Assessing the prevalence of protected species consumption by rural communities in Makira Natural Park, Madagascar, through the unmatched count technique

Charlotte Spira¹ | Rivo Raveloarison¹ | Morgane Cournarie¹ | Samantha Strindberg² | Tim O’Brien² | Michelle Wieland²

¹Wildlife Conservation Society, Maroantsetra, Madagascar
²Wildlife Conservation Society, New York

Correspondence
Charlotte Spira, Wildlife Conservation Society, Maroantsetra 512, Madagascar.
Email: csperia@wcs.org

Abstract
In tropical Africa, wild meat consumption by rural communities who live in or near protected areas can be a major challenge in the conservation of threatened species. Lemurs and the fossa are among the species consumed in Makira Natural Park, Madagascar. Because of their low reproductive rates and the high human population density, these species are known to be hunted unsustainably. We estimated the prevalence of lemur and fossa meat consumption in villages within and around Makira Natural Park using an indirect questioning method, the unmatched count technique (UCT), and compared it with results from direct questioning. The UCT revealed that 53.0% of households had eaten lemur meat over the previous year (95% confidence interval [CI]: 42.0–64.1%) and 24.2% had eaten fossa meat (95% CI: 14.2–34.2%). The percentage of households that ate lemur meat estimated through the UCT was more than 3.3 times higher than that obtained from direct questioning, and 12 times higher for fossa. Our estimates will be used to define the scale needed for a behavior change campaign to be conducted in the study area and will serve as a baseline to assess the impact of conservation activities aimed at reducing the consumption of lemurs and fossas.

Keywords
bushmeat consumption, fossa, indirect questioning, item count technique, lemur, Makira, natural park, protected species, sensitive behavior, unmatched count technique

1 | INTRODUCTION

In tropical Africa, the consumption of wild meat, or bushmeat, by rural communities who live alongside protected areas is a major issue for the conservation of protected and threatened species (Tranquilli et al., 2014). Consumer demand for bushmeat can drive species to extinction (Milner-Gulland & Bennett, 2003; Ripple et al., 2016), largely because species with higher body mass are generally the most heavily hunted, but also tend to have low reproductive rates (Tuomi, 1980) and are therefore particularly at risk of going extinct because of demand for their meat (Ripple et al., 2016; Wilkie et al., 2016). With a growing global human population,
particularly rapidly in sub-Saharan Africa (United Nations, 2019), the demand for wild meat will continue to increase to the detriment of wild species if current consumption figures do not abate (Wilkie et al., 2016).

Evidence shows that hunting of wildlife can be sustainable (a) in areas where human population density is \( \leq 1 \text{ person per km}^2 \), (b) when hunted wildlife species have high reproductive rates, and (c) when hunting is almost exclusively for consumption by the hunter's family and relatives rather than for the market (Robinson & Bennett, 2004; Wilkie et al., 2016). For example, hunting for household consumption in some parts of the Congo Basin where hunters target fast reproducing species like rodents is likely to be sustainable (Wilkie & Carpenter, 1999). However, hunting to supply large urban markets like in West Africa has been shown to severely deplete wildlife populations (e.g., Brashares et al., 2004; Covey & Scott, 2014; Cronin et al., 2015).

In addition to being a conservation issue, wildlife consumption, hunting, and trade have also been the cause of zoonotic disease outbreaks that not only affect the human health of local populations (Karesh & Noble, 2009), but can also impact people across vast regions, as experienced with Ebola (Mari Saéz et al., 2015), Covid-19 (Contini et al., 2020), and other severe acute respiratory syndrome outbreaks (Hu et al., 2017).

In Madagascar, the consumption of endangered and protected species, in particular lemurs, is widespread (Borgerson et al., 2017; Golden, 2009; Rakotondravony, 2006; Razafimanahaka et al., 2012). Lemur consumption is known to be more prevalent in households with signs of poverty, poor health, and child malnutrition (Borgerson, McKean, Sutherland, & Godfrey, 2016). Hunters have been reported to target lemurs because they like the fat, the taste and the feeling of fullness that their meat provides, or are looking to diversify their diet (Borgerson et al., 2016). However, in some rural villages the indri indri indri and the silky sifaka Propithecus candidus lemur species are regarded as spiritual beings such as reincarnated ancestors or forest spirits (Wildlife Conservation Society, unpublished data), which provides them with some level of protection from hunting from the local hunters in these areas. Other lemur species, on the contrary, are sometimes considered pests because they feed on farmers' fruit trees (e.g., western lesser bamboo lemur Hapalemur occidentalis, and local hunters actively hunt them to prevent them from feeding on harvests (Wildlife Conservation Society, unpublished data). In some villages the aye-aye Daubentonia madagascariensis is perceived as a bad omen and would be killed on sight (Randimbiharinirina, Richter, Raharivololona, Ratsimbazafy, & Schüßler, 2021); occurrences of entire villages relocating after an aye-aye entered them have been documented (Simons & Meyers, 2001). The fossa Cryptoprocta ferox, which is the largest of the six Carnivora species found in Madagascar, is also eaten (Golden, 2009), although, like lemurs, it is a protected species under Malagasy and CITES law. Both lemurs and fossas are actively hunted as sources of food, especially in areas where people lack access to, or cannot afford, alternatives to wild meat (Borgerson et al., 2016; Golden, 2009). Fossas are also killed by villagers in retaliation for attacks on livestock like poultry (Merson, Dollar, Johnson, & Macdonald, 2019).

Makira Natural Park, located in northeastern Madagascar, is one of the largest terrestrial protected areas in the country, and is home to the fossa and 17 species of lemurs, 14 of which are threatened with extinction. Past studies have revealed that in some villages along the park border up to 52% of households consumed lemur meat, albeit infrequently (Golden, 2009). Because the human population density in Makira Natural Park's buffer zone is 37 individuals per km\(^2\) and lemur species and fossa have low reproductive rates, hunting of these species is considered to be unsustainable (Golden, 2009).

As all of Madagascar’s lemur species and the fossa are protected by law, it is strictly forbidden to hunt or to eat them (Rakotoarivelohy, Razafimanahaka, Rabesihanaka, Jones, & Jenkins, 2011). In addition to being illegal, the consumption of lemur meat is also subject to local taboos called fady in Malagasy culture, that forbids it (Golden & Comaroff, 2015). Fadys can vary considerably between villages, households, families, and even individuals, due to individual experiences or changes in household composition that may lead to uptaking or discarding certain taboos (Golden & Comaroff, 2015). This makes lemur and fossa meat consumption a sensitive issue to research. It is therefore difficult to quantify the prevalence of this behavior, as people who engage in illegal or socially unacceptable practices are generally reluctant to discuss them openly for fear of being judged, or of being subjected to social, or, in more extreme cases, legal repercussions (Tourangeau & Yan, 2007). Appropriate research methods have therefore been applied to enable researchers to investigate illegal or sensitive behavior (Droitcour et al., 1991; Gavir, Solomon, & Blank, 2009). One such method is the unmatched count technique (UCT), also known as the Item Count Technique or list experiment, which estimates the proportion of a population that takes part in a given sensitive behavior without asking sensitive questions directly to survey respondents, and without knowing whether individual respondents did take part in that sensitive behavior or not (see description in Section 2; Droitcour et al., 1991). Respondents can thereby be spared the discomfort of disclosing their engagement in an illegal activity and are protected from legal repercussions associated with the activity and from the potential judgment they perceive they would receive from the enumerator, while the
researcher can obtain reliable estimates of the proportion of the sampled individuals who engages in the behavior (Hinsley, Keane, St. John, Ibbett, & Nuno, 2019). Other indirect questioning methods exist, such as the Randomized Response Technique (Warner, 1965) that has already been used in Madagascar to estimate illegal wildlife consumption around a protected area (Razafimanahaka et al., 2012). However, it is more difficult to use in areas with low literacy rates and can generate discomfort and confusion among participants (see Hinsley et al., 2019).

This study was conducted to measure the prevalence of lemur and fossa meat consumption in rural communities living within and around Makira Natural Park using the UCT. We compare estimates obtained from the UCT with those from direct questioning methods. As part of an ongoing integrated conservation and development program, the estimated prevalence of lemur and fossa meat consumption will be used to design a behavior change campaign at the appropriate scale, and repeated measures over time will enable us to assess the program’s expected impact on reducing the consumption of these species.

2 | METHODS

2.1 | Sampling effort

The data were collected between October 2019 and February 2020 by trained enumerators in 16 villages bordering Makira Natural Park and 4 villages located inside the park where an initiative aimed at reducing wild meat consumption is being implemented (Figure 1). The initiative is
being implemented in these villages because they lack sustainable animal protein consumption options, which drives people to hunt in the park (Golden, 2009; Golden, Bonds, Brashares, Rodolph Rasolofoniaina, & Kremen, 2014).

For the UCT surveys, we conducted an a priori power analysis that indicated that a sample size of 730 surveys were required if we were to perform a two-sided statistical test between before and after the initiative, that would have 85% power to detect a minimum change of 12% in the proportion of respondents who have eaten lemur or fossa meat over the past year. A total of 659 randomly selected respondents participated in the household UCT survey, out of a population of approximately 13,000 people. In the same villages, an additional 306 randomly selected respondents—out of a target of 300 respondents—participated in a simultaneous survey in which direct questions about their household’s bushmeat consumption were asked. The random selection of participants was achieved by walking through a village so that each house was passed once, to ensure all houses were equally likely to be selected. The enumerators counted houses as they passed them and stopped at each fourth house to conduct a UCT survey and ninth house to conduct a direct questioning survey. The rule for selecting houses was determined by dividing the number of households in the study area (3,266 households) by the target survey sample size (730 UCT surveys and 300 direct questioning surveys). Whenever possible, an adult woman from each survey household was asked to participate, because meals are mostly cooked by women, but if none were available then an adult man was selected. Although more men were surveyed than women (57% men \( n = 377 \) vs. 43% women \( n = 282 \)) in the UCT survey, and 59% men \( n = 180 \) vs. 41% women \( n = 126 \) in the direct questioning survey), it is unlikely to have been a source of bias because domestic or wild meat meals are usually shared by all household members as they do not occur very frequently.

### 2.2 Survey respondent consent and protection

This study was approved by the Wildlife Conservation Society’s Institutional Review Board. Before starting a survey, enumerators explained to respondents what the goal of the study was, how the survey was going to be administered, that the survey was voluntary, that the data would be kept confidential and anonymous, and how the data would be used. Survey participants were told that they could stop the survey at any point, and were asked if they consented to participate or not. The data were stored in a password-protected account of the online data management platform KoboToolbox, which only Wildlife Conservation Society staff members who had received training in social and behavioral research ethics could access.

### 2.3 Unmatched count technique

We used the UCT to investigate lemur and fossa meat consumption. The UCT is a survey method used in social science to investigate sensitive behaviors, as it ensures the confidentiality of survey responses while providing reliable estimates of the actual prevalence of sensitive behavior in the study population (Droitcour et al., 1991; Hinsley et al., 2019).

One of the challenges associated with the UCT is that large sample sizes are required (\( n = 659 \) in this study) to achieve good precision (Ulrich, Schröter, Striegel, & Simon, 2012). A key assumption of the method is that respondents provide truthful answers (Hinsley et al., 2019), which requires enumerators to take great care in explaining the technique to respondents to ensure they understand that the enumerator will not know if they have engaged in the sensitive behavior of interest or not.

### 2.4 UCT card design

For each sensitive behavior studied, namely household lemur and fossa meat consumption over the past year, two sets of cards were designed. A “control” card comprised four images that represented nonsensitive behaviors, which depicted the types of domestic meat a respondent could have eaten over the past year, and a “treatment” card that contained the same four images plus a fifth one that depicted the sensitive behavior of interest (wild meat consumption). Respondents would then be asked to pick one of the two cards at random and to answer the question “Of the following types of meat, how many have you or your household eaten in the last 12 months?”

Of the four control images, one image should represent a meat that everyone would have eaten over the past year, and one image should represent a meat that no one would have eaten, to ensure that none of the respondents would answer “none” or “all” when asked how many types of meat they have eaten last year (see details of Survey administration below), as this would obviate the UCT confidentiality premise (Droitcour et al., 1991; Glynn, 2013). For instance, if survey participants hold the treatment card, which includes the sensitive behavior, and indicate that none of the images apply to them, the enumerator...
will deduce that they did not engage in the sensitive behavior. If they say that all five pictures apply to them, the enumerator will deduce that they did engage in the sensitive behavior. Nonsensitive items should be chosen so that an average of 2 out of 4 items are selected by participants in order to minimize variance (Glynn, 2013), and the average number of times nonsensitive items were selected by the control and treatment samples should not be statistically significantly different (Imai, 2011).

The UCT card images used in this study were piloted prior to deploying the surveys, which resulted in adjustments in the choice of species to depict on the cards. The 20 pilot surveys revealed that one of the species that we initially believed not to be eaten by people in the study area, a snake species, was in fact sometimes consumed and was therefore replaced by a chameleon, which is not a food item for people in the study area.

The control cards used in this study included photographs of geese, chicken, pigs, and chameleons (lemur question) and photographs of zebus, pigs, ducks, and domestic rats (fossa question) (Figure 2). The treatment cards included the same photographs, plus a picture of lemurs and a picture of fossas for the lemur and fossa questions, respectively.

**FIGURE 2** Cards used during unmatched count technique surveys on the consumption of (a) lemurs and (b) fossas
Chameleons and domestic rats were the species that no one would have eaten over the past year, chicken and zebus were the meats that everyone would have consumed, and geese, pigs, and ducks were the meats that approximately half of the people may have eaten in a year. The order in which the animals were displayed varied between the treatment and control cards, and on the treatment cards the location of the lemur image was different from that of the fossa image to minimize the risk that subjects would see the treatment cards for both fossa and lemur deduce the identity of the treatment species.

Our objective was to estimate the proportion of the population that had consumed lemur meat in the past year, all species of lemurs combined. However, in the local language there is no term for the word “lemurs” that encompasses all species of lemurs. Each species has a unique name and the use of the term varika in the Malagasy language, which in theory means lemurs, can be interpreted differently depending on the region and the speaker. For instance, this term can be interpreted as referring to the most common lemur species in a given region, making its use inappropriate in the context of a study covering a large geographical area as it was the case here. We therefore used photographs of two lemur species to depict the consumption of lemur meat on the UCT card, and explained to participants that group referred to all lemur species. We also included several photographs to represent pigs, zebus, and fossas to avoid that only the lemur image would be depicted by several pictures and therefore be represented differently than all the other images on the UCT cards, which would have created bias.

A time period of a year was chosen because the consumption of some lemur species and fossas in the study region has been found to be highly seasonal and rare (Golden, 2009; Golden, Fernald, Brashares, Rasolofoniaina, & Kremen, 2011), for which longer recall periods are recommended (Golden, Wrangham, & Brashares, 2013).

We tested for design effects using the R list package (Blair & Imai, 2010), which indicated no design effect for either the lemur or fossa questions.

2.5 | Survey administration

The principle of the UCT “game” was first explained to respondents using a training card that consisted of a different question and set of pictures from the actual survey cards, which was intended to check whether the participants had understood how the game worked. To administer the survey, the enumerator presented both the control and treatment lemur question cards to the respondents, face down, and asked them to choose one card at random. The enumerator then turned the chosen card over to reveal the pictures and asked the respondent “Of the following types of meat, how many have you or your household eaten in the last 12 months?” and read aloud the name of each type of meat shown on the card. The respondents then said how many of the pictures on the card were types of meat their household had eaten over the past year, without showing or saying which ones. The same process was then repeated with the fossa question cards.

We chose not to include a follow-up question in the UCT survey to assess participants’ level of confidence in the confidentiality provided by the method, because the pilot surveys revealed that this question generated suspicion from participants who, once asked if they trusted that the method gave their responses full confidentiality, reported they were no longer convinced of the protection given by the survey method. Instead, we asked the enumerators to take the time to thoroughly explain to participants how the method guaranteed their response confidentiality before asking if they consented to participate in the study. This also contributed to convince respondents to answer truthfully to the survey questions, which the UCT validity depends on.

Participants of the direct questioning survey were asked how many times their household (themselves included) had eaten lemur meat over the past year, and how many times their household had eaten fossa meat. Respondents whose answers were positive numbers were then counted as having eaten lemur or fossa meat over the past year.

The survey responses were recorded on smartphones using KoboCollect offline electronic forms with data being uploaded to the online platform KoboToolbox (kobotoolbox.org) when the smartphones were re-connected to a WiFi signal.

2.6 | Data analysis

The data were analyzed with R 3.5.3 (R Core Team, 2019). We performed a Wilcoxon rank sum test to assess whether the number of types of meat selected by participants differed statistically significantly between the treatment and control groups, which was considered significant at alpha ≤ .05.

For each set of UCT cards, the estimated proportion \( p \) of the population that had consumed lemur or fossa meat during the past year was calculated by subtracting the average number of meat types eaten by the control group \( \bar{x}_{\text{control}} \) from the average number of meat types eaten by the treatment group \( \bar{x}_{\text{treatment}} \) (Droitcour et al., 1991):
The estimated proportion 95% confidence intervals (CIs) were calculated as:

\[
95\% \text{ CI} = \bar{p} \pm 1.96 \times \sqrt{\frac{\text{var}_{\text{treatment}}}{n_{\text{treatment}}} + \frac{\text{var}_{\text{control}}}{n_{\text{control}}}}
\]

where \(\text{var}_{\text{treatment}}\) and \(\text{var}_{\text{control}}\) are the variances of the number of meat types eaten by the treatment and control groups, respectively, and \(n_{\text{treatment}}\) and \(n_{\text{control}}\) are the sample sizes of the treatment and control groups, respectively. We calculated the estimated proportion coefficients of variation (CV) as:

\[
CV = \frac{\sqrt{\text{var}_{\text{treatment}}/n_{\text{treatment}} + \text{var}_{\text{control}}/n_{\text{control}}}}{\bar{p}} \times 100
\]

We chose to present the coefficients of variation, defined as the ratio of the sample standard deviation to the sample mean (here \(\bar{p}\)), because they are standardized and well suited to compare samples with disparate means (Howell & Everitt, 2005).

### 3 RESULTS

The UCT surveys revealed that 53.0% of households had eaten lemur meat over the past year (95% confidence intervals (95% CI): 42.0–64.1%; percent coefficient of variation (%CV): 10.6%), and 24.2% had eaten fossa meat (95% CI: 14.2–34.2%; %CV: 21.1%) (Figure 3). In comparison, when these questions were asked directly to participants, 16.0% (\(n = 49\)) and 2.0% (\(n = 6\)) of participants reported their household had eaten lemur meat and fossa meat over the past year, respectively.

Slightly less than half of the UCT survey participants picked the control card for the lemur question (control: 47.2%, \(n = 311\); treatment: 52.8%, \(n = 348\)) and fossa question (control: 46.6%, \(n = 307\); treatment: 53.4%, \(n = 352\)). Participants in the lemur and fossa treatment groups had eaten statistically significantly more types of meat in the past 12 months (lemur question: 3.05 meats on average; fossa question: 2.82 meats on average) than participants in the control groups (lemur question: 2.52 meats on average; fossa question: 2.58 meats on average; Wilcoxon rank sum test: lemur question: \(W = 33,201, p < .001\); fossa question: \(W = 44,193, p < .001\)). The mean values that are close to 2 in the control groups suggest that a design that reduced variance was achieved.

Only one participant reported her household did not eat any of the types of meat presented, and 12 and 11 participants from the control groups of the lemur and the fossa questions, respectively, reported they had eaten all of them in the past 12 months (Figure 4).

The vast majority (94.5%) of participants found the UCT easy to understand, and only 5.2 and 0.3% of participants found it moderately or very difficult to understand, respectively. All participants indicated that they enjoyed participating in the game, and some even thanked the enumerators by offering them fruit.

### 4 DISCUSSION

The UCT provided an estimated percentage of households that ate lemur meat over the past year that was more than 3.3 times higher than that obtained by direct questioning, and an estimated percentage of households that ate fossa meat over the past year that was 12 times higher than that obtained by direct questioning. This suggests that indirect questioning methods are better suited than direct questioning methods to measure the prevalence of sensitive behaviors such as the consumption of protected species in villages bordering a protected area. While Nuno, Bunnefeld, Naiman, and Milner-Gulland (2013) also recommend using the UCT to investigate rule-breaking in wildlife conservation, we should point out that indirect questioning methods are not always better suited depending on the study area and subject context and the objective of the study (Davis, Willemsen, Dang, O’Connor, & Glikman, 2020; Hinsley et al., 2019).
Our estimate of the percentage of households that ate lemur meat over the past year is close to that from Golden (2009), in which 52% of the 312 male heads of households he surveyed around Makira Natural Park using direct questioning stated they had eaten White-fronted brown lemur *Eulemur albifrons* meat, one of the most commonly eaten lemur species, over the past year. However, our estimated percentage of households that ate fossa meat is more than three times higher than the 7% of households found in Golden (2009). This could be due to real differences in fossa consumption patterns around Makira Natural Park and to the use of different survey methods.

The use of direct questioning inevitably leads to underreporting of participation in a sensitive behavior due to social desirability and social pressure, which can vary depending on the enumerator's identity or professional affiliation, the degree of trust with the enumerator, the local context at the time of the study, and the history of conservation initiatives in the study area, among others (Newing, Eagle, Puri, & Watson, 2011; Tourangeau & Yan, 2007). It is possible that at the time of Golden’s (2009) research, fossa consumption was a more sensitive topic than lemur consumption, which could explain why the UCT revealed a similar prevalence of lemur consumption, but a higher prevalence of fossa consumption. However, this is unlikely as the fossa does not appear to be a *fady* species (Golden & Comaroff, 2015). The results presented here, unlike those in Golden (2009), are not representative of all the villages around the park, and obtaining estimates that could be extrapolated to the rest of the park was beyond the scope of our study. The difference in the estimated prevalence of fossa consumption between the two studies could therefore potentially be due to different consumption and hunting habits in the two samples and to variation over time. Since the two studies were conducted 15 years apart, it is possible that fossa meat consumption has truly increased in the villages bordering the park. This could potentially be associated with a reported increase in poultry predation by fossas in recent years (Spira, Ranarinina, Cournarie, Andriamampilina, & Wieland, 2020), to which villagers could have reacted by hunting fossas more (Merson et al., 2019). It could also be due to an insufficient supply of affordable domestic meat (Golden, 2009) to feed the region’s growing human population, which may have pushed people to hunting more wildlife, including fossas.
The UCT is a relatively easy-to-deploy method for estimating the prevalence of protected species meat consumption, and we strongly recommend its use by researchers who wish to estimate the prevalence of sensitive behaviors in areas where conservation projects are implemented. We recommend that researchers looking to apply the UCT pay particular attention to enumerator training, UCT card design, and piloting to ensure that all the underlying assumptions to applying this method are met, and that language and representation subtleties associated with the selected UCT list items are taken into account. Although the sampling effort required in UCT studies is high (Hinsley et al., 2019), the duration of a UCT survey was approximately 10 min, which enabled a large number of surveys to be carried out in 1 day (up to 33 surveys per enumerator per day), thereby offsetting the large sample size required with the number of days needed for data collection, and therefore the cost of the study.

The results presented here will be used to define the scale of a behavior change campaign that is planned to be conducted in the study area. Indeed, given that 53% of households are estimated to be lemur meat consumers, the social marketing messages that will be designed as part of the behavior change campaign should be disseminated so they can reach a similar proportion of the ~13,300 people in the study area (figure from 2019). The content of the campaign, that is, the messages and approaches used to disseminate them so they reach the target consumers, will be defined based on results from a more in-depth study on meat consumption preferences, drivers, and behavioral habits that was conducted in parallel to this study. However, these results are not presented here as they are beyond the scope of this article. Our results also serve as a baseline against which the impact of ongoing conservation activities that aim to reduce the consumption of protected species, of which the behavior change campaign is a part, will be assessed through repeated measures over time. Although a social marketing campaign alone may not lead to massive reductions in lemur and fossa consumption, assuming a repeat UCT survey with the same sample size as this study, then one should be able to achieve reasonable power (> 90%) to detect a change if lemur and fossa meat consumption decrease by at least 11 and 20%, respectively.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS
Charlotte Spira, Samantha Strindberg, Morgane Cournarie, and Michelle Wieland designed the study; Rivo Raveloarison collected the data; Samantha Strindberg, Tim O’Brien, and Charlotte Spira analyzed the data.

DATA AVAILABILITY STATEMENT
The data supporting the study’s findings can be accessed by contacting the corresponding author.

ORCID
Charlotte Spira https://orcid.org/0000-0001-6296-1075

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