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What Roadkills Did We Miss in a Driving Survey? A Comparison of Driving and Walking Surveys in Baldwin County, Georgia

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WHAT ROADKILLS DID WE MISS IN A DRIVING SURVEY? A COMPARISON OF DRIVING AND WALKING SURVEYS IN BALDWIN COUNTY, GEORGIA

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ABSTRACT

Accurate estimates of vertebrate road mortalities are necessary prior to the consideration of mitigation measures by resource managers. Due to ease of implementation, driving surveys are more common than walking surveys. From February 2018 to February 2019, two survey methods, driving and walking, were used to monitor a 1.16 km section of Highway 212 in Baldwin County, Georgia. Roadkills were identified and monitored for persistence from sunrise to noon two days a week. Twenty-nine roadkills were recorded over the survey period: 48.3% mammals (14/29), 27.6% herpetofauna (8/29), and 24.1% birds (7/29). Forty-eight percent (14/29) of roadkills were missed by the vehicle survey: 75.0% of herpetofauna, 43.9% of birds, and 35.7% of mammals. Of the roadkills missed, 72.7% (8/14) were located in the roadway compared to the verge. Carcasses smaller than eastern gray squirrel size were more likely missed in the driving survey than those equal to or larger than squirrels ($\chi^2 = 4.36$; $p = 0.04$). This study demonstrates that driving surveys miss a significant portion of roadkills and conducting walking surveys separately or in combination with driving surveys is necessary for an accurate estimate of vertebrate road mortality.

Keywords: roadkill survey, wildlife road mortality, central Georgia

INTRODUCTION

It is estimated that wildlife-vehicle collisions occur throughout the United States at a rate of one to two million mammals per year (United States Department of Transportation 2017). These numbers are based on insurance industry records and generally only reflect large mammals such as white-tailed deer (*Odocoileus virginianus*; Gaskill 2013). This number is clearly an underestimate that does not include unreported smaller mammals, herpetofauna, and birds that do not severely damage vehicles on impact. Field studies in Wales have found that the actual vertebrate road mortality is likely 12–16 times greater than that observed in driving surveys (Slater 2002). With this in mind, some ecologists estimate that one million vertebrates are killed on roads each day in the United States (Murphy 2005). In Georgia alone, it is estimated that as many as 5.4 million mammals are killed along roadways each year (Boitet and Mead 2014). Additional studies estimate that tens of millions of herpetofauna (Bailey et al. 2006) and upwards of 80 million birds

(Kociolek et al. 2015) are killed annually on roadways in the United States. However, to our knowledge, there are no published estimates of herpetofauna or bird road mortality for Georgia.

Driving surveys are the most commonly used method to document roadkill numbers primarily for safety concerns and the great lengths of road that can be covered in short time periods. Previous studies have found that driving surveys miss a portion of the roadkill present due to animal size, vegetation in the verge (the grassy strip along the roadway), road topography, physical road features, displacement of carcasses, and the limited amount of time a driver has to detect a carcass and make a positive identification (Barthelmess and Brooks 2010; Clevenger et al. 2003; Langen et al. 2007; Slater 2002). Several studies (Barthelmess and Brooks 2010; Glista and DeVault 2008; Langen et al. 2007; Smith-Patten and Patten 2008) have found that, while driving at posted highway speeds, it is difficult to notice or identify roadkill smaller than an eastern gray squirrel (*Sciurus carolinensis*). Walking surveys have been used separately and in combination with driving surveys and result in greater numbers of observed roadkill (Coleman et al. 2008; Dutta et al. 2016; Langen et al. 2007; Smith and Dodd 2003). Because roadkill surveys often record more mammals than other vertebrates (Cristoffer 1991; Glista and DeVault 2008; Seibert and Conover 1991), changing methodology from driving to walking increases the detection of herpetofauna and birds (Slater 2002). For example, in a herpetofaunal methodology study comparing walking and driving surveys, walking roadkill observations were 52 times higher than driving (Langen et al. 2007).

Displacement and persistence (the length of time a specimen has been on the roadway or in the verge) often influence observed roadkill numbers. Large mammals, such as white-tailed deer, may move a short distance away from the road after being struck by a vehicle decreasing the likelihood of detection (Main and Allen 2002). Intermediate-sized mammals such as Virginia opossum (*Didelphis virginiana*), northern raccoon (*Procyon lotor*), and nine-banded armadillo (*Dasypus novemcinctus*) may be propelled into the verge upon impact with a vehicle. Smaller vertebrates such as birds may be displaced a significant distance. Although not a bird, a radio-collared squirrel glider (*Petaurus norfolcensis*) was found roadkilled 500 km from the initial study site in Australia as the squirrel glider was stuck on the front of a vehicle and transported away from the study locality (Soanes et al. 2015). Persistence is most affected by the activities of scavengers. A large study ($n = 4447$) of carcass persistence in southern Portugal found that most vertebrate roadkills remain on the roadway for a day or less (Santos et al. 2011). Small roadkills are often removed by scavengers more quickly than large roadkills (Main and Allen 2002; Slater 2002). Antworth et al. (2005) found that carcasses were more often removed from the asphalt during the day and suggested that scavengers were able to find animals on the road by sight or smell. Three field trials showed that 60–82% of small carcasses disappeared from the roadway within 36 hours. Beckmann and Shine (2015) found that frog carcasses persisted longer on the roadway during the night or periods of rainfall, possibly due to less scavenger movement during those times. Other studies indicate that persistence is often quite variable. Seibert and Conover (1991) could not determine a representative average length of time for mammalian persistence because a Virginia opossum persisted in the roadway for one day and some groundhogs (*Marmota monax*) persisted for almost three months.

It has been demonstrated that driving surveys are useful for identifying the locations of roadkill hotspots (Aresco 2005; Boitet and Mead 2014; Glista and DeVault 2008;

Lester 2015, Ogletree et al. 2019). However, walking surveys may be more useful in monitoring identified hotspots (Langen et al. 2007). Comparisons of walking and driving roadkill surveys that determine the percentage of roadkill missed while driving appear to be lacking, thus a better understanding of the difference in roadkill detection rates between these two methods is needed. The objectives for this study were to compare walking and driving surveys to gain a better understanding of 1) which taxa are most often found as roadkill, 2) what percentage of roadkill is missed in a driving survey, and 3) which taxa are most frequently missed in a driving survey.

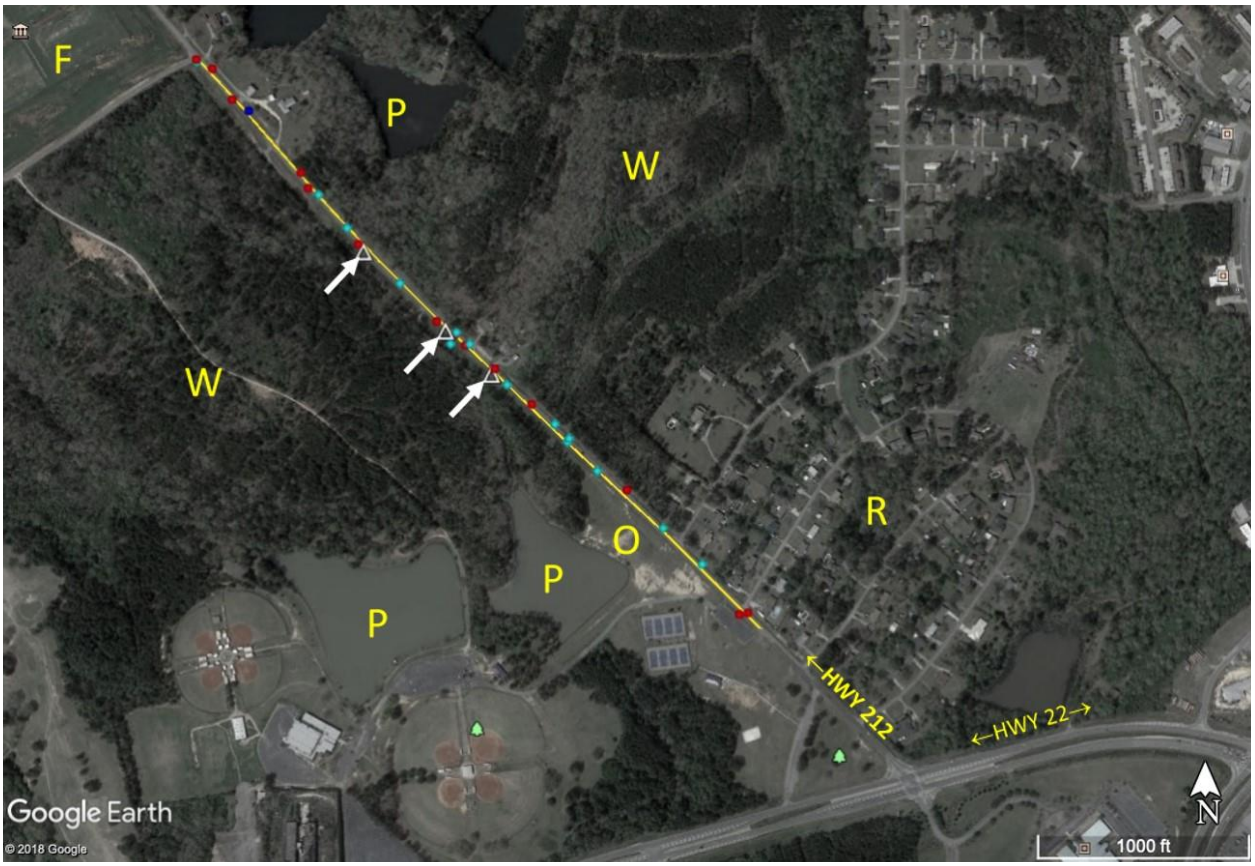

Figure 1. Roadkill observations (dark blue = detected while driving only, cyan = detected while walking only, red = detected while driving and walking) and culvert locations (white arrows) along the survey section (yellow line) on Highway 212 in Baldwin County, Georgia. R = residential; P = pond; O = open field; W = woodland; F = recreational fields. Aerial photo from Google Earth (2018).

MATERIALS & METHODS

Roadkill was surveyed along a 1.16 km section of Highway 212 near the intersection with Highway 22 in Baldwin County, Georgia (Figure 1). The southeast end of the survey section has a residential area (R) on the east side of the road and an open field (O) and two ponds (P) to the west. Moving northwest, the surrounding habitat changes to a small woodland (W) on both sides of the road. The north end of the survey route is surrounded by a few residences and a pond (P) on the east side of the road and a woodland (W) and recreational field (F) to the west. Slight changes in roadway elevation occur between

0.29 km and 0.44 km as well as 0.70 km and 0.95 km. Three small permanent streams flow underneath the road through culverts at 0.53 km, 0.62 km, and 0.79 km. The verge has an average width of 6.39 m and is mowed occasionally by county workers. Additionally, fairly uniform roadside drainage ditches are present along both sides of the roadway.

Driving and walking surveys for roadkill were conducted every Tuesday and Thursday morning (weather permitting) within an hour after sunrise between 1 February 2018 and 31 January 2019. The survey route was driven at an average posted speed limit of 80.5 km/h from south to north (the east side of road) and north to south (the west side of road). Immediately following the driving surveys, walking surveys were carried out following the same pattern. For each roadkill, the species, date, location (roadway or verge), and GPS coordinates (via Google Maps) were recorded the first time it was observed. Each roadkill was categorized according to size—smaller or equal to or larger than an eastern gray squirrel (total length, 38–52 cm; tail length, 15–24 cm; 300–710 g; Steele and Koprowski 2001). Roadkill was monitored for persistence until noon on observation days. Persistence of previously recorded carcasses was noted on subsequent observation days. Roadkill rate was calculated by dividing the yearly total of roadkill by road length (km). Chi-square tests were used to determine whether carcass size, location (roadway or verge), or taxonomic group affiliation influenced the number of roadkills missed by the driving surveys.

RESULTS

During the study period, 29 vertebrate roadkills were observed in the walking survey over 98 observation days (Figure 1, Table I). The roadkill rate was 25.00 roadkills/km/y. Roadkill rates were highest for mammals (12.07 roadkills/km/y) followed by herpetofauna (6.90 roadkills/km/y), and birds (6.03 roadkills/km/y). Mammals accounted for 48.3% (14/29) of the observed roadkill followed by herpetofauna at 27.6% (8/29) and birds at 24.1% (7/29). Species observed more than once include Virginia opossum (4), northern raccoon (3), white-tailed deer (2), eastern gray squirrel (2), and black rat snake (*Pantherophis obsoletus*, [2]). Eleven roadkills were smaller than a squirrel with 18 equal to or larger.

Forty-eight percent (14/29) of roadkills were missed by the vehicle survey (Table I). Herpetofauna were most frequently missed (75.0%, 6/8) followed by birds (43.9%, 3/7) and mammals (35.7%, 5/14), though the difference between taxonomic groups was not significant ($\chi^2 = 3.76$; $p = 0.15$). Roadkills smaller than a squirrel were missed (8/11) significantly more often ($\chi^2 = 4.36$; $p = 0.04$) than those equal to or larger (6/18). For taxa smaller than a squirrel, all mammals (1/1) and herpetofauna (4/4) and half of the birds (3/6) were missed. Fifty percent of herpetofauna (2/4) and 30.8% (4/13) of mammals equal to or larger than a squirrel were missed during the driving survey. The one bird larger than a squirrel was not missed while driving. Missed roadkills were both in the roadway (57.1%, 8/14) and verge (42.9%, 6/14) and did not significantly differ by location ($\chi^2 = 0.28$; $p = 0.60$). All mammalian roadkills missed (5/5) were in the verge and all of the avian roadkills missed (3/3) were in the roadway. More herpetofaunal roadkills missed by the vehicle survey were located in the roadway (83.3%, 5/6) than in the verge (16.7%, 1/6).

Small herpetofaunal roadkills (less than squirrel size) persisted longer on average than small avian and mammalian roadkills. Of the 11 roadkills persisting more than a day, 72.7% (8/11) were located on the asphalt and 27.3% (3/11) were in the verge. For the 18 roadkill persisting for a day or less, 55.6% (10/18) were located on the asphalt and 44.4% (8/18) were in the verge. Twenty-eight percent (8/29) of roadkills were removed prior to noon on the first day of observation. Seventy-six percent (16/21) of roadkills observed on Tuesday were removed by the following Thursday. Eighty-five percent (11/13) of roadkills present on Thursday were removed by the following Tuesday. A white-tailed deer and nine-banded armadillo persisted longer than a week with the white-tailed deer persisting for two weeks from the observation date until the end of the survey period. One Virginia opossum observed in the driving survey was removed by a civilian prior to the walking survey.

Table I. Vertebrate roadkill observed on Highway 212 in Baldwin County, Georgia during walking and driving surveys. Distance in meters was measured from the south end of the transect. N = not missed in the driving survey; Y = missed in the driving survey; R = carcass located on asphalt; V = carcass located in the verge; * = animals smaller than an eastern gray squirrel.

Date	Species	Common Name	Distance	Missed	Location
3-20-2018	*Dasypus novemcinctus*	nine-banded armadillo	536	N	R
4-10-2018	*Odocoileus virginianus*	white-tailed deer	198	N	R
4-17-2018	*Terrapene carolina*	eastern box turtle	1079	N	R
4-19-2018	*Nerodia erythogaster*	red-bellied water snake	24	N	R
4-26-2018	*Corvus brachyrhynchos*	American crow	31	N	V
5-1-2018	*Pantherophis obsoletus*	black rat snake	832	Y	R
5-8-2018	*Storeria dekayi*	brown snake*	324	Y	R
5-8-2018	*Pantherophis obsoletus*	black rat snake*	895	Y	R
5-10-2018	*Procyon lotor*	northern raccoon	650	N	R
5-10-2018	*Spizella passerine*	chipping sparrow*	1153	Y	R
5-10-2018	*Cardinalis cardinalis*	northern cardinal*	455	N	R
6-12-2018	*Lithobates sphenocephalus*	southern leopard frog*	588	Y	V
6-14-2018	*Sciurus carolinensis*	eastern gray squirrel	804	N	R
7-31-2018	*Sciurus carolinensis*	eastern gray squirrel	590	N	R
8-14-2018	*Felis catus*	domestic cat	127	Y	V
8-23-2018	*Virginia valeriae*	smooth earth snake*	506	Y	R
9-18-2018	*Agkistrodon contortrix*	copperhead	384	Y	R
9-18-2018	*Didelphis virginiana*	Virginia opossum	611	N	R
9-18-2018	*Didelphis virginiana*	Virginia opossum	911	N	R
9-18-2018	*Didelphis virginiana*	Virginia opossum	1051	N	V
10-2-2018	*Didelphis virginiana*	Virginia opossum	935	N	V
10-30-2018	*Tamias striatus*	eastern chipmunk*	198	Y	V
11-22-2018	*Dumetella carolinensis*	gray catbird*	1133	N	V
1-15-2019	*Procyon lotor*	northern raccoon	387	Y	V
1-15-2019	*Procyon lotor*	northern raccoon	416	Y	V
1-15-2019	*Odocoileus virginianus*	white-tailed deer	606	Y	V
1-15-2019	*Setophaga pinus*	pine warbler*	613	Y	R
1-15-2019		unidentifiable bird*	722	Y	R
1-22-2019	*Poecile carolinensis*	Carolina chickadee*	277	N	V

DISCUSSION

In the current study, the walking roadkill detection rate was twice as large as the driving roadkill rate. By comparison, in a walking and driving herpetofaunal survey conducted in New York, Langen et al. (2007) found that walking short segments resulted in a roadkill rate of 175.64 roadkills/km/y and driving the entire route produced a rate of only 0.41 roadkills/km/y. Although the difference between the rates in the current study contrasts greatly with Langen et al. (2007), the current study further demonstrates that walking survey routes greatly increases roadkill detection compared to only driving the routes. In a previous driving survey conducted in Baldwin County, Georgia, Boitet and Mead (2014) observed six mammalian roadkills (5.17 roadkills/km/y) on the same 1.16 km of Highway 212, similar to the current driving detection rate for mammals (7.76 roadkills/km/y) and roughly half of that calculated for the current walking survey (12.07 roadkills/km/y). The Baldwin County walking rate is considerably higher than those found in other studies focusing on mammalian roadkills in the United States: 1.44 roadkills/km/y on 206.3 km in New York (Barthelmess and Brooks 2010) and 3.55 roadkills/km/y on 158.5 km in the southern Great Plains (Glista and DeVault 2008). Both of these surveys were conducted as driving surveys for approximately one year. The herpetofaunal roadkill rate for the current study is miniscule compared to herpetofaunal rates in other studies, possibly due to the presence of culverts that allow the passage of herpetofauna under the roadway (Collinson et al. 2017). Dutta et al. (2016) observed herpetofaunal roadkill at 139.14 roadkills/km/y on a 3.5 km transect in India. However, that survey occurred only during peak breeding activity from April–July and the rate is higher than would be expected throughout the year. Smith and Dodd (2003) observed roadkilled herpetofauna, mammals, and birds for an entire year along 3.2 km of roadway through Paynes Prairie in Florida and found a high roadkill rate of 569.06 roadkills/km/y. The roadkills consisted primarily of herpetofauna, likely related to location of the roadway through a preserve and year-round herpetofaunal activity. Both studies were walking surveys, and recorded an abundance of small herpetofauna that most likely would have been missed in driving surveys. Other suveys have found similar or lower roadkill rates compared to the current study. A driving-only survey in southwest Virginia found a rate of 7.28 roadkills/km/y for herpetofauna, mammals, and birds (Vance et al. 2018). In a five year driving study, Husby (2016) found an avian roadkill rate of 4.84 roadkills/km/y along a 25 km survey route in Norway.

Detection of roadkills in this study was influenced by various factors such as carcass size and location. As seen in this study and previous studies (Boitet and Mead 2014; Langen et al. 2007; Slater 2002), animals smaller than a gray squirrel are often missed in driving surveys. Beckmann and Shine (2015) described how identification of small carcasses is difficult due to repeated flattening by vehicles. Most small carcasses found in the roadway in this study were flattened. Half of the snakes were flattened and had to be removed from the asphalt for identification. However, two birds at the edge of the road were not flattened and were probably missed in the driving survey as vegetation obscured them from view even though the pine warbler (*Setophaga pinus*) was brightly colored. Although smaller than a squirrel, the northern cardinal (*Cardinalis cardinalis*), gray catbird (*Dumetella carolinensis*), and Carolina chickadee (*Poecile carolinensis*) were not missed while driving. The northern cardinal was brightly colored and contrasted with the asphalt, increasing visibility. The gray catbird was detected as the vehicle slowed at the end of the survey section. The Carolina chickadee detected by driving survey was struck by the survey vehicle and thrown into the verge. Detection of roadkills in the verge is difficult owing to vegetation height and the presence of ditches (Carvalho et al. 2014; Clevenger et al. 2003). The two additional small roadkills located in the verge, (an eastern chipmunk [*Tamias striatus*] and a southern leopard frog [*Lithobates sphenocephalus*]), were probably missed by the driving survey for the same reason. Although roadkills larger than a squirrel should be identifiable by vehicle, several were not. Two snakes (a copperhead [*Agkistrodon contortrix*] and a black rat snake) located in the roadway were missed by the driving survey, probably due to their coloration not contrasting with the asphalt and extreme flattening. Four large mammals in the verge were missed most likely because of obscuring vegetation. It should be noted that the verge was mowed occasionally and died back during winter months, thus decreasing the likelihood that the vegetation obscured roadkill in the verge during these times.

It is clear that scavenging and displacement of carcasses affect roadkill detections. Herpetofauna smaller than a squirrel persisted longer than mammals and birds in the same size range. This may be related to the smaller size of herpetofauna and the flattening of the carcasses. Many of the snakes observed as roadkill were flattened and persisted longer than larger mammals which were destroyed by the continuous impacts of vehicle tires. However, Antworth et al. (2005) found that body condition does not affect the persistence of carcasses. A study of roadkilled western rattlesnakes (*Crotalus oreganus*) in British Columbia found that 52% of the carcasses persisted less than two days (Winton et al. 2018). The size of the vertebrate typically influences persistence because scavengers remove small carcasses from the roadway quicker than large carcasses, but in this study small carcasses remained in the roadway longer than large carcasses. Slater (2002) observed that large animals hit in the evening were more likely to be scavenged quickly. Antworth et al. (2005), Beckmann and Shine (2015), and Slater (2002) observed that small roadkill was scavenged more quickly earlier in the day, ultimately decreasing the persistence of smaller roadkills. This coincides with the small mammalian and small avian carcass persistence found in the current study. Because persistence was measured based on the survey days, there is the possibility that removal by Georgia Department of Transportation workers, civilians, or scavengers occurred immediately before or after the observation period. For example, a Virginia opossum was recorded while driving but not while walking as the property owner removed the roadkill prior to the walking survey. Since the majority of roadkills persisted less than 48 h and the survey route was monitored only twice a week, it is likely that as many as 60% of the actual roadkills on this section of Highway 212 were missed in this survey.

A concurrent daily driving survey (prior to sunrise and in late afternoon) of a large portion of Highway 212 recorded an additional 12 roadkills (white-tailed deer [3], eastern gray squirrel [3], Virginia opossum [2], domestic dog [1], nine-banded armadillo [1], hawk [*Buteo sp.*, 1], and small bird [1]) in the study area that were not recorded in this survey (Mead, personal observations). Four of the twelve roadkills (a white-tailed deer, an eastern gray squirrel, a domestic dog, and a hawk) were observed on days when the survey route was walked, however because the daily survey was driven in the early morning and near dusk, the amount of time between the two surveys may have given scavengers or Georgia Department of Transportation workers time to remove the animals from the roadway. If the 12 roadkills are added to the current study, a total of 41 roadkills were observed in the survey section, increasing the roadkill rate to 35.34 roadkills/km/y.

Boitet and Mead (2014) previously explored the relationship between roadkill occurrence and vegetation type in this area. For future investigations, it may be beneficial to explore the relationship between roadkill persistence and vegetation. This study illustrates the difficulty of obtaining accurate roadkills numbers. Approximately 50% of roadkills were missed by the driving survey and most roadkills persisted a day or less. Because of the short persistence time, survey routes should be monitored every day, maybe multiple times a day, for a more accurate count. Larger driving surveys would benefit by walking shorter segments to increase the likelihood of roadkill observations and to determine the percentage of roadkills missed while driving. Furthermore, if the survey route is short, walking instead of driving would improve roadkill detection. This study further demonstrates that walking surveys are imperative to achieving more realistic roadkill numbers and should be considered when roadkill sampling occurs.

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