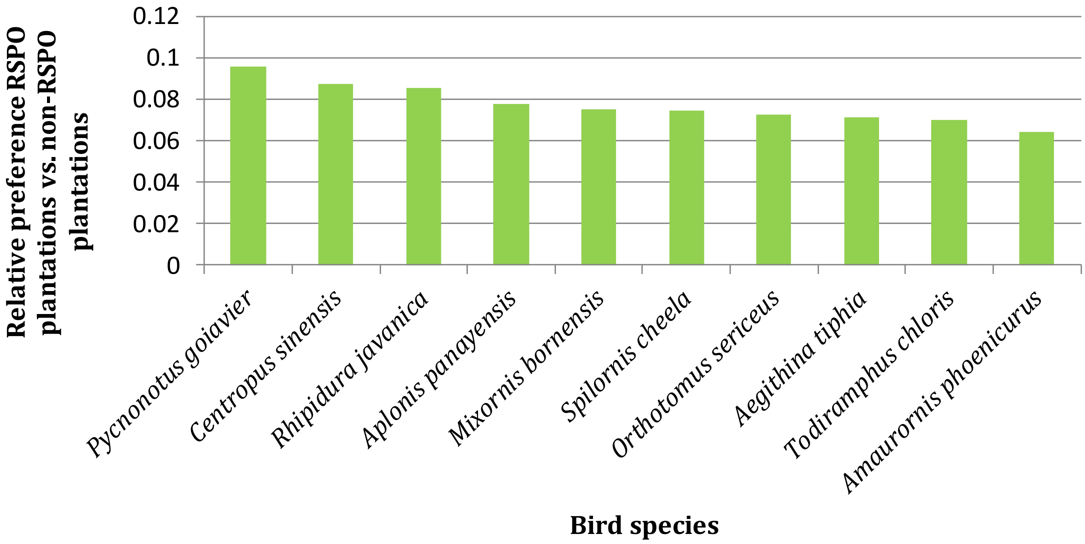

Figure 12. Ten bird species with the highest positive relative preference for RSPO versus non-RSPO plantations.

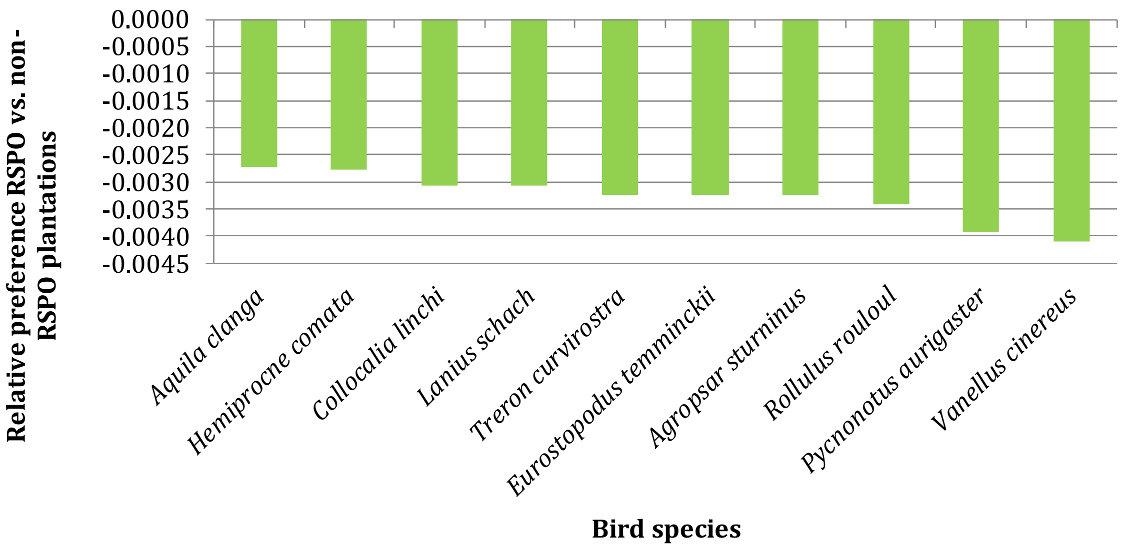

Figure 13. Ten bird species with the lowest negative relative preference for RSPO plantations versus non-RSPO plantations.

Only three of the lizard species that occurred within the investigated plantations seem to have a preference towards RSPO plantations compared to non-RSPO plantations (Figure 14; Figure 15). These three lizard species all fall within the IUCN Red List "Least Concern" category. 18 of the 43 lizard species that are present within the studied plantations were not found within the Red List, meaning that there is no information on their status. The maximum relative positive preference for lizard species for RSPO plantations (Figure 15) is slightly higher than the minimum relative preference – in other words the maximum relative preference for non-RSPO plantations – for lizard species (Figure 16). On the other hand, the number of lizard species with a (slight) preference for non-RSPO plantations is higher.

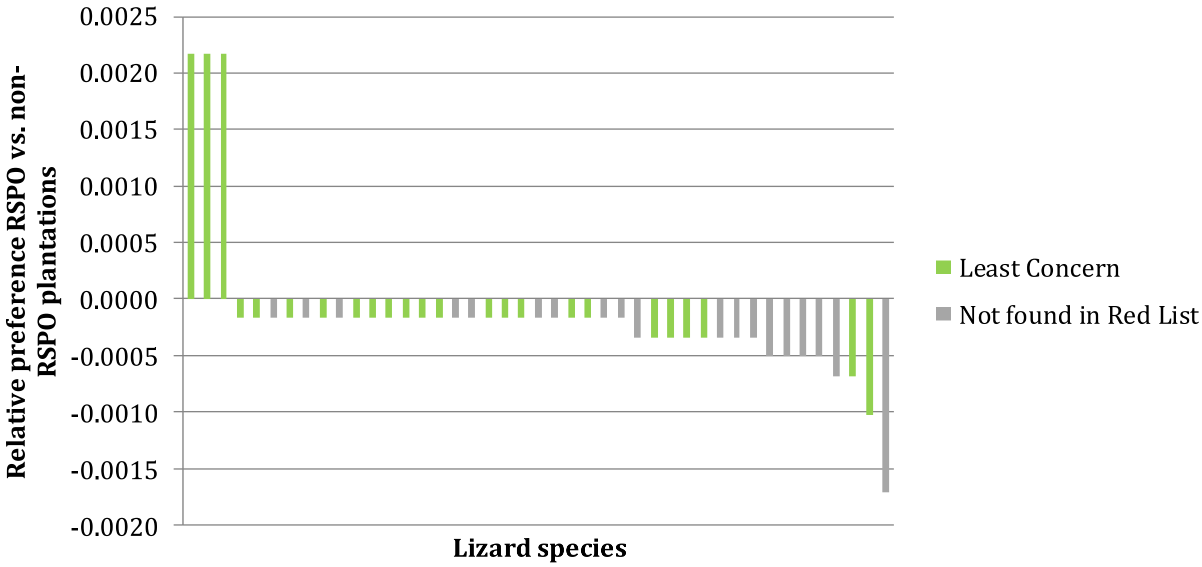

Figure 14. Total overview of relative preference of lizard species in RSPO plantation versus non-RSPO plantations.

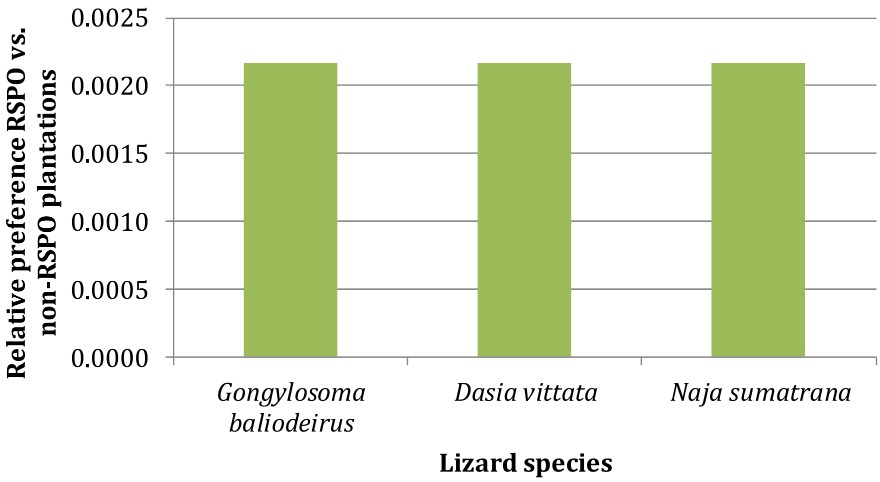

Figure 15. The three lizard species with positive relative preference for RSPO plantations versus non-RSPO plantations.

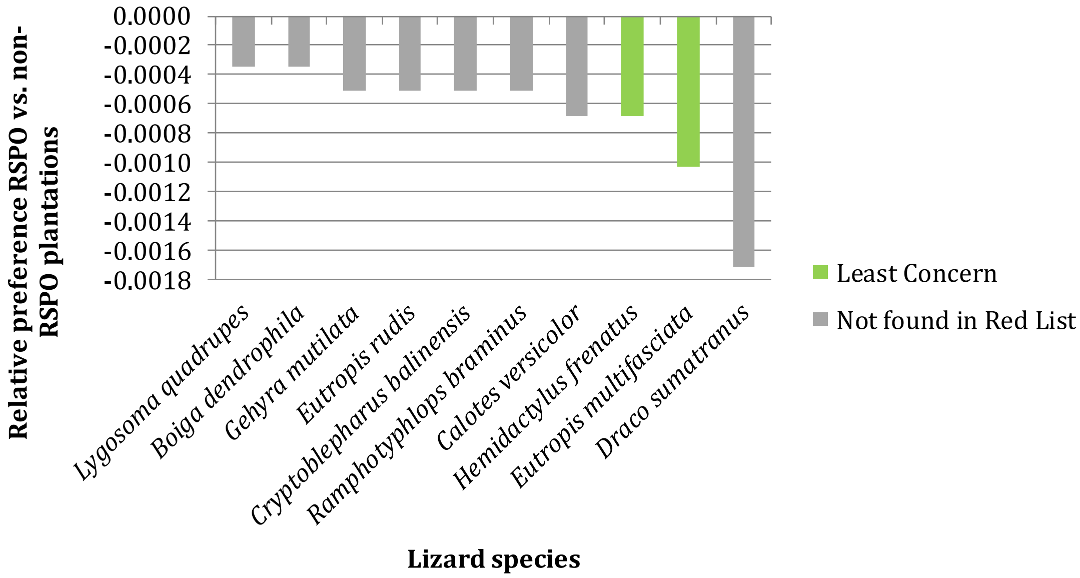

Figure 16. Ten lizard species with the lowest negative relative preference for RSPO plantations versus non-RSPO plantations.

The majority of the primate species has a relative preference for RSPO plantations compared to non-RSPO plantations (Figure 17). The primate species that are found within the studied plantations fall in five different categories of the IUCN Red List and two species are not found within the IUCN Red List data base.

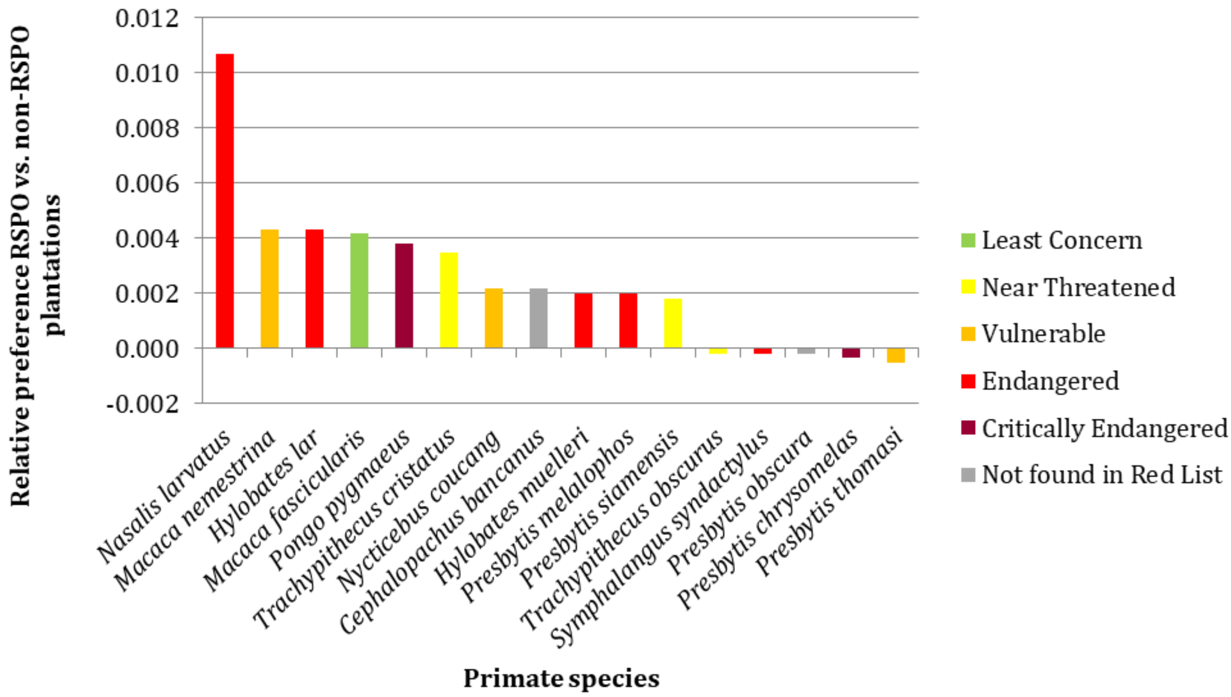

Figure 17. Total overview of relative preference of primate species in RSPO plantations versus non-RSPO plantations. The primate species are distributed along six categories within the IUCN Red List.

The majority of the small mammal species that fall within the investigated plantations seem to have an about equal preference for non-RSPO plantations compared to RSPO plantations (Figure 18). There is one small mammal species that falls within the IUCN Red List "Endangered" category, the rest falls within the "Least Concern", "Near Threatened" or "Vulnerable" category.

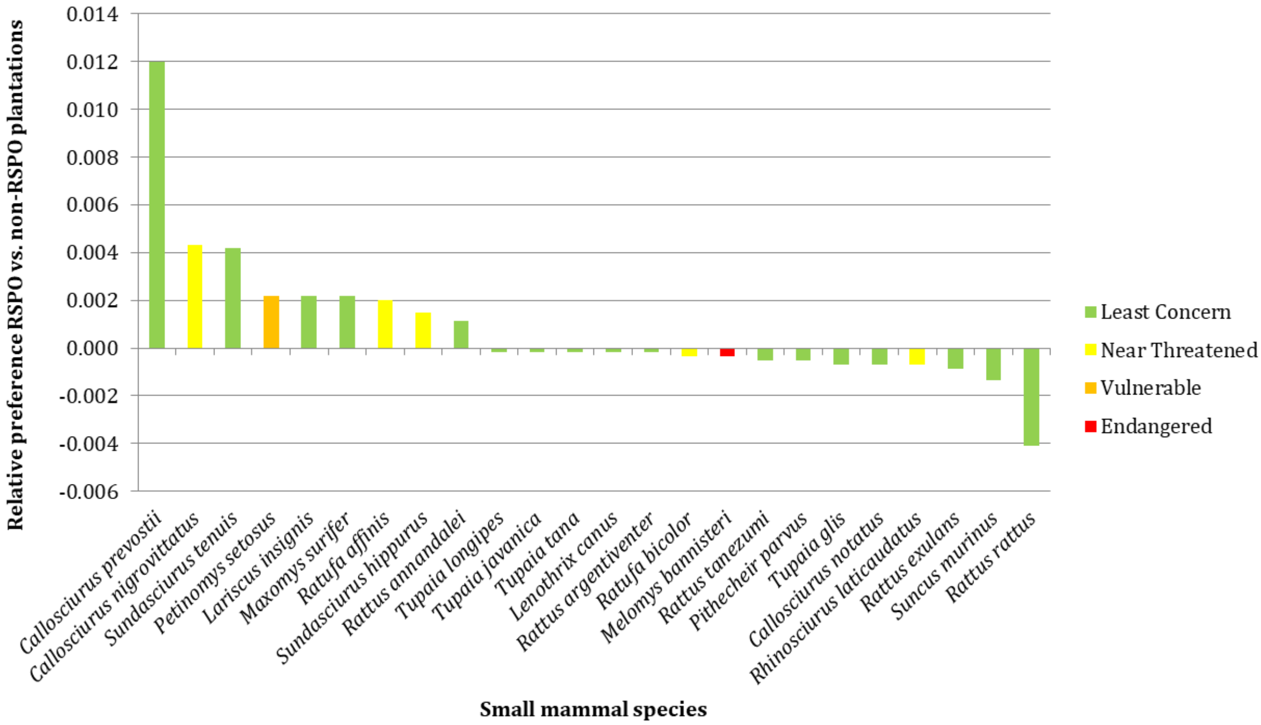

Figure 18. Total overview of relative preference of small mammal species in RSPO plantations versus non-RSPO plantations. The small mammal species are distributed along four categories of the IUCN Red List.

The Microsoft Excel output tables of the species occurrence analyses can be found in Appendix H. An additional section on the absolute numbers of species that is found in this analysis can be found in Appendix I.

Discussion

Very recent research by Cazzolla Gatti et al. (2019) indicates that sustainable palm oil may not be so sustainable. In the period 2001 to 2016, in approximately 40% of the area that is located within certified palm oil plantations, there is evidence of forest loss (Cazzolla Gatti *et al.*, 2019). The result of this study is in line with the findings of the research performed for this thesis. Although it was expected that RSPO-certified and small scale plantations would yield a higher biodiversity, the results of the presented data analysis suggest that RSPO certification and plantation size have no significant influence on the terrestrial biodiversity. This would imply that the measures that are taken by plantations to obtain the RSPO certificate do not affect the level of biodiversity and therefore certification does not protect the species living on plantations better compared to plantations that are not RSPO-certified. The insignificant results found by the investigation of the plantation size do also indicate that there is no difference in biodiversity at different scale levels of plantations. Although the results look as if certification does not have a positive effect on biodiversity and therefore seems to an ineffective measure to preserve biodiversity, the data analysis that is performed in this research is still open to discussion.

The distribution of observations within the four different taxa that were studied was unequal. The majority of the species observations (93%) are of birds and therefore only the size of this taxa's data set is meaningful to draw conclusions from. This implies that there was no dilution over multiple taxa and therefore, the bird analysis is potentially trustworthy. The other taxa data sets are too small to have meaningful results. For this reason, given the statistically insignificant nature of the findings the findings are inconclusive for all taxa except birds. It could be possible that if the data sets were larger, different results would have been found for lizards, primates and small mammals. The attempt to investigate whether certification and plantation size influences the biodiversity holds insignificant results, but there is no certainty in the correctness of this insignificance. The data set for birds is large enough, so the insignificance that was found according this analysis can be accepted, at least for the studied plantations. RSPO certification and plantation size does not impact the bird biodiversity on the investigated palm oil plantations.

Implications

The presented research was the first attempt to study possible differences between plantations on the level of biodiversity. Although the results can only be accepted for the bird species as the other data sets were too small, it still is valuable. As said in the introduction of this research, Meijaard et al. (2018) indicated that there is a need for "analyses to understand the effectiveness of governance initiatives for conservation, including accounting for recent changes in their setworks and implementation" (p. 67). For birds at least, it can be concluded that the effectiveness of the RSPO certification is not proven. There is no significant difference of bird biodiversity in terms of species richness between RSPO and non-RSPO plantations. This implies that the RSPO certification does not have the desired effect on the biodiversity level within plantations. From a societal perspective the results imply that if people buy products that contain RSPO-certified palm oil, the positive impact this has on the biodiversity is questionable. Transparency about this should be achieved, but is not the case at this moment.

Biodiversity is not mentioned in the "RSPO Principles and Criteria" (RSPO P&C) 2018 as such; instead for the "Planet Pillar" preserving High Conservation Values (HCV) forest is mentioned. As the presented research only focuses on the biodiversity levels on plantations themselves, the effect of RSPO on the conservation of HCV forest is not included in the research. The assumption has been made that since biodiversity is key for sustainable ecosystems, it would be likely that RSPO certification would influence this biodiversity, at least the terrestrial, in a positive way. The results indicated that it would be beneficial to put more emphasis on the biodiversity when determining the new RSPO P&C. As the focus of this research is on the terrestrial biodiversity, statements about the aquatic biodiversity cannot be made. Expected is however that this aquatic biodiversity is vulnerable to the runoff of pesticides and fertilizers from the plantations. This runoff can have harmful effects, such as eutrophication. For this reason both aquatic and terrestrial biodiversity should be taken into account when palm oil plantations are evaluated to obtain RSPO-certified. A way to implement biodiversity in the assessment could be by measuring the biodiversity when RSPO certification is obtained and then use this as a benchmark for the reassessment that occurs every five years. If the benchmark is not met in terms of species richness, the RSPO certification will not be extended.

The species occurrence analysis however does show the importance of the RSPO certification. Although the comparison results of the statistical analyses were insignificant, the majority of bird, primate and small mammal species seem to have a relative preference for RSPO-certified plantations. This preference seems to be most vivid within the primate species. Most of the observed primate species within the studied plantations are in the Red List categories that are of concern. The results of the species occurrence analysis stress the importance of the existence of certification, but the benefits of certification have not yet reached their maximum potential. Improving the RSPO P&C when it comes to biodiversity would be a start. The other industrial ecological component within the RSPO is the stakeholder management. The RSPO is unique in its multi-stakeholder scheme, but is not yet using this powerful tool to its full potential. Environmental NGOs could be more involved in determining the RSPO P&C and make sure that important environmental concepts and indicators such as biodiversity are included. When this is achieved in the near future, it is likely that species not only have a relative preference for RSPO plantations, but the biodiversity levels might also be significantly higher on RSPO-certified plantations.

The second indicator – the plantation size – that is studied in this research in addition to certification neither obtained significant differences. According to the presented results, biodiversity does not depend on the size of the plantation. Literature has indicated that smallholders are potentially beneficial for biodiversity levels. This cannot be confirmed by the results obtained in this research. Possible explanations for this are discussed in the next section, in which the limitations of this thesis research are discussed.

Limitations of this research

The largest limitation of the performed research is the fact that the estimations of the species richness within the plantations seem to be questionable. There is a large uncertainty about whether all the species observed at a given location are put in the GBIF databases. Only 161 of the in total 6,311 plantations within the studied data base had more than 1 species observed, which is only 2.6%. If the plantations that only had one species observed were included, the total number would be 216 plantations. 55 of the 216 plantations had only one species observed, which is 25.5%. This implies that the estimates seem to be far from complete. It can be concluded that there is no certainty about the systematically data collection of species observations. This created biased towards the plantations where observations are done, but most likely these observations in itself are also far from complete. If observations are indeed incomplete, it is also less likely that a significant difference will be found between different types of plantations. The only way to eliminate part of this bias would be to take a random sample of the plantations and only study this random sample. The uncertainty related to the systemically data collection of the GBIF species observation can only be eliminated by performing a field study in which data is collected by the researchers themselves. The systematics of an open source, world-wide data base like GBIF will most likely never be watertight.

Not only the GBIF data base that was used was an open source online data base, the plantations data bases were too. No better data sets were available to perform the analyses. Presumably, the used data set were incomplete. As there was no large data set available that contained information on the location of RSPO-certified plantations, it could be that the location and number of the RSPO plantations is underestimated and the uncertified (non-RSPO) plantations are overestimated. However this is only a suspect, as the total percentage of plantations that is RSPO-certified is unknown. However, this could explain the fact that more GBIF species observations are found within non-RSPO plantations. In the species occurrence analysis the counts where normalized for this, by dividing the species counts by the total number of (non-) RSPO plantations. Although normalized for the large difference in type of plantations in the data set, there were still species that seemed to have a relative preference for non-RSPO-certified plantations, especially in the lizard category. It was expected that after the normalization, the relative preference would not be skewed towards non-RSPO plantations anymore. It was also expected that if species had a preference, it would be a preference for the RSPO plantations. The results for the primates seemed to be the most reasonable within this context and expectations.

The number of GBIF species observations that fell within the plantation data set was also very little, only 9,061 of the in total 515,231 observations, which is only 1.8%. This implies that only 1.8% of the land in Malaysia and Indonesia is covered by palm oil plantations, if the GBIF observations would be distributed equally. In reality, according to Austin et al. (2017), in 2010 12.9 Mha of the land in Indonesia and Malaysia was already covered with palm oil plantations. This is approximately 5.8% of the total land surface. The share of land that is covered with palm oil plantations has further increased since 2010, although exact numbers of land use percentages for palm oil plantations up to date are unknown. Therefore, in reality the number of observations that was expected to be found on plantations was higher. A reason for this could be that the GBIF observations are not distributed equally over privately owned property and public area. Fewer observations may be done at privately owned property, maybe due to legal restrictions. Palm oil plantations are owned by companies and therefore it could be possible that in general fewer species observations on these estates are done and therefore are recorded within the GBIF data base. The low number of observations that fell within the studied plantations also made it impossible to perform an ANOVA with the interaction term of certification and plantation size. It could not be studied whether a combination of these factors influences the biodiversity levels. At the same time, a statistical analysis with 9,061 observations seems reasonable. Unfortunately, the 9,061 observations were not distributed equally, as they fell within 216 of the in total 6,311 plantations.

Another limitation of the research is that the biodiversity is calculated as the number of different species per plantation, which is called the species count. Nor the absolute or the relative size of the plantation has been taken into account when determining the species count. As a consequence, larger plantations – and therefore larger "shapes" in the spatial data object – have a higher probability to have a higher species count, simply because they cover more area and thus are more likely to have more GBIF observations. This especially might have affected the analysis on the size of the plantation, which included 117 large plantations versus 44 medium- and small-sized plantations in total. To avoid this impurity, the number of species per pixel could be calculated instead of the number of species per shape.

Lastly, during the analysis in R, a noticeable peculiarity was encountered. The total number of GBIF observations that lay within the studied plantations (including all four taxa), was 9,061. During further analysis, the four taxa were separated by taxon key. When adding the numbers of observations per taxa that were found in Table 7, the total number of GBIF observations is only 8,666. The percentages in Table 7 therefore do not sum up to 100%. 4.45% of the observations is not represented in one of the data sets of a separate taxa. A clear explanation for this could not be found. It might be possible that some of the GBIF observations are missing information on the class key or order key, which were used for generating the subsets for the analysis.

Future research

For this data analysis, biodiversity was expressed as the number of unique species of four taxa that were observed within a plantation. This is a very simplified value to express biodiversity. In further research, more taxa should be taken into account to get a more meaningful quantification of biodiversity. It is also questionable whether species richness – which is used in this thesis – is the best and most complete way to express biodiversity as a whole. Biodiversity can be expressed in terms of species richness, which is often done, but species abundance can also be taken into account.

For future research it would be beneficial to include the species abundance as well. The main reason for this is that the number of species may be high, which implies a high species richness, but if the species abundance is very unequal, the ecosystem is still vulnerable and subject to change. In other words, this means that biodiversity in terms of species richness does not always mean that the ecosystem is resilient to changes and the biodiversity could change rapidly if the species abundance is unequal. Including species abundance in addition to species richness therefore would give a more complete insight in the actual ecosystem health and resilience. In data analyses, it seems to be logic to study biodiversity in terms of species richness, because it is more likely that observations of species are recorded correctly than the exact number of a particular species at a given location. If soil samples at plantations by researchers themselves would be taken, the abundance of invertebrates could be studied for example. For larger and more mobile animals, species abundance is harder to determine, as individual species are moving and a correct estimation of abundance is therefore more difficult to make. Ecologists that are specialized in counting individuals by observing specific unique external characteristics could make species abundance research more feasible. Besides the suggestions to include more taxa to calculate the biodiversity in further research and study species abundance in addition to species richness, an implication for further research is to make use of better data sets. In this case, it is more likely that the numbers of observations are of an appropriate size to draw conclusions from.

An alternative to the performed investigation of terrestrial biodiversity would be the investigation of the aquatic biodiversity of different types of palm oil plantations. The investigation of aquatic biodiversity could be done in a much more direct way, not solely depending on existing data sources. Water samples could be taken from freshwater ecosystems on or in the surroundings of palm oil plantations and these samples can be investigated by eDNA analysis techniques (Thomsen and Willerslev, 2015). A large advantage of such a study setup is that changes in aquatic biodiversity can be measured and observed by this eDNA technique. The aquatic ecosystems in the tropic region usually yield a high level of biodiversity, meaning they support relatively high species diversity per unit area (Dudgeon *et al.*, 2006). This high species diversity is exposed to fertilizer and pesticides from runoff of the palm oil plantations.

Therefore, it is known that palm oil plantations do have a negative impact on the aquatic biodiversity. As certification institutes, including the RSPO, have guidelines on fertilizer and pesticides usage, it could be possible that larger differences in aquatic biodiversity within freshwater ecosystems that are located at or in the surrounding of palm oil plantations may be found. This could indicate a positive effect of certification in terms of the aquatic biodiversity. This study design is likely to obtain more meaningful results, as data can be collected systematically without the use of open source data sets, of which the systematics are questionable. Concequently, many of the uncertainties mentioned in this discussion could be avoided.

Another option would be to study the difference between types of plantations by making use of proxy species. These species can be selected on a particular set of criteria, for example their Red List status and how sensitive they are to, for example, the use of fertilizers and pesticides. The presence of these proxy species could be an indication that the plantation is taking biodiversity into account and takes sufficient measures to preserve the natural ecosystem in some sort of way. The research design in this case would be to indicate the presence of a proxy species (yes or no) against the type of plantations.

Conclusions

The data analysis performed indicates that there is no significant difference in biodiversity levels between palm oil plantations that are RSPO-certified compared to palm oil plantations that are non-RSPO-certified. The size of the plantation neither influences the level of biodiversity. These results were found by quantifying biodiversity in terms of species richness of four taxa; birds, lizards, primates and small mammals. The obtained results seem most robust for bird biodiversity. After investigation of the species occurrence and their relative preference for RSPO plantations, it can be concluded that the majority of bird, primate and small mammal species that occurred within the studied plantations have a relative preference for RSPO plantations. These results stress the importance of the existence of certification, but the benefits of certification have not yet reached their full potential. Further research is needed to determine whether there is indeed no positive impact of RSPO certification and small scale plantations on biodiversity. A suggestion for further research would be the investigation of aquatic biodiversity in freshwater bodies on and in the surroundings of palm oil plantations. Changes in aquatic biodiversity can be observed making use of eDNA sampling techniques.

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Appendix A – Chapter RSPO (2013) on Principle 5

Chapter: **"Environmental responsibility and conservation of natural resources and biodiversity"**

Source: Roundtable on Sustainble Palm Oil RSPO (2013). Principles and criteria for the production of sustainable palm oil. (p. 25-33). Retrieved November 23, 2018, from www.rspo.org/publications/download/224fa0187afb4b7

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.1	Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continual improvement.	**Indicator:** 5.1.1 An environmental impact assessment (EIA) shall be documented. 5.1.2 Where the identification of impacts requires changes in current practices, in order to mitigate negative effects, a timetable for change shall be developed and implemented within a comprehensive management plan. The management plan shall identify the responsible person/persons. 5.1.3 This plan shall incorporate a monitoring protocol, adaptive to operational changes, which shall be implemented to monitor the effectiveness of the mitigation measures. The plan shall be reviewed as a minimum every two years to reflect the results of monitoring and where there are operational changes that may have positive and negative environmental impacts. **Guidance:** The EIA should cover the following activities, where they are undertaken: • Building new roads, processing mills or other infrastructure; • Putting in drainage or irrigation systems; • Replanting and/or expansion of planting areas; • Management of mill effluents (Criterion 4.4); • Clearing of remaining natural vegetation; • Management of pests and diseased palms by controlled burning (Criteria 5.5 and 7.7).

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
		Impact assessment can be a non-restrictive format e.g. ISO 14001 EMS and/or EIA report incorporating elements spelt out in this Criterion and raised through stakeholder consultation. Environmental impacts should be identified on soil and water resources (Criteria 4.3 and 4.4), air quality, greenhouse gases (Criterion 5.6), biodiversity and ecosystems, and people's amenity (Criterion 6.1), both on and off-site. Stakeholder consultation has a key role in identifying environmental impacts. The inclusion of consultation should result in improved processes to identify impacts and to develop any required mitigation measures. For smallholder schemes, the scheme management has the responsibility to undertake impact assessment and to plan and operate in accordance with the results (refer to *'Guidance for Independent Smallholders under Group Certification', June 2010, and 'Guidance on Scheme Smallholders',* July 2009). **For National Interpretation:** National Interpretation will consider any national legal requirements together with any other issues that are not required by law but are nevertheless important, e.g. independent social and environmental impact assessment (SEIA) for replanting may be desirable under specific situations.

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.2	The status of rare, threatened or endangered species and other High Conservation Value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and operations managed to best ensure that they are maintained and/or enhanced.	**Indicator:** 5.2.1 Information shall be collated in a High Conservation Value (HCV) assessment that includes both the planted area itself and relevant wider landscape-level considerations (such as wildlife corridors). 5.2.2 Where rare, threatened or endangered (RTE) species, or HCVs, are present or are affected by plantation or mill operations, appropriate measures that are expected to maintain and/or enhance them shall be implemented through a management plan. 5.2.3 There shall be a programme to regularly educate the workforce about the status of these RTE species, and appropriate disciplinary measures shall be instigated in accordance with company rules and national law if any individual working for the company is found to capture, harm, collect or kill these species. 5.2.4 Where a management plan has been created there shall be ongoing monitoring: • The status of HCV and RTE species that are affected by plantation or mill operations shall be documented and reported; • Outcomes of monitoring shall be fed back into the management plan. 5.2.5 Where HCV set-asides with existing rights of local communities have been identified, there shall be evidence of a negotiated agreement that optimally safeguards both the HCVs and these rights. **Specific Guidance:** For 5.2.1: This information will cover: • Presence of protected areas that could be significantly affected by the grower or miller; • Conservation status (e.g. IUCN status), legal protection, population status and habitat requirements of rare, threatened, or endangered (RTE) species that could be significantly affected by the grower or miller; • Identification of HCV habitats, such as rare and threatened ecosystems, that could be significantly affected by the grower or miller; For 5.2.2: These measures will include: • Ensuring that any legal requirements relating to the protection of the species or habitat are met; • Avoiding damage to and deterioration of HCV habitats such as by ensuring that HCV areas are connected, corridors are conserved, and buffer zones around HCV areas are created;

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
		• Controlling any illegal or inappropriate hunting, fishing or collecting activities, and developing responsible measures to resolve human-wildlife conflicts (e.g. incursions by elephants). For 5.2.5: If a negotiated agreement cannot be reached, there should be evidence of sustained efforts to achieve such an agreement. These could include third party arbitration (see Criteria 2.3, 6.3 and 6.4). **Guidance:** This information gathering should include checking available biological records and consultation with relevant government departments, research institutes and interested NGOs if appropriate. Depending on the biodiversity values that are present, and the level of available information, some additional field survey work may be required. Wherever HCV benefits can be realised outside of the management unit, collaboration and cooperation between other growers, governments and organisations should be considered. **For National Interpretation:** Appropriate sources of information can include government or international lists of threatened species (‘red data lists’), national wildlife protection legislation, authorities responsible for protected areas and species, or relevant NGOs. Note: Operators need to consider a variety of land management and tenure options to secure HCV management areas in ways that also secure local peoples’ rights and livelihoods. Some areas are best allocated to community management and secured through customary or legal tenures, in other cases co-management options can be considered. Where communities are asked to relinquish rights so that HCVs can be maintained or enhanced by the companies or State agencies, then great care needs to be taken to ensure that communities retain access to adequate land and resources to secure their basic needs; all such relinquishment of rights must be subjected to their free, prior, and informed consent (see Criteria 2.2 and 2.3).

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.3	Waste is reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner.	**Indicators:** 5.3.1 All waste products and sources of pollution shall be identified and documented. 5.3.2 All chemicals and their containers shall be disposed of responsibly. 5.3.3 A waste management and disposal plan to avoid or reduce pollution shall be documented and implemented. **Guidance:** The waste management and disposal plan should include measures for: • Identifying and monitoring sources of waste and pollution. • Improving the efficiency of resource utilisation and recycling potential wastes as nutrients or converting them into value-added products (e.g. through animal feeding programmes). • Appropriate management and disposal of hazardous chemicals and their containers. Surplus chemical containers should be reused, recycled or disposed of in an environmentally and socially responsible way using best available practices (e.g. returned to the vendor or cleaned using a triple rinse method), such that there is no risk of contamination of water sources or risk to human health. The disposal instructions on the manufacturers' labels should be adhered to. Use of open fire for waste disposal should be avoided. **For National Interpretation:** National Interpretation (or an RSPO recognised parallel means) should include, as appropriate: details of relevant national laws or policies, a list of waste types (hazardous, non-hazardous, domestic, etc.) which must be considered, any types of disposal which are not acceptable (e.g. untreated waste water may not be discharged directly into streams or rivers (see Criterion 4.4), existing best practice guidelines on recycling and re-use of nutrients, managing effluent ponds, increasing mill extraction efficiency and appropriate disposal of wastes.

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.4	Efficiency of fossil fuel use and the use of renewable energy is optimised.	**Indicators:** 5.4.1 A plan for improving efficiency of the use of fossil fuels and to optimise renewable energy shall be in place and monitored. **Guidance:** Renewable energy use per tonne of Crude Palm Oil (CPO) or palm product in the mill should be monitored. Direct fossil fuel use per tonne of CPO or Fresh Fruit Bunches (FFB) should be monitored. Energy efficiency should be taken into account in the construction or upgrading of all operations. Growers and millers should assess the direct energy use of their operations, including fuel and electricity, and energy efficiency of their operations. This should include estimation of fuel use by on-site contract workers, including all transport and machinery operations. The feasibility of collecting and using biogas should be studied if possible.

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.5	Use of fire for preparing land or replanting is avoided, except in specific situations as identified in the ASEAN guidelines or other regional best practice.	**Indicators:** 5.5.1 There shall be no land preparation by burning, other than in specific situations as identified in the 'Guidelines for the Implementation of the ASEAN Policy on Zero Burning' 2003, or comparable guidelines in other regions. 5.5.2 Where fire has been used for preparing land for replanting, there shall be evidence of prior approval of the controlled burning as specified in 'Guidelines for the Implementation of the ASEAN Policy on Zero Burning' 2003, or comparable guidelines in other regions. **Guidance:** Fire should be used only where an assessment has demonstrated that it is the most effective and least environmentally damaging option for minimising the risk of severe pest and disease outbreaks, and exceptional levels of caution should be required for use of fire on peat. This should be subject to regulatory provisions under respective national environmental legislation. Extension/training programmes for associated smallholders may be necessary. **For National Interpretation:** National Interpretation will identify any specific situations where such use of fire may be acceptable, for example through reference to 'Guidelines for the Implementation of the ASEAN Policy on Zero Burning' 2003, or comparable guidelines in other regions.

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
5.6	*Preamble*	*Growers and millers commit to reporting on operational greenhouse gas emissions. However, it is recognised that these significant emissions cannot be monitored completely or measured accurately with current knowledge and methodology. It is also recognised that it is not always feasible or practical to reduce or minimise these emissions.* *Growers and millers commit to an implementation period until the end of December 2016 for promoting best practices in reporting to the RSPO, and thereafter to public reporting. Growers and millers make this commitment with the support of all other stakeholder groups of the RSPO.*
5.6	Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.	**Indicators:** 5.6.1 An assessment of all polluting activities shall be conducted, including gaseous emissions, particulate/soot emissions and effluent (see Criterion 4.4). 5.6.2 Significant pollutants and greenhouse gas (GHG) emissions shall be identified, and plans to reduce or minimise them implemented. 5.6.3 A monitoring system shall be in place, with regular reporting on progress for these significant pollutants and emissions from estate and mill operations, using appropriate tools. **Specific Guidance:** For 5.6.2: Plans will include objectives, targets and timelines. These should be responsive to context and any changes should be justified. For 5.6.2 and 5.6.3: The treatment methodology for POME will be recorded. For 5.6.3 (GHG): For the implementation period until December 31st 2016, an RSPO-endorsed modified version of PalmGHG which only includes emissions from operations (including land use practices) can be used as a monitoring tool.

PRINCIPLE 5: ENVIRONMENTAL RESPONSIBILITY AND CONSERVATION OF NATURAL RESOURCES AND BIODIVERSITY

NO.	PRINCIPLES AND CRITERIA	INDICATORS/GUIDANCE
		For 5.6.3: In addition, during the implementation period, growers will start to assess, monitor and report emissions arising from changes in carbon stocks within their operations, using the land use in November 2005 as the baseline. The implementation period for Indicator 5.6.3 is the same implementation period for Criterion 7.8. During the implementation period, reporting on GHG will be to a relevant RSPO working group (composed of all membership categories) which will use the information reported to review and fine tune the tools, emission factors and methodologies, and provide additional guidance for the process. Public reporting is desirable, but remains voluntary until the end of the implementation period. During the implementation period the RSPO working group will seek to continually improve PalmGHG, recognising the challenges associated with measuring GHG and carbon stock. PalmGHG or RSPO-endorsed equivalent will be used to assess, monitor and report GHG emissions. Parties seeking to use an alternative to PalmGHG will have to demonstrate its equivalence to the RSPO for endorsement. **Guidance:** Where practically feasible, operations should follow best management practices to measure and reduce emissions. Advice on this is available from the RSPO.

Appendix B – Chapter RSPO (2018) on Impact Goal Planet

Chapter: **“Impact Goal – Planet: Conserved, protected and enhanced ecosystems that provide for the next generation”**

Source: Roundtable on Sustainble Palm Oil RSPO (2018). Principles and criteria for the production of sustainable palm oil. (p.34-42). Retrieved November 29, 2018, from https://rspo.org/publications/download/6a915fbd0acb64d

Impact Goal – Planet: Conserved, protected and enhanced ecosystems that provide for the next generation

Objectives and outcomes

Ecosystems and their services are protected, restored and resilient, supported by sustainable consumption and production, and sustainable management of natural resources (in line with SDG 15 – sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss). Climate change is addressed through continuous GHG reductions; air and water pollution are controlled. There is greater resilience in our food and fibre production. The water and air are cleaner, and carbon is drawn out of the air to regenerate soils for current and future generations. Inputs decrease while yields are maintained, or even improved.

Principle 7: Protect, conserve and enhance ecosystems and the environment

Protect the environment, conserve biodiversity and ensure sustainable management of natural resources.

Criteria	Indicators	ToC Outcomes
7.1 Pests, diseases, weeds and invasive introduced species are effectively managed using appropriate Integrated Pest Management (IPM) techniques.	7.1.1 **(C)** IPM plans are implemented and monitored to ensure effective pest control. 7.1.2 Species referenced in the Global Invasive Species Database and CABI.org are not to be used in managed areas, unless plans to prevent and monitor their spread are implemented. 7.1.3 There is no use of fire for pest control unless in exceptional circumstances, i.e. where no other effective methods exist, and with prior approval of government authorities. [For NI to define process]	**Pollution reduced; Resource use minimised; Productivity optimised**
7.2 Pesticides are used in ways that do not endanger health of workers, families, communities or the environment.	7.2.1 **(C)** Justification of all pesticides used is demonstrated. Selective products and application methods that are specific to the target pest, weed or disease are prioritised. 7.2.2 **(C)** Records of pesticides use (including active ingredients used and their LD50, area treated, amount of active ingredients applied per ha and number of applications) are provided. 7.2.3 **(C)** Any use of pesticides is minimised as part of a plan, eliminated where possible, in accordance with IPM plans. 7.2.4 There is no prophylactic use of pesticides, unless in exceptional circumstances, as identified in national best practice guidelines.	**Reduced pollution; Resource use minimised**

	7.2.5 Pesticides that are categorised as World Health Organisation Class 1A or 1B, or that are listed by the Stockholm or Rotterdam Conventions, and paraquat, are not used, unless in exceptional circumstances, as validated by a due diligence process, or when authorised by government authorities for pest outbreaks. The due diligence refers to: 7.2.5a Judgment of the threat and verify why this is a major threat 7.2.5b Why there is no other alternative which can be used 7.2.5c Which process was applied to verify why there is no other less hazardous alternative 7.2.5d What is the process to limit the negative impacts of the application 7.2.5 e Estimation of the timescale of the application and steps taken to limit application to the specific outbreak. 7.2.6 **(C)** Pesticides are only handled, used or applied by persons who have completed the necessary training and are always applied in accordance with the product label. All precautions attached to the products are properly observed, applied, and understood by workers (see Criterion 3.6). Personnel applying pesticides must show evidence of regular updates on the knowledge about the activity they carry out. 7.2.7 **(C)** Storage of all pesticides is in accordance with recognised best practices. 7.2.8 All pesticide containers are properly disposed of and/or handled responsibly if used for other purposes. 7.2.9 **(C)** Aerial spraying of pesticides is prohibited, unless in exceptional circumstances where no other viable alternatives are available. This requires prior government authority approval. All relevant information is provided to affected local communities at least 48 hours prior to application of aerial spraying. 7.2.10 **(C)** Specific annual medical surveillance for pesticide operators, and documented action to treat related health conditions, is demonstrated. 7.2.11 **(C)** No work with pesticides is undertaken by persons under the age of 18, pregnant or breastfeeding women or other people that have medical restrictions and they are offered alternative equivalent work.	

7.3 Waste is reduced, recycled, reused and disposed of in an environmentally and socially responsible manner.	7.3.1 A waste management plan which includes reduction, recycling, reusing, and disposal based on toxicity and hazardous characteristics, is documented and implemented. 7.3.2 Proper disposal of waste material, according to procedures that are fully understood by workers and managers, is demonstrated. 7.3.3 The unit of certification does not use open fire for waste disposal.	**Reduced pollution; Resource use minimised**
7.4 Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield.	7.4.1 Good agriculture practices, as contained in SOPs, are followed to manage soil fertility to optimise yield and minimise environmental impacts. 7.4.2 Periodic tissue and soil sampling is carried out to monitor and manage changes in soil fertility and plant health. 7.4.3 A nutrient recycling strategy is in place, which includes the recycling of Empty Fruit Bunches (EFB), Palm Oil Mill Effluent (POME), palm residues and optimal use of inorganic fertilisers. 7.4.4 Records of fertiliser inputs are maintained.	**Reduced pollution; Resource use minimised; Productivity optimised**
7.5 Practices minimise and control erosion and degradation of soils.	7.5.1 **(C)** Maps identifying marginal and fragile soils, including steep terrain, are available. 7.5.2 There is no extensive replanting of oil palm on steep terrain. 7.5.3 There is no new planting of oil palm on steep terrain.	**Ecosystems protected; Reduced pollution; Productivity optimised**
7.6 Soil surveys and topographic information are used for site planning in the establishment of new plantings, and the results are incorporated into plans and operations.	7.6.1 **(C)** To demonstrate the long-term suitability of land for palm oil cultivation, soil maps or soil surveys identifying marginal and fragile soils, including steep terrain, are taken into account in plans and operations. 7.6.2 Extensive planting on marginal and fragile soils, is avoided, or, if necessary, done in accordance with the soil management plan for best practices. 7.6.3 Soil surveys and topographic information guide the planning of drainage and irrigation systems, roads and other infrastructure.	**Ecosystems protected; Resource use minimised; Reduced pollution**

7.7 No new planting on peat, regardless of depth after 15 November 2018 and all peatlands are managed responsibly.	7.7.1 **(C)** There is no new planting on peat regardless of depth after 15 November 2018 in existing and new development areas. 7.7.2 Areas of peat within the managed areas are inventoried, documented and reported (effective from 15 November 2018) to RSPO Secretariat. **PROCEDURAL NOTE:** Maps and other documentation of peat soils are provided, prepared and shared in line with RSPO Peatland Working Group (PLWG) audit guidance (see Procedural Note for 7.7.5 below). 7.7.3 **(C)** Subsidence of peat is monitored, documented and minimised. 7.7.4 **(C)** A documented water and ground cover management programme is in place. 7.7.5 **(C)** For plantations planted on peat, drainability assessments are conducted following the RSPO Drainability Assessment Procedure, or other RSPO recognised methods, at least five years prior to replanting. The assessment result is used to set the timeframe for future replanting, as well as for phasing out of oil palm cultivation at least 40 years, or two cycles, whichever is greater, before reaching the natural gravity drainability limit for peat. When oil palm is phased out, it i is replaced with crops suitable for a higher water table (paludiculture) or rehabilitated with natural vegetation. **PROCEDURAL NOTE:** Full details of the RSPO Drainability Assessment Guidelines and related concepts and detailed actions are in the manual currently being fine-tuned/tested by PLWG. A final version should be approved by PLWG in January 2019 and will include additional guidance on the steps to be followed after the decision not to replant as well as implications for other stakeholders, smallholders, local communities and the unit of certification. It is recommended that a further twelve-month methodology trial period is proposed for all related management units (i.e. those with plantations on peat) to utilise the methodology and provide feedback to the PLWG to enable further refinement of procedure as appropriate before January 2020. Units of certification have the option to defer replanting till after the availability of the revised guidelines. Additional	**Ecosystems protected; Reduced pollution; Productivity optimised**

	guidance on alternative crops and rehabilitation of natural vegetation will be provided by PLWG. **PROCEDURAL NOTE:** PLWG and the Smallholder Interim Group (SHIG) will collaboratively develop guidance for Independent Smallholders [cross links to SHIG and GHG issues]. 7.7.6 **(C)** All existing plantings on peat are managed according to the 'RSPO Manual on Best Management Practices (BMPs) for existing oil palm cultivation on peat', version 2 (2018) and associated audit guidance. 7.7.7 **(C)** All areas of unplanted and set-aside peatlands in the managed area (regardless of depth) are protected as "peatland conservation areas"; new drainage, road building and power lines by the unit of certification on peat soils is prohibited; peatlands are managed in accordance with the 'RSPO BMPs for Management and Rehabilitation of Natural Vegetation Associated with Oil Palm Cultivation on Peat', version 2 (2018) and associated audit guidance.	
7.8 Practices maintain the quality and availability of surface and groundwater.	7.8.1 A water management plan is in place and implemented to promote more efficient use and continued availability of water sources and to avoid negative impacts on other users in the catchment. The plan addresses the following: 7.8.1a The unit of certification does not restrict access to clean water or contribute to pollution of water used by communities. 7.8.1 b Workers have adequate access to clean water. 7.8.2 **(C)** Water courses and wetlands are protected, including maintaining and restoring appropriate riparian and other buffer zones in line with 'RSPO Manual on BMPs for the management and rehabilitation of riparian reserves' (April 2017). 7.8.3 Mill effluent is treated to be in compliance with national regulations. Discharge quality of mill effluent, especially Biochemical Oxygen Demand (BOD), is regularly monitored. 7.8.4 Mill water use per tonne of FFB is monitored and recorded.	**Ecosystems protected; Reduced pollution; Resource use minimised**

7.9 Efficiency of fossil fuel use and the use of renewable energy is optimised.	7.9.1 A plan for improving efficiency of the use of fossil fuels and to optimise renewable energy is in place, monitored and reported.	**Ecosystems protected; Reduced pollution; Resource use minimised**
7.10 Plans to reduce pollution and emissions, including greenhouse gases (GHG), are developed, implemented and monitored and new developments are designed to minimise GHG emissions.	7.10.1 **(C)** GHG emissions are identified and assessed for the unit of certification. Plans to reduce or minimise them are implemented, monitored through the Palm GHG calculator and publicly reported. 7.10.2 **(C)** Starting 2014, the carbon stock of the proposed development area and major potential sources of emissions that may result directly from the development are estimated and a plan to minimise them prepared and implemented (following the RSPO GHG Assessment Procedure for New Development). 7.10.3 **(C)** Other significant pollutants are identified and plans to reduce or minimise them implemented and monitored.	**Reduced Pollution**
7.11 Fire is not used for preparing land and is prevented in the managed area.	7.11.1 **(C)** Land for new planting or replanting is not prepared by burning. 7.11.2 The unit of certification establishes fire prevention and control measures for the areas directly managed by the unit of certification. 7.11.3 The unit of certification engages with adjacent stakeholders on fire prevention and control measures.	**Ecosystems protected; Reduced pollution**

PROCEDURAL NOTE for 7.12

The 2018 RSPO P&C include new requirements to ensure the effective contribution of RSPO to halting deforestation. This will be achieved by incorporating the High Carbon Stock Approach (HCSA) Toolkit in the revised standard.

The RSPO ToC also commits RSPO to balancing sustainable livelihoods and poverty reduction with the need to conserve, protect and enhance ecosystems.

High Forest Cover Countries (HFCCs) urgently require economic opportunities that enable communities to choose their own development path, while providing socio-economic benefits and safeguards.

Adapted procedures will be developed to support the sustainable development of palm oil by indigenous peoples and local communities with legal or customary rights. These will apply in specific HFCCs, and within those, in High Forest Cover Landscapes (HFCLs).

The development of these procedures will be guided by a No Deforestation Joint Steering Group (NDJSG) of RSPO and HCSA members. In HFCCs, RSPO will work through national and local participatory processes with governments, communities and other stakeholders to develop these procedures. A timeframe for these activities is stipulated in the Terms of Reference for the NDJSG and publicly available.

7.12 Land clearing does not cause deforestation or damage any area required to protect or enhance High Conservation Values (HCVs) or High Carbon Stock (HCS) forest. HCVs and HCS forests in the managed area are identified and protected or enhanced.	7.12.1 **(C)** Land clearing since November 2005 has not damaged primary forest or any area required to protect or enhance HCVs. Land clearing since 15 November 2018 has not damaged HCVs or HCS forests. A historic Land Use Change Analysis (LUCA) is conducted prior to any new land clearing, in accordance with the RSPO LUCA guidance document. 7.12.2 **(C)** HCVs, HCS forests and other conservation areas are identified as follows: 7.12.2a For existing plantations with an HCV assessment conducted by an RSPO-approved assessor and no new land clearing after 15 November 2018, the current HCV assessment of those plantations remains valid. 7.12.2 b: Any new land clearing (in existing plantations or new plantings) after 15 November 2018 is preceded by an HCV-HCS assessment, using the HCSA Toolkit and the HCV-HCSA Assessment Manual. This will include stakeholder consultation and take into account wider landscape-level considerations. **PROCEDURAL NOTE for 7.12.2:** For details of transitional measures, refer to Annex 5: RSPO transition from HCV assessments to HCV-HCSA assessments. 7.12.3 **(C)** In High Forest Cover Landscapes (HFCLs) within HFCCs, a specific procedure will apply for legacy cases and development by indigenous peoples and local communities with legal or customary rights, taking into consideration regional and national multi-stakeholder processes. Until this procedure is developed and endorsed, 7.12.2 applies.	**Ecosystems protected**

PROCEDURAL NOTE for 7.12.3: There should be demonstrable benefits to the local community; clear recognition of legal and customary lands based on participatory land use planning; development should be proportional to the needs of the local community; with a balance between conservation and development. This procedure will also cover planting on previous or abandoned agricultural land / plantations. All other P&C requirements apply, including FPIC and HCV requirements.

7.12.4 **(C)** Where HCVs, HCS forests after 15 November 2018, peatland and other conservation areas have been identified, they are protected and/or enhanced. An integrated management plan to protect and/or enhance HCVs, HCS forests, peatland and other conservation areas is developed, implemented and adapted where necessary, and contains monitoring requirements. The integrated management plan is reviewed at least once every five years. The integrated management plan is developed in consultation with relevant stakeholders and includes the directly managed area and any relevant wider landscape level considerations (where these are identified).

7.12.5 Where rights of local communities have been identified in HCV areas, HCS forest after 15 November 2018, peatland and other conservation areas, there is no reduction of these rights without evidence of a negotiated agreement, obtained through FPIC, encouraging their involvement in the maintenance and management of these conservation areas.

7.12.6 All rare, threatened or endangered (RTE) species are protected, whether or not they are identified in an HCV assessment. A programme to regularly educate the workforce about the status of RTE species is in place. Appropriate disciplinary measures are taken and documented in accordance with company rules and national law if any individual working for the company is found to capture, harm, collect, trade, possess or kill these species.

7.12.7 The status of HCVs, HCS forests after 15 November 2018, other natural ecosystems, peatland conservation areas and RTE species is monitored. Outcomes of this monitoring are fed back into the management plan.

7.12.8 **(C)** Where there has been land clearing without prior HCV assessment since November 2005, or without

	prior HCV-HCSA assessment since 15 November 2018, the Remediation and Compensation Procedure (RaCP) applies.	

Appendix C – Overview RSPO's Roadmap for Sustainable Palm Oil

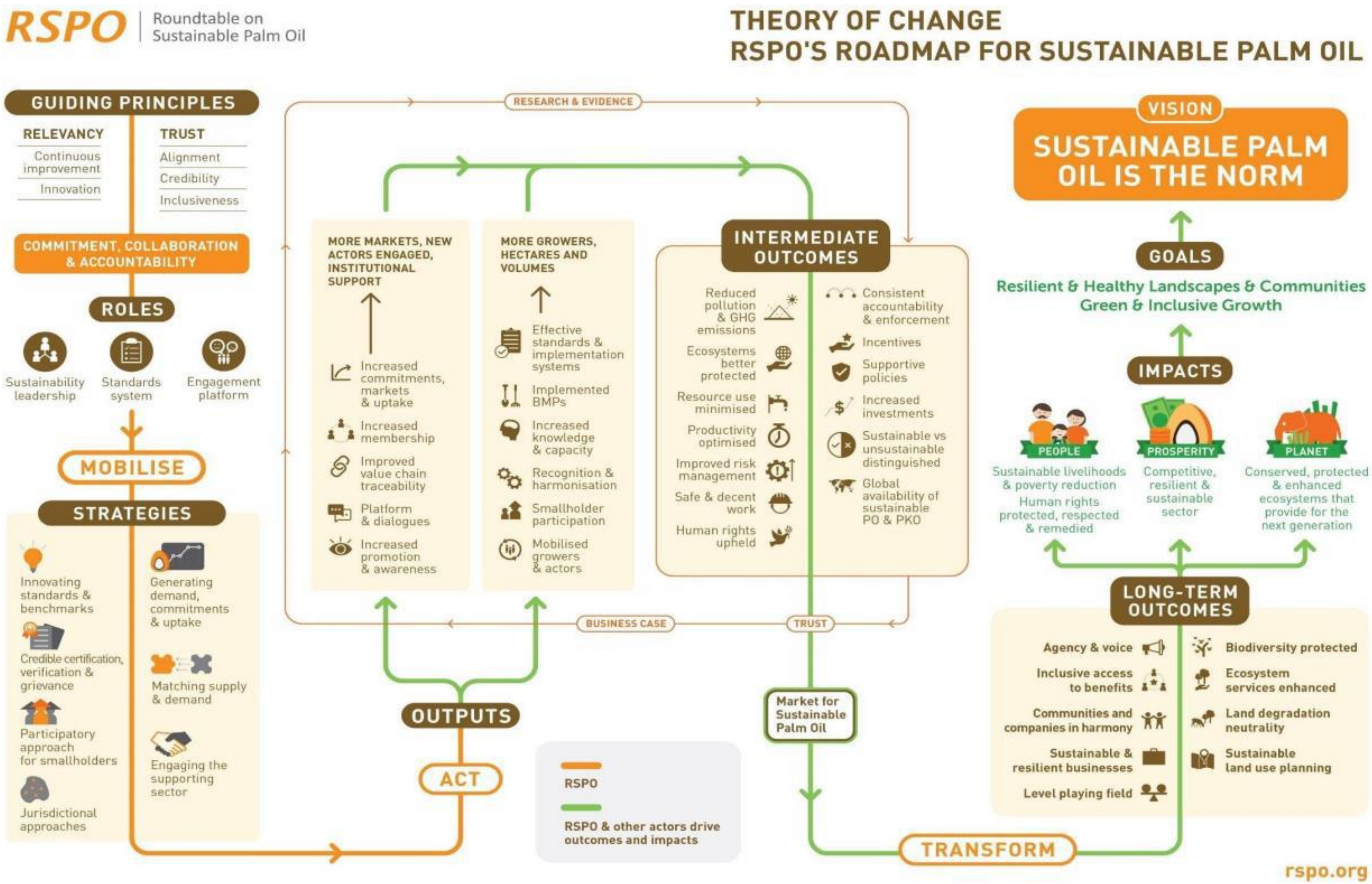

Figure C. RSPO's roadmap for sustainable palm oil (RSPO, 2018, p. 9).

Appendix D – Full executed code

The full code that has been executed can be found below. It must be noted that wherever in the code is referred to "development" or "developmental_stage", this is related to the plantation size parameter.

```
rm(list = ls())
# install raster package
# install.packages("raster")
install.packages("graphics")
# import data set of Development in R
setwd("C:/Users/Cathelijne Stikkers/Documents/R/")
# first row contains variable names, comma is separator
# development <- read.csv("development.csv", header=TRUE)
# checking if the dimensions are correct by dim()--> CORRECT
# filtering spec_org is 'Oil palm'
# x.sub1 <- subset(development, spec_org == 'Oil palm')
# checking new dimenstion by dim() --> CORRECT
# install more packages to go from CSV to geographical data
# install.packages("sp")
# install.packages("rgdal")
# install.packages('ggplot2')
# load all libraries
library(graphics)
library(rgdal)
library(ggplot2)
library(raster)
library(sp)
# import gbif data
source("GBIF second.R") # run script
# import shape file
Shape_development <- readOGR(dsn=path.expand("Development data set"),
           layer="Tree_plantations")
# extract again the Oil palm
subset_development1 <- subset(Shape_development, spec_org == 'Oil palm')
# Make a subset in which countries are also filtered (Indonesia and
Malaysia)
subset_development <- subset(subset_development1, country == 'Indonesia' |
country == 'Malaysia')
# package maptools to visualize data
# install.packages("maptools")
library(maptools)
# plot(x.sub2)
# summary(x.sub2)
subset_development$type_text<-as.factor(subset_development$type_text)
# x.sub3 <- x.sub2[x.sub2$country == "Indonesia",]
# plot(x.sub2, col=x.sub2$type_text)
# information about type_text for Palm Oil is in x.sub2
# CVS file will not be used anymore, only shape file
# RSPO data sets imported
Shape_RSPO_1 <- readOGR(dsn=path.expand("RSPO_1"),
                  layer="RSPO_mills")
Shape_RSPO_2 <- readOGR(dsn=path.expand("RSPO_2"),
                  layer="RSPOcertified_oil_palm_supply_bases_in_Indonesia")
# make subsets that only contain useful information of Shape_RSPO_1
subset_RSPO_1 <- subset(Shape_RSPO_1, select="objectid")
subset_RSPO_2 <- subset(Shape_RSPO_2, select="objectid")
# add a column so you know what file the RSPO is coming from
subset_RSPO_1$mydata='RSPO1'
subset_RSPO_2$mydata='RSPO2'
# rename the IDs of RSPO_2 to make sure the 2 files can be combined
```

```
require(maptools)
xx1 <- spChFIDs(subset_RSPO_2,
as.character((length(subset_RSPO_1)+1):(length(subset_RSPO_1)+length(subset
_RSPO_2))))
# make a buffer for RSPO_1
# install.packages("rgeos")
library(rgeos)
RSPO_1_buf <- buffer(SpatialPoints(subset_RSPO_1, proj4string =
crs(subset_RSPO_1)), width=100, dissolve=FALSE)
RSPO_1_buf_df <- SpatialPolygonsDataFrame(RSPO_1_buf, subset_RSPO_1@data,
match.ID = FALSE)
# Rbind the two data sets
RSPO_combined <- spRbind(RSPO_1_buf_df, xx1)

# make an overlay between development(x.sub2) and RSPO_combined to
determine where there is overlap
overlay <- over(subset_development, RSPO_combined)
subset_development@data <- cbind(subset_development@data, mydata =
overlay$mydata)

overlay2 <- over(RSPO_combined,subset_development)
RSPO_combined_NA <- RSPO_combined[is.na(overlay2$objectid),]

RSPO_combined_NA@data <- cbind(RSPO_combined_NA@data, image = NA, type =
NA, percent = NA, country = NA, type_text = NA, area_ha = NA,
                               spec_org = NA, spec_1 = NA, spec_2 = NA,
spec_simp = NA, spec_3 = NA, spec_4 = NA , spec_5 = NA,
                               st_areasha = NA, st_lengths = NA)
complete_data_set <- spRbind(RSPO_combined_NA,subset_development)
# change the NA's into non-RSPO
complete_data_set$mydata  <- as.character(complete_data_set$mydata)
complete_data_set$mydata[is.na(complete_data_set$mydata)] <- "non_RSPO"

# making overlay between gbif_all and complete_data_set
gbif_all <- as.data.frame(gbif_all[, c("speciesKey", "familyKey",
"orderKey", "classKey", "year", "countryCode", "decimalLatitude",
"decimalLongitude")])
coordinates(gbif_all) = ~decimalLongitude + decimalLatitude
crs(gbif_all) <- crs(complete_data_set)
overlay_gbif <- over(gbif_all,complete_data_set)
# save.image("workspace_line81.RData")
# load("workspace_line81.RData")
# add information of species in the overlay
overlay_gbif <- cbind(overlay_gbif, speciesKey = gbif_all$speciesKey,
                      familyKey = gbif_all$familyKey, classKey =
gbif_all$classKey, orderKey = gbif_all$orderKey)

# change columnames to make more sense
colnames (overlay_gbif)[2] <- "certification"
colnames (overlay_gbif)[7] <- "developmental_stage"

sapply(overlay_gbif, function(x) sum(!is.na(x)))
# objectid     mydata      image       type    percent    country
type_text    area_ha   spec_org
# 9061       2276       9061       9061       9061       9061       9061
9061       9061
# spec_1     spec_2  spec_simp     spec_3     spec_4     spec_5 st_areasha
st_lengths
# 9061          0       9061          0          0          0       9061
9061
sapply(overlay_gbif, function(x) sum(is.na(x)))
```

```
# objectid     mydata      image       type    percent    country
type_text    area_ha   spec_org
# 506170     512955     506170     506170     506170     506170     506170
506170     506170
# spec_1     spec_2  spec_simp     spec_3     spec_4     spec_5 st_areasha
st_lengths
# 506170     515231     506170     515231     515231     515231     506170
506170

# plot(complete_data_set)
# plot(gbif_all, add = TRUE, col = "red", pch = 20, cex = 0.5)
# -> function writeOGR to export shapefiles

# RSPO_combined_NA<-subset(RSPO_combined, data.mydata)
# which(is.na(as.data.frame(overlay2$data.mydata)))
#see where there are intersections
#intersections <- gIntersection(x.sub2, RSPO_combined)
#define the intersections as RSPO, and the non intersecting non-RSPO. put
NA in the empty cells of the development stage

# Export file to QGIS
# writeOGR(obj = gbif_all, dsn = 'R', layer = 'QGIS_file_GBIF',
driver='ESRI Shapefile')
# writeOGR(obj = complete_data_set, dsn = 'R', layer =
'QGIS_file_geographicaldevelopment', driver='ESRI Shapefile')

# make a dataset of point where there is overlay, to study the distribution
GBIF_in_plantations <- subset(overlay_gbif, !is.na(overlay_gbif[,1]))

#---------------------------------------------------------------------------
-----------------------# all species combined

# rename RSPO1 and RSPO 2 into RSPO in GBIF_in_plantations, because this is
nicer for statistical analysis
GBIF_in_plantations$certification [GBIF_in_plantations$certification ==
"RSPO1"] <- "RSPO"
GBIF_in_plantations$certification [GBIF_in_plantations$certification ==
"RSPO2"] <- "RSPO"

# subsetting per species
subset_birds <- subset(GBIF_in_plantations, classKey == '212')
subset_birds$species <- "bird"

subset_lizard <- subset(GBIF_in_plantations, orderKey == '715')
subset_lizard$species <- "lizard"

subset_primates <- subset(GBIF_in_plantations, orderKey == '798')
subset_primates$species <- "primate"

subset_smallmammals <- subset(GBIF_in_plantations, familyKey == '5722' |
orderKey == '359' | orderKey == '801' | orderKey == '1459' | orderKey ==
'803')
# subset_small2 <- subset(GBIF_in_plantations, familyKey == '5722' |
orderKey == c('359', '801', '1459','803'))
subset_smallmammals$species <- "small_mammals"

# produce tables to check de distribution of both the overlay_gbif and
GBIF_in_plantations
table_all_RSPO <- table(overlay_gbif$certification, exclude=NULL)
table_all_development <- table(overlay_gbif$developmental_stage,
exclude=NULL)
# GBIF_in_plantations
```

```
table_withinplantations_RSPO <- table(GBIF_in_plantations$certification,
exclude=NULL)
table_withplantations_development <-
table(GBIF_in_plantations$developmental_stage, exclude=NULL)

# response variable is count of point data of gbif data, later vegan
package will be looked into
# biodiversity <- diversity(overlay_gbif) --> spp information is lost
# response variable at this moment is just the sum of species
# install.packages("dplyr")
library(dplyr)
response_variable1 <- aggregate(GBIF_in_plantations$objectid,
list(GBIF_in_plantations$objectid), FUN = "length")
# only unique species in dataset
response_variable2 <- aggregate(GBIF_in_plantations$objectid,
list(GBIF_in_plantations$objectid, GBIF_in_plantations$speciesKey), FUN =
"length")
response_variable_2.2 <-aggregate(response_variable2$Group.1,
list(response_variable2$Group.1), FUN= "length")

# check why 217 --> 216
# install.packages("xlsx")
library(xlsx)
# write.xlsx(response_variable, ".response_variable.xlsx")
# write.xlsx(response_variable3, ".response_variable2.xlsx")
# write.xlsx(response_variable5, ".response_variable5.xlsx")
# import xlsx file to have response variable with 217 enteries
response_variable <- read.table(file = "responsevariableall.txt",
                                sep = "\t", header=TRUE)

# change col name in response_variable before merging
colnames (response_variable)[2] <- "objectid"
# merging 2 data frames
total_spp_per_location_incl1 <- merge(response_variable,
unique(GBIF_in_plantations[,c("objectid",
"certification","developmental_stage")]),
                                by="objectid")
colnames (total_spp_per_location_incl1)[3] <- "speciescount"

# check distributions by looking at histograms
png('histogram_total.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
hist(total_spp_per_location_incl1$speciescount, breaks=20, xlab="Species
count", main=" ", cex.lab=1.5, cey.lab=1.5)
dev.off()

# log transformation needed after investigating the distribution
total_spp_per_location_incl1$log_speciescount <-
log10(total_spp_per_location_incl1$speciescount)

# histogram after log transformation
png('historgram_total_log.png')
hist(total_spp_per_location_incl1$log_speciescount, breaks=20)
dev.off()

# make subset that has only >1, as it is likely that there will be more
than 1 species per location
total_spp_per_location <- subset(total_spp_per_location_incl1,
log_speciescount >0)
```

```
# export to do analysis in SPSS
write.xlsx(total_spp_per_location, ".dataframetotal.xlsx")

# install.packages("extrafont")
library(extrafont)
font_import()
loadfonts()

# make boxplots
png('boxplot_certification_all.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ certification, total_spp_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,250), ylab = "Species count",
cex.lab=1.5)
dev.off()

png('boxplot_size_all.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ developmental_stage, total_spp_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,250), ylab = "Species count",
cex.lab=1.5, xaxt="n")
axis(side=1, at=1:3, labels=FALSE)
dev.off()

# change names into smalle, medium and large
total_spp_per_location$developmental_stage
[total_spp_per_location$developmental_stage == "Large industrial
plantation"] <- "Large"
total_spp_per_location$developmental_stage
[total_spp_per_location$developmental_stage == "Mosaic of medium-sized
plantations"] <- "Medium"
total_spp_per_location$developmental_stage
[total_spp_per_location$developmental_stage == "Mosaic of small-sized
plantations"] <- "Small"

lmtotal <-
lm(log_speciescount~certification*developmental_stage,total_spp_per_locatio
n)
# lmtotal <-
lm(speciescount~certification+developmental_stage,total_spp_per_location)

anova_total <- anova(lmtotal)
summary(lmtotal)
png('anova_total_log.png')
plot(lmtotal)
dev.off()

capture.output(summary(lmtotal),file="anova_total_log.doc")

lmtotal_certification <-
lm(log_speciescount~certification,total_spp_per_location)
lmtotal_development <-
lm(log_speciescount~developmental_stage,total_spp_per_location)

anova(lmtotal_certification)
summary(lmtotal_certification)
```

```
capture.output(summary(lmtotal_certification),file="anova_total_RSPO_log.do
c")

anova(lmtotal_development)
summary(lmtotal_development)
capture.output(summary(lmtotal_development),file="anova_total_development_l
og.doc")
#---------------------------------------------------------------------------
-------------------# end all species

# same tests but then for birds

response_variable_birds1 <- aggregate(subset_birds$objectid,
list(subset_birds$objectid), FUN = "length")
response_variable_birds2 <- aggregate(subset_birds$objectid,
list(subset_birds$objectid, subset_birds$speciesKey), FUN = "length")
response_variable_birds1.1 <-aggregate(response_variable_birds2$Group.1,
list(response_variable_birds2$Group.1), FUN= "length")

write.xlsx(response_variable_birds1, ".response_variable_birds1.xlsx")
write.xlsx(response_variable_birds1.1, ".response_variable_birds2.xlsx")
# compare 186 --> 185
# import birds 186
response_variable_birds <- read.table(file = "responsevariablebirds.txt",
                                sep = "\t", header=TRUE)

# change col name in response_variable before merging
colnames (response_variable_birds)[2] <- "objectid"
# merging 2 data frames
total_birds_per_location_incl1 <- merge(response_variable_birds,
unique(subset_birds[,c("objectid",
"certification","developmental_stage")]),
                                by="objectid")
colnames (total_birds_per_location_incl1)[3] <- "speciescount"

# counts of birds, to see difference in bird species
count_birds<-as.data.frame(table(subset_birds$speciesKey,
subset_birds$certification))
# export file to xlsx
write.xlsx(count_birds, "birdspp.xlsx")

# check distributions by looking at histograms
png('histogram_birds.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
hist(total_birds_per_location_incl1$speciescount, breaks=20, xlab="Species
count", main=" ", cex.lab=1.5, cey.lab=1.5)
dev.off()

# log transformation needed after investigating the distribution
total_birds_per_location_incl1$log_speciescount <-
log10(total_birds_per_location_incl1$speciescount)
png('histogram_log_birds.png')
hist(total_birds_per_location_incl1$log_speciescount, breaks=20)
dev.off()

# make subset that has only >1, as it is likely that there will be more
than 1 species per location
total_birds_per_location <- subset(total_birds_per_location_incl1,
log_speciescount >0)
```

```
# export to do analysis in SPSS
write.xlsx(total_birds_per_location, ".dataframebirds.xlsx")

# make boxplots
png('boxplot_certification_birds.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ certification, total_birds_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,250), ylab = "Species count",
cex.lab=1.5)
dev.off()

png('boxplot_size_birds.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ developmental_stage, total_birds_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,250), ylab = "Species count",
cex.lab=1.5, xaxt="n")
axis(side=1, at=1:3, labels=FALSE)
dev.off()

# change names into small, medium and large
total_birds_per_location$developmental_stage
[total_birds_per_location$developmental_stage == "Large industrial
plantation"] <- "Large"
total_birds_per_location$developmental_stage
[total_birds_per_location$developmental_stage == "Mosaic of medium-sized
plantations"] <- "Medium"
total_birds_per_location$developmental_stage
[total_birds_per_location$developmental_stage == "Mosaic of small-sized
plantations"] <- "Small"

lmbirds <-
lm(log_speciescount~certification*developmental_stage,total_birds_per_locat
ion)

anova_birds <- anova(lmbirds)
summary(lmbirds)
png('anova_birds_log.png')
plot(lmbirds)
dev.off()

capture.output(summary(lmbirds),file="anova_birds_log.doc")

lmbirds_certification <-
lm(log_speciescount~certification,total_birds_per_location)
lmbirds_development <-
lm(log_speciescount~developmental_stage,total_birds_per_location)

anova(lmbirds_certification)
summary(lmbirds_certification)
capture.output(summary(lmbirds_certification),file="anova_birds_RSPO_log.do
c")

anova(lmbirds_development)
summary(lmbirds_development)
capture.output(summary(lmbirds_development),file="anova_birds_development_l
og.doc")
```

```
#------------------------------------------

# same tests but then for lizard

response_variable_lizard1 <- aggregate(subset_lizard$objectid,
list(subset_lizard$objectid), FUN = "length")
response_variable_lizard2 <- aggregate(subset_lizard$objectid,
list(subset_lizard$objectid, subset_lizard$speciesKey), FUN = "length")
response_variable_lizard <-aggregate(response_variable_lizard2$Group.1,
list(response_variable_lizard2$Group.1), FUN= "length")

#23 remains check! --> export and import to stay consistent
write.xlsx(response_variable_lizard, ".response_variable_lizard.xlsx")

response_variable_lizard <- read.table(file = "lizard.txt",
                                      sep = "\t", header=TRUE)

# change col name in response_variable before merging
colnames (response_variable_lizard)[2] <- "objectid"
# merging 2 data frames
total_lizard_per_location_incl1 <- merge(response_variable_lizard,
unique(subset_lizard[,c("objectid",
"certification","developmental_stage")]),
                                   by="objectid")
colnames (total_lizard_per_location_incl1)[3] <- "speciescount"

# counts of lizard, to see difference in species
count_lizard <- as.data.frame(table(subset_lizard$speciesKey,
subset_lizard$certification))
# export file to xlsx
write.xlsx(count_lizard, "lizardspp.xlsx")

# check distributions by looking at histograms
png('histogram_lizard.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
hist(total_lizard_per_location_incl1$speciescount, xlab="Species count",
main=" ", cex.lab=1.5, cey.lab=1.5)
dev.off()

#log transformation needed after investigating the distribution
total_lizard_per_location_incl1$log_speciescount <-
log10(total_lizard_per_location_incl1$speciescount)

#histogram after transformation
png('histogram_log_lizard.png')
hist(total_lizard_per_location_incl1$log_speciescount)
dev.off()

# make subset that has only >1, as it is likely that there will be more
than 1 species per location
total_lizard_per_location <- subset(total_lizard_per_location_incl1,
log_speciescount >0)
# export to do analysis in SPSS
write.xlsx(total_lizard_per_location, ".dataframelizard.xlsx")

# make boxplots
png('boxplot_certification_lizard.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
```

```
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ certification, total_lizard_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,15), ylab = "Species count",
cex.lab=1.5,
        show.names=TRUE)
dev.off()

png('boxplot_size_lizard.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ developmental_stage, total_lizard_per_location, col
= "cornflowerblue", yaxs = "i", ylim=c(0,15), ylab = "Species count",
cex.lab=1.5, xaxt="n")
axis(side=1, at=1:3, labels=FALSE)
dev.off()

# change names into small, medium and large
total_lizard_per_location$developmental_stage
[total_lizard_per_location$developmental_stage == "Large industrial
plantation"] <- "Large"
total_lizard_per_location$developmental_stage
[total_lizard_per_location$developmental_stage == "Mosaic of medium-sized
plantations"] <- "Medium"
total_lizard_per_location$developmental_stage
[total_lizard_per_location$developmental_stage == "Mosaic of small-sized
plantations"] <- "Small"

lmlizard <-
lm(log_speciescount~certification*developmental_stage,total_lizard_per_loca
tion)

anova(lmlizard)
summary(lmlizard)
png('anova_lizard_log.png')
plot(lmlizard)
dev.off()

capture.output(summary(lmlizard),file="anova_lizard_log.doc")

lmlizard_certification <-
lm(log_speciescount~certification,total_lizard_per_location)
lmlizard_development <-
lm(log_speciescount~developmental_stage,total_lizard_per_location)

anova(lmlizard_certification)
summary(lmlizard_certification)
capture.output(summary(lmlizard_certification),file="anova_lizard_RSPO_log.
doc")

anova_lizard <- anova(lmlizard_development)
summary(lmlizard_development)
capture.output(summary(lmlizard_development),file="anova_lizard_development
_log.doc")
#------------------------------------------

# same tests but then for primates

response_variable_primates1 <- aggregate(subset_primates$objectid,
list(subset_primates$objectid), FUN = "length")
```

```
response_variable_primates2 <- aggregate(subset_primates$objectid,
list(subset_primates$objectid, subset_primates$speciesKey), FUN = "length")
response_variable_primates <-
aggregate(response_variable_primates2$Group.1,
list(response_variable_primates2$Group.1), FUN= "length")

#export and import
write.xlsx(response_variable_primates, ".response_variable_primates.xlsx")

response_variable_primates <- read.table(file = "primates.txt",
                                       sep = "\t", header=TRUE)

# change col name in response_variable before merging

colnames (response_variable_primates)[2] <- "objectid"
# merging 2 data frames
total_primates_per_location_incl1 <- merge(response_variable_primates,
unique(subset_primates[,c("objectid",
"certification","developmental_stage")]),
                                     by="objectid")
colnames (total_primates_per_location_incl1)[3] <- "speciescount"

# counts of primates, to see difference in primate species
count_primates <- as.data.frame(table(subset_primates$speciesKey,
subset_primates$certification))
# export file to xlsx
write.xlsx(count_primates, "primatespp.xlsx")

png('histogram_primates.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
hist(total_primates_per_location_incl1$speciescount, xlab="Species count",
main=" ", cex.lab=1.5, cey.lab=1.5)
dev.off()

# log transformation needed after investigating the distribution
total_primates_per_location_incl1$log_speciescount <-
log10(total_primates_per_location_incl1$speciescount)

png('histogram_log_primates.png')
hist(total_primates_per_location_incl1$log_speciescount)
dev.off()

# make subset that has only >1, as it is likely that there will be more
than 1 species per location
total_primates_per_location <- subset(total_primates_per_location_incl1,
log_speciescount >0)
# export to do analysis in SPSS
write.xlsx(total_primates_per_location, ".dataframeprimates.xlsx")

# make boxplots
png('boxplot_certification_primate.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ certification, total_primates_per_location, col =
"cornflowerblue", yaxs = "i", ylim=c(0,6), ylab = "Species count",
cex.lab=1.5)
dev.off()
```

```
png('boxplot_size_primate.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ developmental_stage, total_primates_per_location,
col = "cornflowerblue", yaxs = "i", ylim=c(0,6), ylab = "Species count",
cex.lab=1.5, xaxt="n")
axis(side=1, at=1:1, labels=FALSE)
dev.off()

# change names into small, medium and large
total_primates_per_location$developmental_stage
[total_primates_per_location$developmental_stage == "Large industrial
plantation"] <- "Large"
total_primates_per_location$developmental_stage
[total_primates_per_location$developmental_stage == "Mosaic of medium-sized
plantations"] <- "Medium"
total_primates_per_location$developmental_stage
[total_primates_per_location$developmental_stage == "Mosaic of small-sized
plantations"] <- "Small"

lmprimates <-
lm(log_speciescount~certification*developmental_stage,total_primates_per_lo
cation)

anova(lmprimates)
summary(lmprimates)
png('anova_primates_log.png')
plot(lmprimates)
dev.off()

capture.output(summary(lmprimates),file="anova_primates_log.doc")

lmprimates_certification <-
lm(log_speciescount~certification,total_primates_per_location)
lmprimates_development <-
lm(log_speciescount~developmental_stage,total_primates_per_location)

anova_primates <- anova(lmprimates_certification)
summary(lmprimates_certification)
capture.output(summary(lmprimates_certification),file="anova_primates_RSPO_
log.doc")

anova(lmprimates_development)
summary(lmprimates_development)
capture.output(summary(lmprimates_development),file="anova_primates_develop
ment_log.doc")
#------------------------------------------

# same tests but then for small mammals

response_variable_smallmammals1 <- aggregate(subset_smallmammals$objectid,
list(subset_smallmammals$objectid), FUN = "length")
response_variable_smallmammals2 <- aggregate(subset_smallmammals$objectid,
list(subset_smallmammals$objectid, subset_smallmammals$speciesKey), FUN =
"length")
response_variable_smallmammals <-
aggregate(response_variable_smallmammals2$Group.1,
list(response_variable_smallmammals2$Group.1), FUN= "length")
```

```
#export and import
write.xlsx(response_variable_smallmammals,
".response_variable_smallmammals.xlsx")


response_variable_smallmammals <- read.table(file = "smallmammals.txt",
                                         sep = "\t", header=TRUE)

# change col name in response_variable before merging
colnames (response_variable_smallmammals)[2] <- "objectid"
# merging 2 data frames
total_smallmammals_per_location_incl1 <-
merge(response_variable_smallmammals,
unique(subset_smallmammals[,c("objectid",
"certification","developmental_stage")]),
                                         by="objectid")
colnames (total_smallmammals_per_location_incl1)[3] <- "speciescount"

# counts of small mammals, to see difference in species
count_smallmammals <- as.data.frame(table(subset_smallmammals$speciesKey,
subset_smallmammals$certification))
# export file to xlsx
write.xlsx(count_smallmammals, "smallmammalsspp.xlsx")

png('histogram_smallmammals.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
hist(total_smallmammals_per_location_incl1$speciescount, xlab="Species
count", main=" ", cex.lab=1.5, cey.lab=1.5)
dev.off()

# log transformation needed after investigating the distribution
total_smallmammals_per_location_incl1$log_speciescount <-
log10(total_smallmammals_per_location_incl1$speciescount)

png('histogram_log_smallmammals.png')
hist(total_smallmammals_per_location_incl1$log_speciescount)
dev.off()

# make subset that has only >1, as it is likely that there will be more
than 1 species per location
total_smallmammals_per_location <-
subset(total_smallmammals_per_location_incl1, log_speciescount >0)
# export to do analysis in SPSS
write.xlsx(total_smallmammals_per_location, ".dataframesmallmammals.xlsx")

# make boxplots
png('boxplot_certification_smallmammals.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ certification, total_smallmammals_per_location, col
= "cornflowerblue", yaxs = "i", ylim=c(0,8), ylab = "Species count",
cex.lab=1.5)
dev.off()

png('boxplot_size_smallmammals.png')
windowsFonts(C = windowsFont("Cambria"))
par(family="C")
```

```
par(cex.axis=1.5)
par(cex.yxis=1.5)
boxplot(speciescount ~ developmental_stage,
total_smallmammals_per_location, col = "cornflowerblue", yaxs = "i",
ylim=c(0,8), ylab = "Species count", cex.lab=1.5, xaxt="n")
axis(side=1, at=1:2, labels=FALSE)
dev.off()

# change names into small, medium and large
total_smallmammals_per_location$developmental_stage
[total_smallmammals_per_location$developmental_stage == "Large industrial
plantation"] <- "Large"
total_smallmammals_per_location$developmental_stage
[total_smallmammals_per_location$developmental_stage == "Mosaic of medium-
sized plantations"] <- "Medium"
total_smallmammals_per_location$developmental_stage
[total_smallmammals_per_location$developmental_stage == "Mosaic of small-
sized plantations"] <- "Small"

lmsmallmammals <-
lm(log_speciescount~certification*developmental_stage,total_smallmammals_pe
r_location)

anova_smallmammals <- anova(lmsmallmammals)
summary(lmsmallmammals)
png('anova_smallmammals_log.png')
plot(lmsmallmammals)
dev.off()

capture.output(summary(lmsmallmammals),file="anova_small_mammals_log.doc")

lmsmallmammals_certification <-
lm(log_speciescount~certification,total_smallmammals_per_location)
lmsmallmammals_development <-
lm(log_speciescount~developmental_stage,total_smallmammals_per_location)

anova(lmsmallmammals_certification)
summary(lmsmallmammals_certification)
capture.output(summary(lmsmallmammals_certification),file="anova_small_mamm
als_RSPO_log.doc")

anova(lmsmallmammals_development)
summary(lmsmallmammals_development)
capture.output(summary(lmsmallmammals_development),file="anova_small_mammal
s_development_log.doc")
```

Code to obtain the GBIF data set ("gbif_all") in R.

```
# install and open rgbif to import GBIF data
# install.packages("rgbif")
library("rgbif")
Development <- raster(Shape_development)
occ_count(datasetKey=Development)
indonesia_code <- isocodes[grep("Indonesia", isocodes$name), "code"]
occ_count(country=indonesia_code)
# install.packages("maps")
library("maps")

# look up taxon keys ====================================================
# find classKey of species by using the backbone function
aves <- name_backbone(name='Aves', kingdom='animalia')
# taxonKey aves is classKey = 212 CHECK

lizard <- name_backbone(name='Lacertilia', kingdom='animalia',
phylum='Chordata', class='Reptilia', order='Squamata')
# taxonKey is orderkey = 715 CHECK

rodentia <- name_backbone(name='Rodentia', kingdom='animalia')
# usagekey is orderkey = 1459 CHECK

scandentia <- name_backbone(name='Scandentia', kingdom='animalia')
# usagekey is order key = 801 CHECK

eulipotyphla <- name_backbone(name='Eulipotyphla', kingdom='animalia',
      class='Mammalia')
# usagekey = orderkey = 359 CHECK
# Order Eulipotyphla (= 'Erinaceomorpha' + 'Soricomorpha')
erinaceidae <- name_backbone(name='Erinaceidae', class='Mammalia')
# usagekey is familykey = 5722 CHECK

soricomorpha <- name_backbone(name='Soricomorpha', class='Mammalia')
# usagekey is orderkey = 803, taxonkey would be expected

primates <- name_backbone (name='Primates', kingdom = 'animalia')
# usagekey is orderkey = 798 CHECK

# name_suggest("Rod", rank = "order")
# name_suggest("Euli", rank = "order")
# name_suggest("Eulipo")

# downloads ============================================================
# download request, get and import in R for all
request_all <- occ_download('taxonKey = 212,715,1459,801,359,5722,803,798',
'country = ID,MY', 'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                              user = "cathelijnestikkers", pwd = "###",
email = "cathelijnestikkers@gmail.com")
# gbif_all <- occ_download_get("0047517-180508205500799", overwrite = TRUE)
%>%
#  occ_download_import
downloaded_data <- as.download("0047517-180508205500799.zip")
gbif_all <- occ_download_import (downloaded_data)
# did work!

# downloads by taxon ===================================================
# download request, get and import in R for birds

request_birds <- occ_download('taxonKey = 212',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
```

```
                        user = "cathelijnestikkers", pwd = "###", email =
"cathelijnestikkers@gmail.com")
# gbif_birds <- occ_download_get("0047503-180508205500799", overwrite =
TRUE) %>%
#  occ_download_import
downloaded_data <- as.download("0047503-180508205500799.zip")
gbif_birds <- occ_download_import (downloaded_data)

# request lizard
request_lizard <- occ_download('taxonKey = 715',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                              user = "cathelijnestikkers", pwd = "###",
email = "cathelijnestikkers@gmail.com")
# gbif_lizards <- occ_download_get("0047519-180508205500799", overwrite =
TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047519-180508205500799.zip")
gbif_lizards <- occ_download_import (downloaded_data)
# did work!

# request rodentia
request_rodentia <- occ_download('taxonKey = 1459',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                user = "cathelijnestikkers", pwd = "###",
email = "cathelijnestikkers@gmail.com")
# gbif_rodentia <- occ_download_get("0047526-180508205500799", overwrite =
TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047526-180508205500799.zip")
gbif_rodentia <- occ_download_import (downloaded_data)
# worked!

# request scandentia
request_scandentia <- occ_download('taxonKey = 801',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                  user = "cathelijnestikkers", pwd = "###",
email = "cathelijnestikkers@gmail.com")
# gbif_scandentia <- occ_download_get("0047556-180508205500799", overwrite
= TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047556-180508205500799.zip")
gbif_scandentia <- occ_download_import (downloaded_data)
# worked!

# request eulipotyphla
request_eulipotyphla <- occ_download('taxonKey = 359',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                    user = "cathelijnestikkers", pwd =
"###", email = "cathelijnestikkers@gmail.com")
# gbif_eulipotyphla <- occ_download_get("0047558-180508205500799",
overwrite = TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047558-180508205500799.zip")
gbif_eulipotyphla <- occ_download_import (downloaded_data)
# worked

# request erinaceida
request_erinaceida <- occ_download('taxonKey = 5722',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                    user = "cathelijnestikkers", pwd =
"###", email = "cathelijnestikkers@gmail.com")
```

```
# gbif_erinaceida <- occ_download_get("0047560-180508205500799", overwrite
= TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047560-180508205500799.zip")
gbif_erinaceida <- occ_download_import (downloaded_data)
# worked

# request soricomorpha
request_sorimorpha <- occ_download('taxonKey = 803',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                    user = "cathelijnestikkers", pwd =
"###", email = "cathelijnestikkers@gmail.com")
# gbif_sorimorpha <- occ_download_get("0047562-180508205500799", overwrite
= TRUE) %>%
#   occ_download_import
downloaded_data <- as.download("0047562-180508205500799.zip")
gbif_sorimorpha <- occ_download_import (downloaded_data)
# worked

# request primates
request_primates <- occ_download('taxonKey = 798',  'country = ID,MY',
'hasCoordinate = TRUE', 'hasGeospatialIssue = FALSE',
                                    user = "cathelijnestikkers", pwd =
"###", email = "cathelijnestikkers@gmail.com")
# gbif_primates <- occ_download_get("0047563-180508205500799", overwrite =
TRUE) %>%
# occ_download_import
downloaded_data <- as.download("0047563-180508205500799.zip")
gbif_primates <- occ_download_import (downloaded_data)
# worked!
```

Appendix E – Histograms of response variables after log transformation

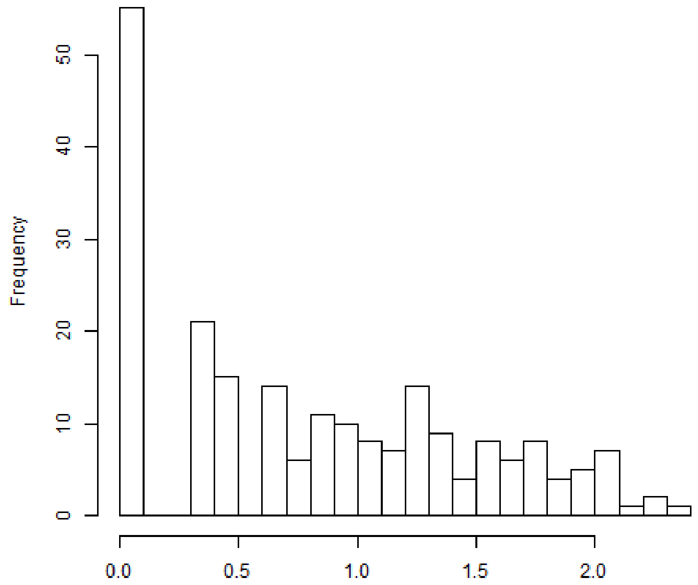

Figure E1. Histogram of distribution of species count per plantation of all species combined. After log transformation; species count of 1 included.

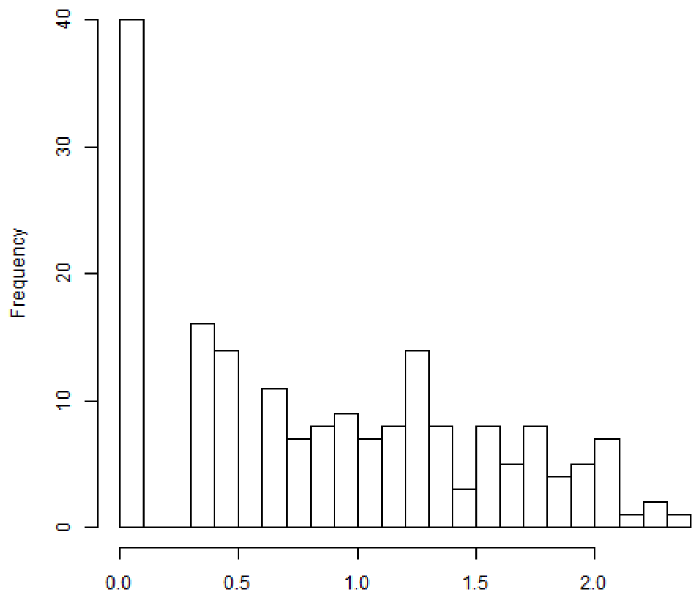

Figure E2. Histogram of distribution of species count per plantation of bird species. After log transformation; species count of 1 included.

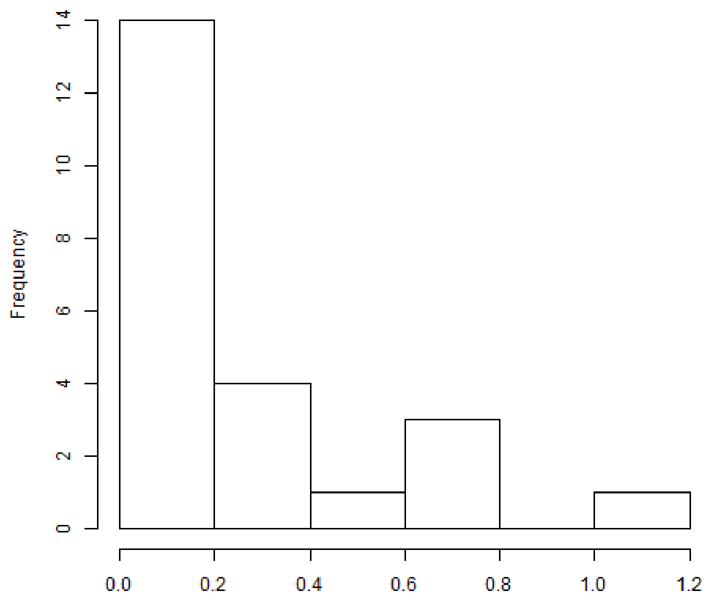

Figure E3. Histogram of distribution of species count per plantation of lizard species. After log transformation; species count of 1 included.

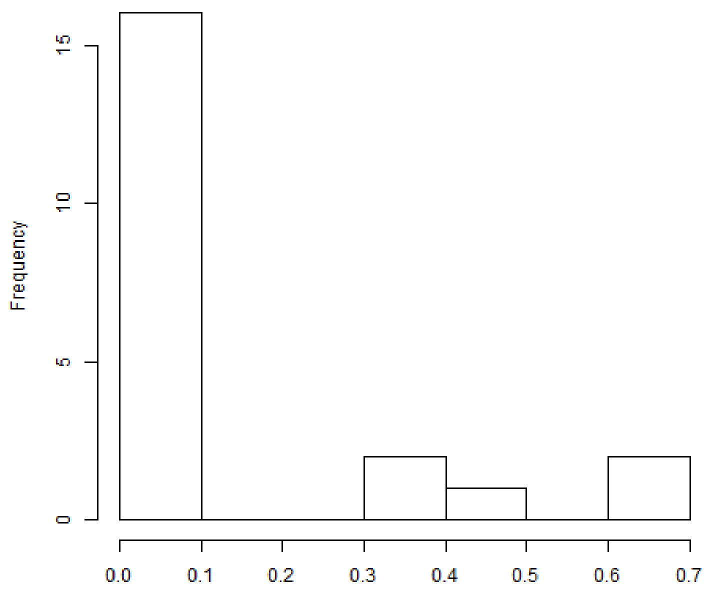

Figure E4. Histogram of distribution of species count per plantation of primate species. After log transformation; species count of 1 included.

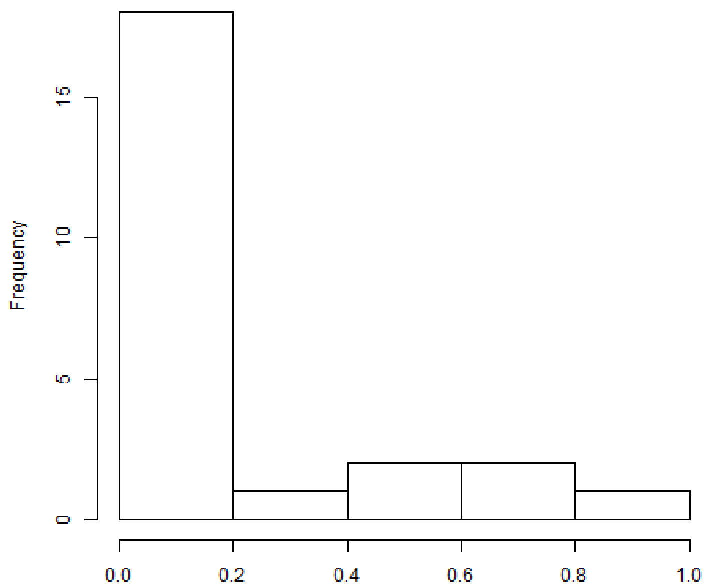

Figure E5. Histogram of distribution of species count per plantation of small mammal species. After log transformation; species count of 1 included.

Appendix F – Descriptive Statistics (SPSS)

Table F1. Descriptive statistics of all species data set.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
speciescount	161	2	213	27,15	37,792
Valid N (listwise)	161				

Table F2. Descriptive statistics of birds data set.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
speciescount	146	2	208	28,51	38,194
Valid N (listwise)	146				

Table F3. Descriptive statistics of lizards data set.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
speciescount	9	2	14	4,44	3,877
Valid N (listwise)	9				

Table F4. Descriptive statistics of primates data set.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
speciescount	5	2	5	3,20	1,304
Valid N (listwise)	5				

Table F3. Descriptive statistics of small mammals data set.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
speciescount	6	2	7	3,83	1,722
Valid N (listwise)	6				

Appendix G – ANOVA Tables from execution of analysis (R)

The "developmental_stage" in the Tables is related to the **"plantation size"** parameter. Code to generate the Tables:

```
install.packages("knitr")
library(knitr)
kable(anova_total, digits=8)
kable(anova_birds, digits=8)
kable(anova_lizard, digits=8)
kable(anova_primates, digits=8)
kable(anova_smallmammals, digits=8)
```

Table G1. ANOVA output of lineair model of the total (all species included) data set.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
certification	1	0.5335790	0.5335790	1.7034506	0.1937469
developmental_stage	2	0.1635652	0.0817826	0.2610909	0.7705446
Residuals	157	49.1777677	0.3132342	NA	NA

Table G2. ANOVA output of lineair model of birds data set.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
certification	1	0.1707786	0.1707786	0.5483275	0.4602245
developmental_stage	2	0.2499599	0.1249800	0.4012795	0.6702196
Residuals	142	44.2264190	0.3114537	NA	NA

Table G3. ANOVA output of lineair model of lizards data set.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
developmental_stage	2	0.06729398	0.03364699	0.3266298	0.733416
Residuals	6	0.61807575	0.10301263	NA	NA

Table G4. ANOVA output of lineair model of primates data set.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
certification	1	0.03828661	0.03828661	1.297113	0.3374524
Residuals	3	0.08855039	0.02951680	NA	NA

Table G5. ANOVA output of lineair model of small mammals data set.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
certification	1	0.00037349	0.00037349	0.00691875	0.9389485
developmental_stage	1	0.00278864	0.00278864	0.05165846	0.8348104
Residuals	3	0.16194654	0.05398218	NA	NA

Appendix H – Output tables of the species occurrence analysis per species

Table H1. Output of the bird species occurrence analysis derived from Microsoft Excel 2010. Common names are only indicated for the ten bird species with the highest relative preference for RSPO plantations. NA in Red List column indicates the species did not occurred in the IUCN Red List category "Vulnerable", "Endangered" or "Critically Endangered" (indicated by the highlighted color within the Table) and therefore are either not available, fall in the "Least Concern" or in the "Nearly Threatened" category. The ten bird species with the highest positive and highest negative preference were manually found. The total number of RSPO plantations to calculate Y_1 was 461. The total number of non-RSPO plantations to calculate Y_2 was 5,850.

Scientific name	**Common name**	**GBIF Specieskey**	**Count in non-RSPO plantations (*y*)**	**Fraction (Y_2) = count *y* over total non-RSPO plantations**	**Count in RSPO plantations (*x*)**	**Fraction (Y_1) = count *x* over total RSPO plantations**	**Relative preference of bird species for RSPO vs. non-RSPO plantations (Y_1-Y_2)**	**Red List**
Pycnonotus goiavier	Yellow-vented bulbul	2486144	101	0.017264957	52	0.112798265	0.095533307	Least Concern
Centropus sinensis	The greater coucal/crow pheasant	5232005	34	0.005811966	43	0.093275488	0.087463522	Least Concern
Rhipidura javanica	Malaysian pied fantail	5231747	34	0.005811966	42	0.091106291	0.085294325	Least Concern
Aplonis panayensis	Asian glossy starling	2489036	55	0.009401709	40	0.086767896	0.077366186	Least Concern
Mixornis bornensis	Bold-striped tit-babbler	7387112	19	0.003247863	36	0.078091106	0.074843243	Least Concern
Spilornis cheela	Crested serpent eagle	2480433	48	0.008205128	38	0.082429501	0.074224373	Least Concern
Orthotomus sericeus	Rufous-tailed tailorbird	2493038	34	0.005811966	36	0.078091106	0.07227914	Least Concern
Aegithina tiphia	Common iora	2484096	53	0.009059829	37	0.080260304	0.071200475	Least Concern
Todiramphus chloris	Collared kingfisher	2475742	35	0.005982906	35	0.075921909	0.069939003	Least Concern
Amaurornis phoenicurus	White-breasted waterhen	2474732	32	0.005470085	32	0.069414317	0.063944231	Least Concern
Streptopelia chinensis		2495715	94	0.016068376	35	0.075921909	0.059853533	NA
Hirundo tahitica		5230787	95	0.016239316	33	0.071583514	0.055344198	NA
Anthracoceros albirostris		2475991	22	0.003760684	26	0.056399132	0.052638449	NA
Gallus gallus		9326020	18	0.003076923	25	0.054229935	0.051153012	NA
Eurystomus orientalis		5228280	33	0.005641026	26	0.056399132	0.050758107	NA
Merops viridis		2475449	36	0.006153846	26	0.056399132	0.050245286	NA
Buceros rhinoceros		2476004	31	0.005299145	25	0.054229935	0.04893079	NA

Ardea alba		9752617	40	0.006837607	25	0.054229935	0.047392328	NA
Pelargopsis capensis		5228417	17	0.002905983	23	0.04989154	0.046985557	NA
Anthracoceros malayanus		2475989	26	0.004444444	23	0.04989154	0.045447096	NA
Passer montanus		5231198	55	0.009401709	25	0.054229935	0.044828226	NA
Corvus enca		2482470	18	0.003076923	20	0.043383948	0.040307025	NA
Haliastur indus		2480437	61	0.01042735	23	0.04989154	0.03946419	NA
Halcyon smyrnensis		5228328	74	0.012649573	24	0.052060738	0.039411165	NA
Prinia flaviventris		2492765	31	0.005299145	20	0.043383948	0.038084803	NA
Actitis hypoleucos		2481800	58	0.00991453	22	0.047722343	0.037807813	NA
Collocalia affinis		9478106	22	0.003760684	19	0.041214751	0.037454067	NA
Egretta garzetta		2480876	63	0.010769231	22	0.047722343	0.036953112	NA
Pycnonotus brunneus		2486149	38	0.006495726	19	0.041214751	0.034719024	NA
Alcedo meninting		2475494	14	0.002393162	17	0.036876356	0.034483193	NA
Acridotheres javanicus		5845375	41	0.007008547	19	0.041214751	0.034206204	NA
Anhinga melanogaster		2482081	16	0.002735043	17	0.036876356	0.034141313	NA
Orthotomus ruficeps		2493031	16	0.002735043	17	0.036876356	0.034141313	NA
Bubulcus ibis		2480830	58	0.00991453	20	0.043383948	0.033469418	NA
Cacomantis merulinus		2496253	29	0.004957265	17	0.036876356	0.031919091	NA
Lonchura atricapilla		2493623	17	0.002905983	16	0.034707158	0.031801175	NA
Cymbirhynchus macrorhynchos		2484543	21	0.003589744	16	0.034707158	0.031117415	NA
Ardea purpurea		2480934	36	0.006153846	17	0.036876356	0.03072251	NA
Anthreptes malacensis		2484632	27	0.004615385	16	0.034707158	0.030091774	NA
Ardea cinerea		9797180	6	0.001025641	14	0.030368764	0.029343123	NA
Arachnothera longirostra		2484653	32	0.005470085	16	0.034707158	0.029237073	NA
Aethopyga siparaja		2484677	7	0.001196581	14	0.030368764	0.029172182	NA
Treron vernans		2495817	23	0.003931624	15	0.032537961	0.028606337	NA
Aegithina viridissima		2484095	19	0.003247863	14	0.030368764	0.0271209	NA
Leptoptilos javanicus		2481947	8	0.001367521	12	0.026030369	0.024662847	NA
Elanus caeruleus		2480372	36	0.006153846	14	0.030368764	0.024214917	NA
Artamus leucoryn		8117515	36	0.006153846	14	0.030368764	0.024214917	NA

Alcedo atthis		2475532	11	0.001880342	12	0.026030369	0.024150027	NA
Eurylaimus ochromalus		2484548	30	0.005128205	13	0.028199566	0.023071361	NA
Acridotheres tristis		2489005	48	0.008205128	14	0.030368764	0.022163635	NA
Hirundo rustica		9515886	74	0.012649573	16	0.034707158	0.022057586	NA
Geopelia striata		2495486	41	0.007008547	13	0.028199566	0.021191019	NA
Pycnonotus plumosus		2486122	29	0.004957265	12	0.026030369	0.021073104	NA
Ceyx erithaca		5228386	23	0.003931624	11	0.023861171	0.019929547	NA
Oriolus chinensis		9750846	32	0.005470085	11	0.023861171	0.018391086	NA
Dicrurus paradiseus		2493969	58	0.00991453	13	0.028199566	0.018285036	NA
Cinnyris jugularis		7340578	23	0.003931624	10	0.021691974	0.01776035	NA
Treron olax		2495811	37	0.006324786	11	0.023861171	0.017536385	NA
Rhinortha chlorophaea		5231928	37	0.006324786	11	0.023861171	0.017536385	NA
Ixobrychus cinnamomeus		2480849	12	0.002051282	9	0.019522777	0.017471495	NA
Ducula aenea		2495934	25	0.004273504	10	0.021691974	0.01741847	NA
Centropus bengalensis		5231979	25	0.004273504	10	0.021691974	0.01741847	NA
Dinopium javanense		5228803	15	0.002564103	9	0.019522777	0.016958674	NA
Aerodramus fuciphagus		2477269	16	0.002735043	9	0.019522777	0.016787734	NA
Halcyon pileata		5228310	5	0.000854701	8	0.017353579	0.016498878	NA
Corvus macrorhynchos		2482487	20	0.003418803	9	0.019522777	0.016103973	NA
Nisaetus limnaeetus		8197964	21	0.003589744	9	0.019522777	0.015933033	NA
Lanius cristatus		2492846	47	0.008034188	11	0.023861171	0.015826983	NA
Columba livia		2495414	11	0.001880342	8	0.017353579	0.015473237	NA
Butorides striata		2480824	25	0.004273504	9	0.019522777	0.015249272	NA
Psittacula longicauda		5229038	26	0.004444444	9	0.019522777	0.015078332	NA
Tringa totanus		2481714	2	0.00034188	7	0.015184382	0.014842501	NA
Oriolus xanthonotus		2488971	16	0.002735043	8	0.017353579	0.014618536	NA
Acridotheres fuscus		2489006	29	0.004957265	9	0.019522777	0.014565512	NA
Dendrocopos moluccensis		2477942	4	0.000683761	7	0.015184382	0.014500621	NA
Lonchura fuscans		2493619	4	0.000683761	7	0.015184382	0.014500621	NA
Pellorneum capistratum		2493252	17	0.002905983	8	0.017353579	0.014447596	NA

Pycnonotus erythropthalmos		2486125	32	0.005470085	9	0.019522777	0.014052691	NA
Ciconia stormi		2481917	9	0.001538462	7	0.015184382	0.01364592	Endangered
Rhyticeros undulatus		2475916	10	0.001709402	7	0.015184382	0.01347498	NA
Haliaeetus leucogaster		2480455	12	0.002051282	7	0.015184382	0.0131331	NA
Arborophila charltonii		2473622	0	0	6	0.013015184	0.013015184	NA
Mycteria cinerea		2481935	0	0	6	0.013015184	0.013015184	Endangered
Copsychus stricklandii		2492678	0	0	6	0.013015184	0.013015184	NA
Pycnonotus atriceps		2486134	39	0.006666667	9	0.019522777	0.01285611	NA
Pernis ptilorhynchus		5793241	14	0.002393162	7	0.015184382	0.012791219	NA
Argusianus argus		5227762	16	0.002735043	7	0.015184382	0.012449339	NA
Loriculus galgulus		2479372	29	0.004957265	8	0.017353579	0.012396314	NA
Egretta intermedia		2480880	29	0.004957265	8	0.017353579	0.012396314	NA
Malacopteron affine		2493506	17	0.002905983	7	0.015184382	0.012278399	NA
Berenicornis comatus		2476030	5	0.000854701	6	0.013015184	0.012160484	Endangered
Gerygone sulphurea		2486554	5	0.000854701	6	0.013015184	0.012160484	NA
Orthotomus atrogularis		2493033	19	0.003247863	7	0.015184382	0.011936519	NA
Strix leptogrammica		2497546	7	0.001196581	6	0.013015184	0.011818603	NA
Pitta sordida		2489527	10	0.001709402	6	0.013015184	0.011305783	NA
Hemipus hirundinaceus		2486749	23	0.003931624	7	0.015184382	0.011252758	NA
Chalcoparia singalensis		7341060	23	0.003931624	7	0.015184382	0.011252758	NA
Anorrhinus galeritus		2475930	11	0.001880342	6	0.013015184	0.011134843	NA
Niltava rufigastra		9062544	0	0	5	0.010845987	0.010845987	NA
Zanclostomus curvirostris		2496397	13	0.002222222	6	0.013015184	0.010792962	NA
Microhierax latifrons		2481077	2	0.00034188	5	0.010845987	0.010504107	NA
Cyanoderma erythropterum		7951961	28	0.004786325	7	0.015184382	0.010398057	NA
Icthyophaga ichthyaetus		6066180	3	0.000512821	5	0.010845987	0.010333166	NA
Corvus splendens		2482499	29	0.004957265	7	0.015184382	0.010227117	NA
Nisaetus nanus		5788505	5	0.000854701	5	0.010845987	0.009991286	NA
Nycticorax nycticorax		2480863	6	0.001025641	5	0.010845987	0.009820346	NA
Tricholestes criniger		5230303	19	0.003247863	6	0.013015184	0.009767321	NA

Philentoma pyrhoptera		7340865	19	0.003247863	6	0.013015184	0.009767321	NA
Lophotriorchis kienerii		5788511	7	0.001196581	5	0.010845987	0.009649406	NA
Arachnothera hypogrammicum		7384180	21	0.003589744	6	0.013015184	0.009425441	NA
Anthus rufulus		2490277	22	0.003760684	6	0.013015184	0.009254501	NA
Dicaeum trigonostigma		2484724	35	0.005982906	7	0.015184382	0.009201476	NA
Pycnonotus eutilotus		2486142	10	0.001709402	5	0.010845987	0.009136585	NA
Aceros corrugatus		5228455	10	0.001709402	5	0.010845987	0.009136585	NA
Pellorneum rostratum		7891543	10	0.001709402	5	0.010845987	0.009136585	NA
Hypothymis azurea		2486625	25	0.004273504	6	0.013015184	0.00874168	NA
Nisaetus alboniger		5788510	0	0	4	0.00867679	0.00867679	NA
Chrysocolaptes lucidus		2478040	1	0.00017094	4	0.00867679	0.008505849	NA
Pericrocotus speciosus		6101031	14	0.002393162	5	0.010845987	0.008452825	NA
Collocalia esculenta		2477292	2	0.00034188	4	0.00867679	0.008334909	NA
Aviceda jerdoni		2480708	2	0.00034188	4	0.00867679	0.008334909	NA
Arachnothera robusta		2484656	2	0.00034188	4	0.00867679	0.008334909	NA
Streptopelia tranquebarica		2495691	2	0.00034188	4	0.00867679	0.008334909	NA
Apus nipalensis		5228679	15	0.002564103	5	0.010845987	0.008281884	NA
Aerodramus maximus		2477215	3	0.000512821	4	0.00867679	0.008163969	NA
Chlidonias hybrida		2481121	3	0.000512821	4	0.00867679	0.008163969	NA
Numenius arquata		2481792	3	0.000512821	4	0.00867679	0.008163969	NA
Ictinaetus malayensis		5229198	3	0.000512821	4	0.00867679	0.008163969	NA
Meiglyptes tukki		2478057	16	0.002735043	5	0.010845987	0.008110944	NA
Pycnonotus simplex		2486137	30	0.005128205	6	0.013015184	0.007886979	NA
Tyto alba		2497921	5	0.000854701	4	0.00867679	0.007822089	NA
Icthyophaga humilis		6066181	5	0.000854701	4	0.00867679	0.007822089	NA
Anthreptes simplex		2484635	18	0.003076923	5	0.010845987	0.007769064	NA
Irena puella		2488929	32	0.005470085	6	0.013015184	0.007545099	NA
Tringa nebularia		2481726	7	0.001196581	4	0.00867679	0.007480208	NA
Ixobrychus sinensis		2480848	8	0.001367521	4	0.00867679	0.007309268	NA
Strix seloputo		2497492	8	0.001367521	4	0.00867679	0.007309268	NA

Picus mentalis		2478499	21	0.003589744	5	0.010845987	0.007256243	NA
Malacopteron magnirostre		2493508	21	0.003589744	5	0.010845987	0.007256243	NA
Arachnothera chrysogenys		2484658	9	0.001538462	4	0.00867679	0.007138328	NA
Celeus brachyurus		5228923	22	0.003760684	5	0.010845987	0.007085303	NA
Pitta granatina		2489550	10	0.001709402	4	0.00867679	0.006967388	NA
Merops philippinus		2475452	49	0.008376068	7	0.015184382	0.006808313	NA
Accipiter trivirgatus		2480603	12	0.002051282	4	0.00867679	0.006625508	NA
Cuculus fugax		5231897	0	0	3	0.006507592	0.006507592	NA
Cuculus vagans		5231926	0	0	3	0.006507592	0.006507592	NA
Sterna hirundo		9367409	0	0	3	0.006507592	0.006507592	NA
Coracias benghalensis		2475379	1	0.00017094	3	0.006507592	0.006336652	NA
Gracula religiosa		2488999	1	0.00017094	3	0.006507592	0.006336652	NA
Surniculus lugubris		2496506	14	0.002393162	4	0.00867679	0.006283627	NA
Aerodramus salangana		2477220	2	0.00034188	3	0.006507592	0.006165712	NA
Clamator coromandus		2496467	2	0.00034188	3	0.006507592	0.006165712	NA
Pycnonotus cyaniventris		2486152	15	0.002564103	4	0.00867679	0.006112687	NA
Arachnothera affinis		2484652	3	0.000512821	3	0.006507592	0.005994772	NA
Acridotheres cristatellus		2489010	3	0.000512821	3	0.006507592	0.005994772	NA
Alophoixus phaeocephalus		2486196	16	0.002735043	4	0.00867679	0.005941747	NA
Kenopia striata		2492940	4	0.000683761	3	0.006507592	0.005823832	NA
Napothera macrodactyla		5231406	4	0.000683761	3	0.006507592	0.005823832	NA
Aviceda leuphotes		2480706	5	0.000854701	3	0.006507592	0.005652891	NA
Chlidonias leucopterus		2481120	5	0.000854701	3	0.006507592	0.005652891	NA
Philentoma velata		7340857	5	0.000854701	3	0.006507592	0.005652891	NA
Lalage fimbriata		8230793	5	0.000854701	3	0.006507592	0.005652891	NA
Pericrocotus divaricatus		2486818	6	0.001025641	3	0.006507592	0.005481951	NA
Dendrocygna arcuata		2498398	7	0.001196581	3	0.006507592	0.005311011	NA
Rhipidura perlata		5231725	7	0.001196581	3	0.006507592	0.005311011	NA
Turdinus abbotti		7537333	7	0.001196581	3	0.006507592	0.005311011	NA
Ardeola bacchus		2480907	8	0.001367521	3	0.006507592	0.005140071	NA

Pycnonotus melanoleucos		2486133	8	0.001367521	3	0.006507592	0.005140071	NA
Enicurus leschenaulti		2492629	8	0.001367521	3	0.006507592	0.005140071	NA
Halcyon coromanda		5228311	8	0.001367521	3	0.006507592	0.005140071	NA
Hemiprocne longipennis		2477451	21	0.003589744	4	0.00867679	0.005087046	NA
Cyornis turcosus		2492436	9	0.001538462	3	0.006507592	0.004969131	NA
Sitta frontalis		9610931	9	0.001538462	3	0.006507592	0.004969131	NA
Actenoides concretus		2475663	10	0.001709402	3	0.006507592	0.00479819	NA
Accipiter gularis		2480583	11	0.001880342	3	0.006507592	0.00462725	NA
Malacopteron magnum		2493507	11	0.001880342	3	0.006507592	0.00462725	NA
Lalage nigra		5230456	11	0.001880342	3	0.006507592	0.00462725	NA
Pastor roseus		5845386	0	0	2	0.004338395	0.004338395	NA
Ardea modesta		6066379	0	0	2	0.004338395	0.004338395	NA
Megalaima australis		2478718	39	0.006666667	5	0.010845987	0.00417932	NA
Pycnonotus zeylanicus		2486118	1	0.00017094	2	0.004338395	0.004167455	Critically Endangered
Caprimulgus affinis		2496952	1	0.00017094	2	0.004338395	0.004167455	NA
Porphyrio indicus		7721976	1	0.00017094	2	0.004338395	0.004167455	NA
Megalaima mystacophanos		2478731	14	0.002393162	3	0.006507592	0.00411443	NA
Caprimulgus macrurus		2496890	14	0.002393162	3	0.006507592	0.00411443	NA
Mixornis gularis		7772947	14	0.002393162	3	0.006507592	0.00411443	NA
Rhinoplax vigil		2475951	2	0.00034188	2	0.004338395	0.003996514	Critically Endangered
Numenius phaeopus		2481784	2	0.00034188	2	0.004338395	0.003996514	NA
Sternula albifrons		5789279	2	0.00034188	2	0.004338395	0.003996514	NA
Parus cinereus		6101070	2	0.00034188	2	0.004338395	0.003996514	NA
Ixos malaccensis		2486081	15	0.002564103	3	0.006507592	0.00394349	NA
Pycnonotus finlaysoni		2486127	15	0.002564103	3	0.006507592	0.00394349	NA
Tringa glareola		2481713	41	0.007008547	5	0.010845987	0.00383744	NA
Ardeola speciosa		2480904	3	0.000512821	2	0.004338395	0.003825574	NA
Phylloscopus borealis		2493071	3	0.000512821	2	0.004338395	0.003825574	NA
Carpococcyx radiceus		2496388	3	0.000512821	2	0.004338395	0.003825574	NA
Megalurus palustris		5231392	3	0.000512821	2	0.004338395	0.003825574	NA

Blythipicus rubiginosus		2478225	16	0.002735043	3	0.006507592	0.003772549	NA
Copsychus saularis		2492680	16	0.002735043	3	0.006507592	0.003772549	NA
Stachyris maculata		2493415	16	0.002735043	3	0.006507592	0.003772549	NA
Platysmurus leucopterus		2482536	29	0.004957265	4	0.00867679	0.003719525	NA
Alcedo euryzona		2475500	4	0.000683761	2	0.004338395	0.003654634	Critically Endangered
Ketupa ketupu		5232234	4	0.000683761	2	0.004338395	0.003654634	NA
Otus rufescens		5232308	4	0.000683761	2	0.004338395	0.003654634	NA
Hemicircus concretus		2478593	17	0.002905983	3	0.006507592	0.003601609	NA
Chloropsis cyanopogon		5230729	17	0.002905983	3	0.006507592	0.003601609	NA
Harpactes duvaucelii		5232068	30	0.005128205	4	0.00867679	0.003548584	NA
Trichastoma bicolor		2493244	5	0.000854701	2	0.004338395	0.003483694	NA
Lophura ignita		5227961	5	0.000854701	2	0.004338395	0.003483694	NA
Dicaeum cruentatum		2484710	18	0.003076923	3	0.006507592	0.003430669	NA
Falco peregrinus		2481047	6	0.001025641	2	0.004338395	0.003312754	NA
Treron fulvicollis		2495740	6	0.001025641	2	0.004338395	0.003312754	NA
Cacomantis sonneratii		2496280	6	0.001025641	2	0.004338395	0.003312754	NA
Leptocoma calcostetha		6088419	6	0.001025641	2	0.004338395	0.003312754	NA
Enicurus ruficapillus		2492631	7	0.001196581	2	0.004338395	0.003141814	NA
Treron capellei		2495803	7	0.001196581	2	0.004338395	0.003141814	NA
Phodilus badius		2497972	7	0.001196581	2	0.004338395	0.003141814	NA
Circus spilonotus		5229180	7	0.001196581	2	0.004338395	0.003141814	NA
Bubo sumatranus		5959152	7	0.001196581	2	0.004338395	0.003141814	NA
Pellorneum malaccense		7608728	7	0.001196581	2	0.004338395	0.003141814	NA
Pellorneum bicolor		7885735	7	0.001196581	2	0.004338395	0.003141814	NA
Criniger phaeocephalus		9001965	7	0.001196581	2	0.004338395	0.003141814	NA
Orthotomus sutorius		2493028	20	0.003418803	3	0.006507592	0.003088789	NA
Gallicrex cinerea		2474404	8	0.001367521	2	0.004338395	0.002970873	NA
Corydon sumatranus		5229948	8	0.001367521	2	0.004338395	0.002970873	NA
Tephrodornis virgatus		5845038	8	0.001367521	2	0.004338395	0.002970873	NA
Megalaima chrysopogon		2478700	21	0.003589744	3	0.006507592	0.002917849	NA

Microhierax fringillarius		2481076	21	0.003589744	3	0.006507592	0.002917849	NA
Culicicapa ceylonensis		2492634	9	0.001538462	2	0.004338395	0.002799933	NA
Gallinula chloropus		5228199	9	0.001538462	2	0.004338395	0.002799933	NA
Eumyias thalassinus		7341536	9	0.001538462	2	0.004338395	0.002799933	NA
Dicrurus aeneus		2493971	10	0.001709402	2	0.004338395	0.002628993	NA
Arachnothera flavigaster		2484650	11	0.001880342	2	0.004338395	0.002458053	NA
Eudynamys scolopaceus		2496347	11	0.001880342	2	0.004338395	0.002458053	NA
Iole crypta		9577865	24	0.004102564	3	0.006507592	0.002405028	NA
Copsychus malabaricus		2492675	12	0.002051282	2	0.004338395	0.002287113	NA
Stachyris poliocephala		2493417	12	0.002051282	2	0.004338395	0.002287113	NA
Vanellus indicus		5229131	12	0.002051282	2	0.004338395	0.002287113	NA
Rhaphidura leucopygialis		5228605	25	0.004273504	3	0.006507592	0.002234088	NA
Arborophila campbelli		2473647	0	0	1	0.002169197	0.002169197	NA
Anthracoceros coronatus		2475988	0	0	1	0.002169197	0.002169197	NA
Threskiornis melanocephalus		2480767	0	0	1	0.002169197	0.002169197	NA
Dupetor flavicollis		2480871	0	0	1	0.002169197	0.002169197	NA
Arachnothera everetti		2484654	0	0	1	0.002169197	0.002169197	NA
Monticola solitarius		2490955	0	0	1	0.002169197	0.002169197	NA
Muscicapa ferruginea		2492579	0	0	1	0.002169197	0.002169197	NA
Niltava sumatrana		2492651	0	0	1	0.002169197	0.002169197	NA
Macropygia unchall		2496157	0	0	1	0.002169197	0.002169197	NA
Upupa epops		2498415	0	0	1	0.002169197	0.002169197	NA
Napothera atrigularis		5231405	0	0	1	0.002169197	0.002169197	NA
Caloenas nicobarica		5231891	0	0	1	0.002169197	0.002169197	NA
Turdinus atrigularis		5789030	0	0	1	0.002169197	0.002169197	NA
Bubulcus coromandus		6066393	0	0	1	0.002169197	0.002169197	NA
Actinodura strigula		8372464	0	0	1	0.002169197	0.002169197	NA
Coracina striata		2486751	13	0.002222222	2	0.004338395	0.002116173	NA
Pericrocotus igneus		2486814	13	0.002222222	2	0.004338395	0.002116173	NA
Motacilla cinerea		2490310	13	0.002222222	2	0.004338395	0.002116173	NA

Rhopodytes diardi		2496381	13	0.002222222	2	0.004338395	0.002116173	NA
Buceros bicornis		2476012	1	0.00017094	1	0.002169197	0.001998257	NA
Pluvialis squatarola		2480327	1	0.00017094	1	0.002169197	0.001998257	NA
Tachybaptus ruficollis		2482048	1	0.00017094	1	0.002169197	0.001998257	NA
Arachnothera crassirostris		2484651	1	0.00017094	1	0.002169197	0.001998257	NA
Pycnonotus squamatus		2486124	1	0.00017094	1	0.002169197	0.001998257	NA
Alophoixus bres		2486198	1	0.00017094	1	0.002169197	0.001998257	NA
Acridotheres grandis		2489008	1	0.00017094	1	0.002169197	0.001998257	NA
Treron bicinctus		2495776	1	0.00017094	1	0.002169197	0.001998257	NA
Macropygia ruficeps		2496161	1	0.00017094	1	0.002169197	0.001998257	NA
Ficedula narcissina		5231288	1	0.00017094	1	0.002169197	0.001998257	NA
Leptocoma sperata		7340838	1	0.00017094	1	0.002169197	0.001998257	NA
Trichastoma malaccense		8861015	1	0.00017094	1	0.002169197	0.001998257	NA
Zapornia fusca		9343558	1	0.00017094	1	0.002169197	0.001998257	NA
Phylloscopus trivirgatus		9769734	1	0.00017094	1	0.002169197	0.001998257	NA
Turnix suscitator		2474982	14	0.002393162	2	0.004338395	0.001945232	NA
Sasia abnormis		2478207	14	0.002393162	2	0.004338395	0.001945232	NA
Dryocopus javensis		5228839	14	0.002393162	2	0.004338395	0.001945232	NA
Arachnothera magna		2484659	2	0.00034188	1	0.002169197	0.001827317	NA
Zosterops palpebrosus		2489362	2	0.00034188	1	0.002169197	0.001827317	NA
Trichastoma rostratum		2493245	2	0.00034188	1	0.002169197	0.001827317	NA
Locustella certhiola		2493556	2	0.00034188	1	0.002169197	0.001827317	NA
Batrachostomus javensis		2497137	2	0.00034188	1	0.002169197	0.001827317	NA
Sterna nilotica		5229240	2	0.00034188	1	0.002169197	0.001827317	NA
Chloropsis sonnerati		5230730	2	0.00034188	1	0.002169197	0.001827317	NA
Thalasseus bergii		5789283	2	0.00034188	1	0.002169197	0.001827317	NA
Terpsiphone affinis		7790821	2	0.00034188	1	0.002169197	0.001827317	NA
Platylophus galericulatus		5229486	15	0.002564103	2	0.004338395	0.001774292	NA
Butastur indicus		2480477	3	0.000512821	1	0.002169197	0.001656377	NA
Glareola maldivarum		2480759	3	0.000512821	1	0.002169197	0.001656377	NA

Hemipus picatus		2486748	3	0.000512821	1	0.002169197	0.001656377	NA
Muscicapa sibirica		2492566	3	0.000512821	1	0.002169197	0.001656377	NA
Apus pacificus		5228670	3	0.000512821	1	0.002169197	0.001656377	NA
Anthreptes rhodolaemus		5788731	3	0.000512821	1	0.002169197	0.001656377	NA
Aethopyga temminckii		6086743	3	0.000512821	1	0.002169197	0.001656377	NA
Cecropis badia		6094981	3	0.000512821	1	0.002169197	0.001656377	NA
Turdinus sepiarius		8416814	3	0.000512821	1	0.002169197	0.001656377	NA
Amaurornis cinerea		9280197	3	0.000512821	1	0.002169197	0.001656377	NA
Nyctyornis amictus		2475461	16	0.002735043	2	0.004338395	0.001603352	NA
Caloramphus hayii		8855774	16	0.002735043	2	0.004338395	0.001603352	NA
Polyplectron malacense		2474087	4	0.000683761	1	0.002169197	0.001485437	NA
Egretta sacra		2480899	4	0.000683761	1	0.002169197	0.001485437	NA
Cyornis tickelliae		2492428	4	0.000683761	1	0.002169197	0.001485437	NA
Prinia familiaris		2492756	4	0.000683761	1	0.002169197	0.001485437	NA
Eupetes macrocerus		2495050	4	0.000683761	1	0.002169197	0.001485437	NA
Batrachostomus stellatus		2497147	4	0.000683761	1	0.002169197	0.001485437	NA
Psilopogon chrysopsis		7719043	4	0.000683761	1	0.002169197	0.001485437	NA
Halcyon concreta		8891414	4	0.000683761	1	0.002169197	0.001485437	NA
Meiglyptes tristis		2478064	17	0.002905983	2	0.004338395	0.001432412	Endangered
Muscicapa dauurica		9472137	17	0.002905983	2	0.004338395	0.001432412	NA
Chrysococcyx xanthorhynchus		2496321	5	0.000854701	1	0.002169197	0.001314497	NA
Pycnonotus flaviventris		7340244	5	0.000854701	1	0.002169197	0.001314497	NA
Picus miniaceus		2478512	18	0.003076923	2	0.004338395	0.001261472	NA
Psittinus cyanurus		2479524	18	0.003076923	2	0.004338395	0.001261472	NA
Harpactes diardii		5232061	18	0.003076923	2	0.004338395	0.001261472	NA
Picus vittatus		2478502	6	0.001025641	1	0.002169197	0.001143556	NA
Macheiramphus alcinus		2480379	6	0.001025641	1	0.002169197	0.001143556	NA
Ardea sumatrana		2480924	6	0.001025641	1	0.002169197	0.001143556	NA
Iole olivacea		5230290	6	0.001025641	1	0.002169197	0.001143556	NA
Otus bakkamoena		5232251	6	0.001025641	1	0.002169197	0.001143556	NA

Trichixos pyrropygus		5788884	6	0.001025641	1	0.002169197	0.001143556	NA
Lonchura striata		2493618	19	0.003247863	2	0.004338395	0.001090532	NA
Ploceus philippinus		2494056	19	0.003247863	2	0.004338395	0.001090532	NA
Cuculus micropterus		5231904	19	0.003247863	2	0.004338395	0.001090532	NA
Gallirallus striatus		2474525	7	0.001196581	1	0.002169197	0.000972616	NA
Prinia rufescens		2492760	7	0.001196581	1	0.002169197	0.000972616	NA
Malacocincla malaccensis		2493400	7	0.001196581	1	0.002169197	0.000972616	NA
Dinopium rafflesii		5228810	7	0.001196581	1	0.002169197	0.000972616	NA
Mulleripicus pulverulentus		2478328	8	0.001367521	1	0.002169197	0.000801676	NA
Caloramphus fuliginosus		2478987	8	0.001367521	1	0.002169197	0.000801676	NA
Ducula badia		2495993	8	0.001367521	1	0.002169197	0.000801676	NA
Prionochilus xanthopygius		5229961	8	0.001367521	1	0.002169197	0.000801676	NA
Arachnothera modesta		7340385	8	0.001367521	1	0.002169197	0.000801676	NA
Calidris subminuta		2481750	21	0.003589744	2	0.004338395	0.000748651	NA
Cypsiurus balasiensis		2477102	9	0.001538462	1	0.002169197	0.000630736	NA
Pomatorhinus montanus		2493335	9	0.001538462	1	0.002169197	0.000630736	NA
Cecropis daurica		9717283	9	0.001538462	1	0.002169197	0.000630736	NA
Hirundapus giganteus		2477127	10	0.001709402	1	0.002169197	0.000459796	NA
Zosterops everetti		2489395	10	0.001709402	1	0.002169197	0.000459796	NA
Rhopodytes sumatranus		2496377	10	0.001709402	1	0.002169197	0.000459796	NA
Hypogramma hypogrammicum		5229965	10	0.001709402	1	0.002169197	0.000459796	NA
Eurylaimus javanicus		9574405	23	0.003931624	2	0.004338395	0.000406771	NA
Harpactes kasumba		5232070	11	0.001880342	1	0.002169197	0.000288856	NA
Macronus ptilosus		6100830	24	0.004102564	2	0.004338395	0.000235831	NA
Terpsiphone paradisi		2486687	12	0.002051282	1	0.002169197	0.000117915	NA
Lonchura maja		2493599	12	0.002051282	1	0.002169197	0.000117915	NA
Hemixos flavala		2486188	13	0.002222222	1	0.002169197	-5.30248E-05	NA
Ninox scutulata		2497840	13	0.002222222	1	0.002169197	-5.30248E-05	NA
Arborophila javanica		2473642	1	0.00017094	0	0	-0.00017094	NA
Heliopais personatus		2474351	1	0.00017094	0	0	-0.00017094	Endangered

Blythipicus pyrrhotis		2478226	1	0.00017094	0	0	-0.00017094	NA
Picus flavinucha		2478531	1	0.00017094	0	0	-0.00017094	NA
Megalaima lineata		2478658	1	0.00017094	0	0	-0.00017094	NA
Megalaima haemacephala		2478661	1	0.00017094	0	0	-0.00017094	NA
Megalaima armillaris		2478682	1	0.00017094	0	0	-0.00017094	NA
Trichoglossus haematodus		2479686	1	0.00017094	0	0	-0.00017094	NA
Fregata minor		2480187	1	0.00017094	0	0	-0.00017094	NA
Charadrius alexandrinus		2480311	1	0.00017094	0	0	-0.00017094	NA
Henicopernis longicauda		2480464	1	0.00017094	0	0	-0.00017094	NA
Accipiter virgatus		2480595	1	0.00017094	0	0	-0.00017094	NA
Stiltia isabella		2480749	1	0.00017094	0	0	-0.00017094	NA
Plegadis falcinellus		2480773	1	0.00017094	0	0	-0.00017094	NA
Ixobrychus eurhythmus		2480847	1	0.00017094	0	0	-0.00017094	NA
Nycticorax caledonicus		2480857	1	0.00017094	0	0	-0.00017094	NA
Ardeola grayii		2480905	1	0.00017094	0	0	-0.00017094	NA
Falco moluccensis		2481001	1	0.00017094	0	0	-0.00017094	NA
Limnodromus semipalmatus		2481671	1	0.00017094	0	0	-0.00017094	NA
Limosa lapponica		2481681	1	0.00017094	0	0	-0.00017094	NA
Limosa limosa		2481685	1	0.00017094	0	0	-0.00017094	NA
Tringa ochropus		2481728	1	0.00017094	0	0	-0.00017094	NA
Calidris minuta		2481749	1	0.00017094	0	0	-0.00017094	NA
Arenaria interpres		2481776	1	0.00017094	0	0	-0.00017094	NA
Gallinago megala		2481815	1	0.00017094	0	0	-0.00017094	NA
Phalacrocorax sulcirostris		2481895	1	0.00017094	0	0	-0.00017094	NA
Tachybaptus novaehollandiae		2482043	1	0.00017094	0	0	-0.00017094	NA
Aethopyga saturata		2484682	1	0.00017094	0	0	-0.00017094	NA
Dicaeum trochileum		2484699	1	0.00017094	0	0	-0.00017094	NA
Pycnonotus jocosus		2486151	1	0.00017094	0	0	-0.00017094	NA
Alophoixus ochraceus		2486195	1	0.00017094	0	0	-0.00017094	NA
Terpsiphone cinnamomea		2486685	1	0.00017094	0	0	-0.00017094	NA

Philemon moluccensis		2487091	1	0.00017094	0	0	-0.00017094	NA
Lichmera lombokia		2487353	1	0.00017094	0	0	-0.00017094	NA
Aplonis minor		2489035	1	0.00017094	0	0	-0.00017094	NA
Anthus cervinus		2490283	1	0.00017094	0	0	-0.00017094	NA
Cyornis unicolor		2492429	1	0.00017094	0	0	-0.00017094	NA
Cyornis superbus		2492442	1	0.00017094	0	0	-0.00017094	NA
Saxicola caprata		2492519	1	0.00017094	0	0	-0.00017094	NA
Cisticola exilis		2492836	1	0.00017094	0	0	-0.00017094	NA
Ptilocichla leucogrammica		2492897	1	0.00017094	0	0	-0.00017094	NA
Pteruthius melanotis		2492994	1	0.00017094	0	0	-0.00017094	NA
Phylloscopus inornatus		2493095	1	0.00017094	0	0	-0.00017094	NA
Yuhina everetti		2493179	1	0.00017094	0	0	-0.00017094	NA
Malacocincla abbotti		2493399	1	0.00017094	0	0	-0.00017094	NA
Lonchura molucca		2493600	1	0.00017094	0	0	-0.00017094	NA
Dicrurus remifer		2493977	1	0.00017094	0	0	-0.00017094	NA
Gallicolumba rufigula		2495243	1	0.00017094	0	0	-0.00017094	NA
Geopelia placida		2495495	1	0.00017094	0	0	-0.00017094	NA
Treron griseicauda		2495765	1	0.00017094	0	0	-0.00017094	NA
Treron oxyurus		2495818	1	0.00017094	0	0	-0.00017094	NA
Henicophaps albifrons		2495831	1	0.00017094	0	0	-0.00017094	NA
Chrysococcyx basalis		2496314	1	0.00017094	0	0	-0.00017094	NA
Ninox rufa		2497792	1	0.00017094	0	0	-0.00017094	NA
Anas clypeata		2498089	1	0.00017094	0	0	-0.00017094	NA
Anas acuta		2498112	1	0.00017094	0	0	-0.00017094	NA
Nettapus pulchellus		2498309	1	0.00017094	0	0	-0.00017094	NA
Lonchura oryzivora		4845776	1	0.00017094	0	0	-0.00017094	Endangered
Lophura erythrophthalma		5228002	1	0.00017094	0	0	-0.00017094	NA
Halcyon cyanoventris		5228327	1	0.00017094	0	0	-0.00017094	NA
Ceyx lepidus		5228396	1	0.00017094	0	0	-0.00017094	NA
Psilopogon pyrolophus		5229003	1	0.00017094	0	0	-0.00017094	NA

Sterna sumatrana		5229214	1	0.00017094	0	0	-0.00017094	NA
Chloropsis cochinchinensis		5230732	1	0.00017094	0	0	-0.00017094	NA
Acrocephalus bistrigiceps		5231332	1	0.00017094	0	0	-0.00017094	NA
Alcippe peracensis		5231376	1	0.00017094	0	0	-0.00017094	NA
Napothera epilepidota		5231400	1	0.00017094	0	0	-0.00017094	NA
Erythrura prasina		5231416	1	0.00017094	0	0	-0.00017094	NA
Cuculus optatus		5231898	1	0.00017094	0	0	-0.00017094	NA
Centropus menbeki		5231996	1	0.00017094	0	0	-0.00017094	NA
Otus sagittatus		5232350	1	0.00017094	0	0	-0.00017094	NA
Nisaetus cirrhatus		5788501	1	0.00017094	0	0	-0.00017094	NA
Accipiter hiogaster		5788526	1	0.00017094	0	0	-0.00017094	NA
Acrocephalus tangorum		5789158	1	0.00017094	0	0	-0.00017094	NA
Microcarbo melanoleucos		6066513	1	0.00017094	0	0	-0.00017094	NA
Geokichla citrina		6100882	1	0.00017094	0	0	-0.00017094	NA
Geokichla sibirica		6100888	1	0.00017094	0	0	-0.00017094	NA
Hydrornis caeruleus		6101088	1	0.00017094	0	0	-0.00017094	NA
Caprimulgus jotaka		6101184	1	0.00017094	0	0	-0.00017094	NA
Stachyridopsis rufifrons		7340311	1	0.00017094	0	0	-0.00017094	NA
Synoicus chinensis		8082581	1	0.00017094	0	0	-0.00017094	NA
Anas crecca		8214667	1	0.00017094	0	0	-0.00017094	NA
Cyanoderma chrysaeum		8324497	1	0.00017094	0	0	-0.00017094	NA
Chrysocolaptes validus		8767545	1	0.00017094	0	0	-0.00017094	NA
Anthracoceros malabaricus		8785534	1	0.00017094	0	0	-0.00017094	NA
Niltava banyumas		8838138	1	0.00017094	0	0	-0.00017094	NA
Dryobates analis		8913822	1	0.00017094	0	0	-0.00017094	NA
Eurylaimus ochromelas		8915615	1	0.00017094	0	0	-0.00017094	NA
Collocalia lowi		9049159	1	0.00017094	0	0	-0.00017094	NA
Macropygia doreya		9129560	1	0.00017094	0	0	-0.00017094	NA
Pachycephala fulvotincta		9363385	1	0.00017094	0	0	-0.00017094	NA
Anthus richardi		9465111	1	0.00017094	0	0	-0.00017094	NA

Parus major		9705453	1	0.00017094	0	0	-0.00017094	NA
Charadrius mongolus		9722670	1	0.00017094	0	0	-0.00017094	NA
Zanclostomus javanicus		2496392	14	0.002393162	1	0.002169197	-0.000223965	NA
Porzana fusca		2474622	2	0.00034188	0	0	-0.00034188	NA
Merops leschenaulti		2475392	2	0.00034188	0	0	-0.00034188	NA
Alcedo coerulescens		2475531	2	0.00034188	0	0	-0.00034188	NA
Dendrocopos macei		2477911	2	0.00034188	0	0	-0.00034188	NA
Megalaima zeylanica		2478692	2	0.00034188	0	0	-0.00034188	NA
Loriculus amabilis		2479374	2	0.00034188	0	0	-0.00034188	NA
Charadrius peronii		2480306	2	0.00034188	0	0	-0.00034188	NA
Aviceda subcristata		2480707	2	0.00034188	0	0	-0.00034188	NA
Xenus cinereus		2481703	2	0.00034188	0	0	-0.00034188	NA
Calidris temminckii		2481740	2	0.00034188	0	0	-0.00034188	NA
Calidris ruficollis		2481746	2	0.00034188	0	0	-0.00034188	NA
Pityriasis gymnocephala		2482591	2	0.00034188	0	0	-0.00034188	NA
Pericrocotus flammeus		2486819	2	0.00034188	0	0	-0.00034188	NA
Cyanoptila cyanomelana		2492391	2	0.00034188	0	0	-0.00034188	NA
Enicurus velatus		2492630	2	0.00034188	0	0	-0.00034188	NA
Malacopteron albogulare		2493509	2	0.00034188	0	0	-0.00034188	NA
Lonchura leucogastra		2493597	2	0.00034188	0	0	-0.00034188	NA
Streptopelia bitorquata		2495720	2	0.00034188	0	0	-0.00034188	NA
Macropygia emiliana		2496149	2	0.00034188	0	0	-0.00034188	NA
Scythrops novaehollandiae		2496204	2	0.00034188	0	0	-0.00034188	NA
Chrysococcyx minutillus		2496334	2	0.00034188	0	0	-0.00034188	NA
Rhopodytes tristis		2496369	2	0.00034188	0	0	-0.00034188	NA
Caprimulgus concretus		2496897	2	0.00034188	0	0	-0.00034188	NA
Batrachostomus auritus		2497148	2	0.00034188	0	0	-0.00034188	NA
Anastomus oscitans		5229410	2	0.00034188	0	0	-0.00034188	NA
Prionochilus thoracicus		5229957	2	0.00034188	0	0	-0.00034188	NA
Lalage sueurii		5230465	2	0.00034188	0	0	-0.00034188	NA

Ficedula mugimaki		5231268	2	0.00034188	0	0	-0.00034188	NA
Rhipidura albicollis		5231750	2	0.00034188	0	0	-0.00034188	NA
Centropus rectunguis		5231972	2	0.00034188	0	0	-0.00034188	NA
Gracupica nigricollis		5845390	2	0.00034188	0	0	-0.00034188	NA
Phyllergates cuculatus		6100901	2	0.00034188	0	0	-0.00034188	NA
Gracupica contra		7341597	2	0.00034188	0	0	-0.00034188	NA
Cecropis striolata		7342267	2	0.00034188	0	0	-0.00034188	NA
Cyanoderma rufifrons		8182183	2	0.00034188	0	0	-0.00034188	NA
Criniger ochraceus		9165051	2	0.00034188	0	0	-0.00034188	NA
Pyrrhula nipalensis		9320930	2	0.00034188	0	0	-0.00034188	NA
Cuculus saturatus		9548093	2	0.00034188	0	0	-0.00034188	NA
Lanius tigrinus		2492868	15	0.002564103	1	0.002169197	-0.000394905	NA
Stachyris nigricollis		2493416	15	0.002564103	1	0.002169197	-0.000394905	NA
Charadrius dubius		7937336	15	0.002564103	1	0.002169197	-0.000394905	NA
Coturnix chinensis		2474128	3	0.000512821	0	0	-0.000512821	NA
Probosciger aterrimus		2479187	3	0.000512821	0	0	-0.000512821	NA
Fregata ariel		2480186	3	0.000512821	0	0	-0.000512821	NA
Tringa stagnatilis		2481719	3	0.000512821	0	0	-0.000512821	NA
Gallinago stenura		2481828	3	0.000512821	0	0	-0.000512821	NA
Mycteria leucocephala		2481938	3	0.000512821	0	0	-0.000512821	NA
Pycnonotus melanicterus		2486145	3	0.000512821	0	0	-0.000512821	NA
Setornis criniger		2486216	3	0.000512821	0	0	-0.000512821	NA
Pericrocotus cinnamomeus		2486822	3	0.000512821	0	0	-0.000512821	NA
Melanochlora sultanea		2487922	3	0.000512821	0	0	-0.000512821	NA
Pitta baudii		2489526	3	0.000512821	0	0	-0.000512821	NA
Orthotomus sepium		2493032	3	0.000512821	0	0	-0.000512821	NA
Phylloscopus coronatus		2493060	3	0.000512821	0	0	-0.000512821	NA
Abroscopus superciliaris		2493238	3	0.000512821	0	0	-0.000512821	NA
Stachyris melanothorax		2493433	3	0.000512821	0	0	-0.000512821	NA
Lonchura leucogastroides		2493622	3	0.000512821	0	0	-0.000512821	NA

Anas querquedula		2498083	3	0.000512821	0	0	-0.000512821	NA
Apus affinis		5228662	3	0.000512821	0	0	-0.000512821	NA
Indicator archipelagicus		5229002	3	0.000512821	0	0	-0.000512821	NA
Psittacula alexandri		5229045	3	0.000512821	0	0	-0.000512821	NA
Macronus flavicollis		6100831	3	0.000512821	0	0	-0.000512821	NA
Malacocincla sepiaria		7341134	3	0.000512821	0	0	-0.000512821	NA
Megalaima henricii		2478715	16	0.002735043	1	0.002169197	-0.000565845	NA
Acrocephalus orientalis		5817100	16	0.002735043	1	0.002169197	-0.000565845	NA
Malacopteron cinereum		2493505	29	0.004957265	2	0.004338395	-0.00061887	NA
Lonchura punctulata		2493598	42	0.007179487	3	0.006507592	-0.000671895	NA
Rallina fasciata		2474481	4	0.000683761	0	0	-0.000683761	NA
Todiramphus sanctus		2475802	4	0.000683761	0	0	-0.000683761	NA
Chalcopsitta sintillata		2479710	4	0.000683761	0	0	-0.000683761	NA
Charadrius leschenaultii		2480297	4	0.000683761	0	0	-0.000683761	NA
Dicaeum sanguinolentum		2484697	4	0.000683761	0	0	-0.000683761	NA
Coracina fimbriata		2486792	4	0.000683761	0	0	-0.000683761	NA
Lichmera indistincta		2487341	4	0.000683761	0	0	-0.000683761	NA
Pellorneum pyrrogenys		2493251	4	0.000683761	0	0	-0.000683761	NA
Stachyris erythroptera		2493420	4	0.000683761	0	0	-0.000683761	NA
Stachyris leucotis		2493423	4	0.000683761	0	0	-0.000683761	NA
Locustella fasciolata		2493552	4	0.000683761	0	0	-0.000683761	NA
Dicrurus annectans		2493979	4	0.000683761	0	0	-0.000683761	NA
Ficedula dumetoria		5231277	4	0.000683761	0	0	-0.000683761	NA
Saxicola maurus		5846290	4	0.000683761	0	0	-0.000683761	NA
Pachycephala cinerea		6093626	4	0.000683761	0	0	-0.000683761	NA
Macronus gularis		6100835	4	0.000683761	0	0	-0.000683761	NA
Leptocoma brasiliana		7340843	4	0.000683761	0	0	-0.000683761	NA
Dicaeum minullum		7341207	4	0.000683761	0	0	-0.000683761	NA
Turdinus macrodactylus		7341226	4	0.000683761	0	0	-0.000683761	NA
Cyornis rufigastra		7341635	4	0.000683761	0	0	-0.000683761	NA

Pluvialis fulva		2480331	17	0.002905983	1	0.002169197	-0.000736786	NA
Prionochilus maculatus		5229960	17	0.002905983	1	0.002169197	-0.000736786	NA
Erpornis zantholeuca		7341397	17	0.002905983	1	0.002169197	-0.000736786	NA
Dacelo gaudichaud		2475647	5	0.000854701	0	0	-0.000854701	NA
Megalaima javensis		2478704	5	0.000854701	0	0	-0.000854701	NA
Pitta moluccensis		2489520	5	0.000854701	0	0	-0.000854701	NA
Cyornis caerulatus		2492437	5	0.000854701	0	0	-0.000854701	NA
Rhinomyias umbratilis		2492663	5	0.000854701	0	0	-0.000854701	NA
Macropygia amboinensis		2496170	5	0.000854701	0	0	-0.000854701	NA
Dendrocygna javanica		2498404	5	0.000854701	0	0	-0.000854701	NA
Philomachus pugnax		5229387	5	0.000854701	0	0	-0.000854701	NA
Harpactes orrhophaeus		5232042	5	0.000854701	0	0	-0.000854701	NA
Hydrornis irena		6101086	5	0.000854701	0	0	-0.000854701	NA
Lacedo pulchella		2475559	18	0.003076923	1	0.002169197	-0.000907726	NA
Accipiter soloensis		2480588	6	0.001025641	0	0	-0.001025641	NA
Pandion haliaetus		2480726	6	0.001025641	0	0	-0.001025641	NA
Rostratula benghalensis		2482029	6	0.001025641	0	0	-0.001025641	NA
Dicaeum chrysorrheum		2484696	6	0.001025641	0	0	-0.001025641	NA
Luscinia cyane		2492543	6	0.001025641	0	0	-0.001025641	NA
Prinia polychroa		2492751	6	0.001025641	0	0	-0.001025641	NA
Picus puniceus		2478518	32	0.005470085	2	0.004338395	-0.001131691	NA
Calidris ferruginea		2481741	7	0.001196581	0	0	-0.001196581	NA
Coracina tenuirostris		2486768	7	0.001196581	0	0	-0.001196581	NA
Circus melanoleucos		5229171	7	0.001196581	0	0	-0.001196581	NA
Collocalia fuciphaga		5788562	7	0.001196581	0	0	-0.001196581	NA
Leptocoma sericea		7340804	7	0.001196581	0	0	-0.001196581	NA
Rhamphococcyx curvirostris		8962440	7	0.001196581	0	0	-0.001196581	NA
Lorius roratus		9022701	7	0.001196581	0	0	-0.001196581	NA
Dendronanthus indicus		2490317	8	0.001367521	0	0	-0.001367521	NA
Stachyris nigriceps		2493424	8	0.001367521	0	0	-0.001367521	NA

Merops superciliosus		2475440	9	0.001538462	0	0	-0.001538462	NA
Ptilinopus jambu		2495581	9	0.001538462	0	0	-0.001538462	NA
Prionochilus percussus		5229962	9	0.001538462	0	0	-0.001538462	NA
Himantopus himantopus		5229126	22	0.003760684	1	0.002169197	-0.001591486	NA
Ficedula zanthopygia		5231276	10	0.001709402	0	0	-0.001709402	NA
Pitta guajana		2489514	11	0.001880342	0	0	-0.001880342	NA
Dicrurus macrocercus		2493970	11	0.001880342	0	0	-0.001880342	NA
Milvus migrans		5229167	11	0.001880342	0	0	-0.001880342	NA
Alcippe brunneicauda		5231379	11	0.001880342	0	0	-0.001880342	NA
Cisticola juncidis		2492822	24	0.004102564	1	0.002169197	-0.001933367	NA
Gallinago gallinago		2481819	12	0.002051282	0	0	-0.002051282	NA
Dicrurus leucophaeus		9600020	12	0.002051282	0	0	-0.002051282	NA
Motacilla tschutschensis		2490303	25	0.004273504	1	0.002169197	-0.002104307	NA
Calyptomena viridis		2484559	13	0.002222222	0	0	-0.002222222	NA
Alophoixus finschii		2486193	13	0.002222222	0	0	-0.002222222	NA
Treron pompadora		2495745	13	0.002222222	0	0	-0.002222222	NA
Cacomantis variolosus		2496264	13	0.002222222	0	0	-0.002222222	NA
Ptilinopus melanospilus		2495630	14	0.002393162	0	0	-0.002393162	NA
Reinwardtipicus validus		2478588	15	0.002564103	0	0	-0.002564103	NA
Megalaima rafflesii		2478674	15	0.002564103	0	0	-0.002564103	NA
Aquila heliaca		2480500	15	0.002564103	0	0	-0.002564103	NA
Aquila clanga		2480509	16	0.002735043	0	0	-0.002735043	Least Concern
Hemiprocne comata		2477440	29	0.004957265	1	0.002169197	-0.002788068	Least Concern
Collocalia linchi		2477326	18	0.003076923	0	0	-0.003076923	Least Concern
Lanius schach		9273219	18	0.003076923	0	0	-0.003076923	Least Concern
Treron curvirostra		2495730	19	0.003247863	0	0	-0.003247863	Least Concern
Eurostopodus temminckii		2497099	19	0.003247863	0	0	-0.003247863	Least Concern
Agropsar sturninus		6100940	19	0.003247863	0	0	-0.003247863	Least Concern
Rollulus rouloul		2474113	20	0.003418803	0	0	-0.003418803	Least Concern
Pycnonotus aurigaster		2486121	23	0.003931624	0	0	-0.003931624	Least Concern

Vanellus cinereus		5229145	24	0.004102564	0	0	-0.004102564	Least Concern

Table H2. Output of the lizard species occurrence analysis derived from Microsoft Excel. Common names are only indicated for the three lizard species with a relative preference for RSPO plantations. "Not found" in the online IUCN Red List column indicates that the particular species was not found in the Red List. "Least Concern" species are highlighted with green. All species where searched in the online IUCN Red List. The total number of RSPO plantations to calculate Y_1 was 461. The total number of non-RSPO plantations to calculate Y_2 was 5,850.

Scientific name	**Common name**	**GBIF Specieskey**	**Count in non-RSPO plantations (*y*)**	**Fraction (Y_2) = count *y* over total non-RSPO plantations**	**Count in RSPO plantations (*x*)**	**Fraction (Y_1) = count *x* over total RSPO plantations**	**Relative preference of bird species for RSPO vs. non-RSPO plantations (Y_1-Y_2)**	**Red List**
Gongylosoma baliodeirus	Orange-bellied Snake	2452539	0	0	1	0.0021692	0.0021692	Least Concern
Dasia vittata	Borneo skink/striped tree skink	5225125	0	0	1	0.0021692	0.0021692	Least Concern
Naja sumatrana	Equatorial spitting cobra/black spitting cobra	7992764	0	0	1	0.0021692	0.0021692	Least Concern
Gekko smithii		2447316	1	0.0001709	0	0	-0.0001709	Least Concern
Pareas margaritophorus		2453034	1	0.0001709	0	0	-0.0001709	Least Concern
Rabdion forsteni		2455813	1	0.0001709	0	0	-0.0001709	Not found
Boiga drapiezii		2457975	1	0.0001709	0	0	-0.0001709	Least Concern
Emoia atrocostata		2463327	1	0.0001709	0	0	-0.0001709	Not found
Python breitensteini		2465353	1	0.0001709	0	0	-0.0001709	Least Concern
Bronchocela cristatella		2466852	1	0.0001709	0	0	-0.0001709	Not found
Varanus salvator		2470685	1	0.0001709	0	0	-0.0001709	Least Concern
Varanus salvadorii		2470727	1	0.0001709	0	0	-0.0001709	Least Concern
Oligodon octolineatus		5222587	1	0.0001709	0	0	-0.0001709	Least Concern
Ptyas fusca		5224058	1	0.0001709	0	0	-0.0001709	Least Concern
Tropidophorus brookei		5225227	1	0.0001709	0	0	-0.0001709	Least Concern
Gonocephalus grandis		5225865	1	0.0001709	0	0	-0.0001709	Least Concern
Draco quinquefasciatus		5226126	1	0.0001709	0	0	-0.0001709	Not found
Draco palawanensis		5226182	1	0.0001709	0	0	-0.0001709	Not found

Draco lineatus		5226207	1	0.0001709	0	0	-0.0001709	Least Concern
Bungarus flaviceps		5226806	1	0.0001709	0	0	-0.0001709	Least Concern
Bungarus candidus		5226820	1	0.0001709	0	0	-0.0001709	Least Concern
Cyrtodactylus fumosus		5960125	1	0.0001709	0	0	-0.0001709	Not found
Cyrtodactylus consobrinus		5960155	1	0.0001709	0	0	-0.0001709	Not found
Cyrtodactylus malayanus		5960193	1	0.0001709	0	0	-0.0001709	Least Concern
Trimeresurus albolabris		8219807	1	0.0001709	0	0	-0.0001709	Least Concern
Natrix chrysargoides		8971818	1	0.0001709	0	0	-0.0001709	Not found
Indotyphlops ozakiae		9419322	1	0.0001709	0	0	-0.0001709	Not found
Gekko gecko		2447367	2	0.0003419	0	0	-0.0003419	Not found
Dendrelaphis formosus		2459276	2	0.0003419	0	0	-0.0003419	Least Concern
Eutropis rugifera		2460912	2	0.0003419	0	0	-0.0003419	Least Concern
Lycodon capucinus		5222820	2	0.0003419	0	0	-0.0003419	Least Concern
Draco volans		5226131	2	0.0003419	0	0	-0.0003419	Least Concern
Draco melanopogon		5226226	2	0.0003419	0	0	-0.0003419	Not found
Lygosoma quadrupes		6161138	2	0.0003419	0	0	-0.0003419	Not found
Boiga dendrophila		9792907	2	0.0003419	0	0	-0.0003419	Not found
Gehyra mutilata		2446249	3	0.0005128	0	0	-0.0005128	Not found
Eutropis rudis		2460851	3	0.0005128	0	0	-0.0005128	Not found
Cryptoblepharus balinensis		2463548	3	0.0005128	0	0	-0.0005128	Not found
Ramphotyphlops braminus		2471672	3	0.0005128	0	0	-0.0005128	Not found
Calotes versicolor		9125207	4	0.0006838	0	0	-0.0006838	Not found
Hemidactylus frenatus		9537238	4	0.0006838	0	0	-0.0006838	Least Concern
Eutropis multifasciata		2460886	6	0.0010256	0	0	-0.0010256	Least Concern
Draco sumatranus		7622553	10	0.0017094	0	0	-0.0017094	Not found

Table H3. Output of the primate species occurrence analysis derived from Microsoft Excel. The highlight colors in the Red List column indicate the status of a species in the IUCN Red List: "Least Concern", "Near Threatened", "Vulnerable", "Endangered" or "Critically Endangered" . "Not found" in the Red List column indicates that the particular species was not found in the online IUCN Red List. The total number of RSPO plantations to calculate Y1 was 461. The total number of RSPO plantations to calculate Y_1 was 461. The total number of non-RSPO plantations to calculate Y_2 was 5,850.

Scientific name	**Common name**	**GBIF Specieskey**	**Count in non-RSPO plantations (*y*)**	**Fraction (Y_2) = count *y* over total non-RSPO plantations**	**Count in RSPO plantations (*x*)**	**Fraction (Y_1) = count *x* over total RSPO plantations**	**Relative preference of bird species for RSPO vs. non-RSPO plantations (Y_1-Y_2)**	**Red List**
Nasalis larvatus	Proboscis monkey	2436525	1	0.000171	5	0.010846	0.010675	Endangered
Macaca nemestrina	Southern pig-tailed macaque	2436611	0	0	2	0.004338	0.004338	Vulnerable
Hylobates lar	Lar gibbon/white-handed gibbon	5219553	0	0	2	0.004338	0.004338	Endangered
Macaca fascicularis	Crab-eating macaque/long-tailed macaque	2436603	1	0.000171	2	0.004338	0.004167	Least Concern
Pongo pygmaeus	Bornean orangutan	5219532	3	0.000513	2	0.004338	0.003826	Critically Endangered
Trachypithecus cristatus	Silvery lutung/silvered leaf monkey/silvery langur	2436542	5	0.000855	2	0.004338	0.003484	Nearly Threatened
Nycticebus coucang	Sunda slow loris/greater slow loris	2436629	0	0	1	0.002169	0.002169	Vulnerable
Cephalopachus bancanus	Horsfield's tarsier/western tarsier	7503658	0	0	1	0.002169	0.002169	Not found
Hylobates muelleri	Müeller's gibbon/grey gibbon	5219548	1	0.000171	1	0.002169	0.001998	Endangered
Presbytis melalophos	Sumatran surili	5219561	1	0.000171	1	0.002169	0.001998	Endangered
Presbytis siamensis	White-thighed surili	7262013	2	0.000342	1	0.002169	0.001827	Nearly Threatened
Trachypithecus obscurus	Dusky leaf monkey/spectacled langur/spectacled leaf monkey	2436535	1	0.000171	0	0	-0.00017	Nearly Threatened
Symphalangus syndactylus	Siamang	4267277	1	0.000171	0	0	-0.00017	Endangered
Presbytis obscura	Spectacled langur	8812426	1	0.000171	0	0	-0.00017	Not found
Presbytis chrysomelas	Sarawak surili	7262008	2	0.000342	0	0	-0.00034	Critically Endangered
Presbytis thomasi	Thomas's langur	5219558	3	0.000513	0	0	-0.00051	Vulnerable

Table H4. Output of the small mammal species occurrence analysis derived from Microsoft Excel. Common names are only indicated for the nine small mammal species with a relative preference for RSPO plantations. The highlight colors in the Red List column indicate the status of a species in the IUCN Red List: "Least Concern", "Near Threatened", "Vulnerable" or "Endangered" . DD indicates "Data Deficient" indicated in the online IUCN Red List. The total number of RSPO plantations to calculate Y_1 was 461. The total number of non-RSPO plantations to calculate Y_2 was 5,850.

Scientific name	Common name	GBIF Specieskey	Count in non-RSPO plantations (*y*)	Fraction (Y_2) = count *y* over total non-RSPO plantations	Count in RSPO plantations (*x*)	Fraction (Y_1) = count *x* over total RSPO plantations	Relative preference of bird species for RSPO vs. non-RSPO plantations (Y_1-Y_2)	Red List
Callosciurus prevostii	Prevost's squirrel/Asian tri-colored squirrel	2437397	6	0.001026	6	0.013015	0.011989543	Least Concern
Callosciurus nigrovittatus	Black-striped squirrel	2437400	0	0	2	0.004338	0.004338395	Nearly Threatened
Sundasciurus tenuis	Slender squirrel	2437480	1	0.000171	2	0.004338	0.004167455	Least Concern
Petinomys setosus	Temminck's flying squirrel	2437253	0	0	1	0.002169	0.002169197	Vulnerable
Lariscus insignis	Three-striped ground squirrel	2437524	0	0	1	0.002169	0.002169197	Least Concern
Maxomys surifer	Red spiny rat	2438837	0	0	1	0.002169	0.002169197	Least Concern
Ratufa affinis	Cream-coloured giant squirrel/pale giant squirrel	2437564	1	0.000171	1	0.002169	0.001998257	Nearly Threatened
Sundasciurus hippurus	Horse-tailed squirrel	2437473	4	0.000684	1	0.002169	0.001485437	Nearly Threatened
Rattus annandalei	Annandale's rat	2439227	6	0.001026	1	0.002169	0.001143556	Least Concern
Tupaia longipes		2436272	1	0.000171	0	0	-0.00017094	Least Concern
Tupaia javanica		2436298	1	0.000171	0	0	-0.00017094	Least Concern
Tupaia tana		2436303	1	0.000171	0	0	-0.00017094	Least Concern
Lenothrix canus		2437947	1	0.000171	0	0	-0.00017094	Least Concern
Rattus argentiventer		2439275	1	0.000171	0	0	-0.00017094	Least Concern
Ratufa bicolor		2437566	2	0.000342	0	0	-0.00034188	Nearly Threatened
Melomys bannisteri		4264959	2	0.000342	0	0	-0.00034188	Endangered
Rattus tanezumi		2439262	3	0.000513	0	0	-0.000512821	Least Concern
Pithecheir parvus		5219810	3	0.000513	0	0	-0.000512821	DD
Tupaia glis		2436271	4	0.000684	0	0	-0.000683761	Least Concern
Callosciurus notatus		2437396	4	0.000684	0	0	-0.000683761	Least Concern

Rhinosciurus laticaudatus		5219658	4	0.000684	0	0	-0.000683761	Nearly Threatened
Rattus exulans		2439244	5	0.000855	0	0	-0.000854701	Least Concern
Suncus murinus		2435520	8	0.001368	0	0	-0.001367521	Least Concern
Rattus rattus		2439270	24	0.004103	0	0	-0.004102564	Least Concern

Appendix I – Additional information species occurrence analysis

The total number of individual species per taxa that occurred within the studied plantations is summarized in Table I. These numbers are mostly – in terms of ranking by order of size – in line with the total number of GBIF observations of Table 7 (in the Results section). The only exception for this is the number of individual lizard species, which is larger than expected according to the second smallest number of observations of Table 7.

Table I. Total number of individual species occurring per taxa and total number of GBIF observations within the studied plantations.

Taxa	Total number of individual species occurring (RSPO and non-RSPO plantations combined)	Number of observations (Results Table 7)
Birds	588	8,425
Lizards	43	79
Primates	16	42
Small mammals	24	120