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A PIONEER STUDY ON THE WILDLIFE PROPERTIES OF ANATOLIAN SWEETGUM FORESTS, A CASE ASSESMENT ON MAMMALIAN DIVERSITY IN TERMS OF ECOSYSTEM INTEGRITY

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ABSTRACT

With this study, the existence of the mammalian species were used as a tool to reveal rehabilitation suggestions for the Anatolian (Oriental) Sweetgum Forests which are tertiary relict endemic for the Eastern Mediterranean Basin, heavily fragmented and in danger of becoming extinct. As the survey methodology; 2976 camera trap days with 9 different camera traps had been applied on three different forest patches (non-isolated, semi-isolated and isolated) to assess their ecological status by following some indices of mammalian community properties. Fragmentation is a major factor to assess diversity of species because numerous ecological variables are highly similar for this unique ecosystem. The findings of richness and diversity indices for both ecosystems are consistent with each other. According to richness index results; as isolation and fragmentation increase, richness decrease relatively, together with decreasing frequency (0,29 < 0,57 < 0,87). As well as the richness index, the diversity is decreasing inversely with the isolation and fragmentation (0,24 < 0,81 < 1,03). According to the results; as isolation and fragmentation increase, species diversity and number of observations decrease relatively. As a consequence of this current problem, corridor methodology was utilised to stop the fragmentation and various necessary conservation actions were suggested for the indicator mammals to live inside those forests. These results have important implications for the conservation of this ecosystem sustainability.

KEYWORDS:
Anatolian (Oriental) Sweetgum Forests, Mammalian Wildlife, Habitat Fragmentation, Forest Corridors, Diversity, Richness

INTRODUCTION

The Oriental Sweetgum (*Liquidambar orientalis* Miller) forests are rare, Eastern Mediterranean Basin endemic and an endangered forest ecosystem. A living fossil, records of the sweetgum tree goes back more than 60 million years [1]. A kind of oil (resin) is obtained from the body of these trees, and they all have a reputation in their respective regions. In scientific literature, the tree is called Liquidambar due to the fluid obtained from its body [2]. Locals have benefited from this charismatic and holy species in many different ways for ages.

The species creates forests or woodlands just around the coastal districts of South-western Turkey. The trees may also be seen in groups or individually, in shallow, creek water and riverbanks. These tree communities are called shallow gallery forests. These forests are often seen in places with less inclination, and more water [3].

Since the 1950s, farming initiatives in Turkey led to a massive shrinkage of sweetgum forests. From 6.312 hectares in 1949, the groves shrank to 1.337 hectares in 1987, and currently stand at no more than 2000 hectares due to the changing urbanization and local agriculture policies (incentives for citrus plantation) which paves the way for locals to transform its living area for other uses. Another factor for the number to reduce is the emergence of mass tourism. The forests are now broken and on the brink of extinction [4].

This species has been entered into Endangered (EN - A2c) statue on IUCN Red List Categories, and European Forest Genetic Resources Programme (EUFORGEN) has listed this species as protected tree on the scale of European Continent, which is why the species has been listed as Critically Endangered over European Continent. According to the forestry statistics published by Ministry of Agriculture and Forestry in Turkey, the occupation area of Sweetgum forests declined sharply during last decades, resulting also in increased forest fragmentation [5].

Main Effects of Sweetgum Forests' Fragmentation on the Wildlife Properties and The Importance of The Forest Corridors. The fragmentation of forest ecosystems is one of the most important reasons for accelerating the destruction of natural resources. Small fragmentation of forests leads to a decline in the internal areas of the forests and habitat quality. Deforestation in forests is considered the primary reason for the reduction of terrestrial biodiversity. Naturally, forest areas are divided into small areas by human use for farming or invasion by non-forest plant species [6].

Much of what the study of habitat fragmentation is concerned with today is the ecological consequences of land-use change for organisms living in networks of remnant patches surrounded by a mosaic of modified or novel land use types. This was not always the case, though. The historical roots of habitat fragmentation are embedded in the stochastic spatial model of Island Biogeography Theory (IBT) [7], which in its strictest form considers just patch area and isolation, incorporates no external influence beyond the probabilistic arrival of colonists across an inhospitable matrix and no internal patch dynamics beyond probabilistic extinction rates, and is 'neutral' to species identities or functional traits.

The concept of fragmentation is that it transforms the original habitat into smaller patches that are isolated from one another by a matrix of habitats that are unlike the original [8]. Several studies argue that habitat fragmentation is one of the leading causes of biodiversity loss [9, 10, 11]. This is due, in part, to the misconception that fragmentation is both the breaking apart and loss of habitat [10].

Moreover, even if there is no threat according to the principles of island biogeography and landscape ecology, the ecological and genetic structure of disconnected parts is rapidly deteriorating and it is inevitable that they will disappear in the long run [7]. Corridors are the forest clusters that provide integrity between forest pieces. Biological corridors reinforce the interplay between forest fragments [12]. The genetic diversity is preserved between the forest clusters that combined with the corridors, thereby the survival capacities and the sustainability of the species are increased. The provision of links between forest clusters or the strengthening of existing links have an important place in ecology and landscape conservation planning.

The size, the shape and the internal area ratios covered by the environmental boundaries of the forest parts, and the existing corridor systems are the evaluation criteria used for the status of forest habitats. These information are the current status of the forest parts and provides a basis for the establishment of the protection strategies.

With this study, mammal wildlife species of The Oriental Sweetgum (*Liquidambar orientalis* Miller) forests were determined for the first time. We focused on large mammalian species to assess ecological status and integrity of the forest patches in the region. Especially large mammals and mesocarnivore species are ecologically important because even small populations can cause a strong predation-driven direct or fear-driven indirect effects that could influence the ecosystem in terms of structure and function [13]. As a result large and mesocarnivores are sensitive indicators of ecosystem integrity [14, 15, 7]. We used the mammalian species existence as a tool to evaluate the sweetgum forests status and reveal rehabilitation suggestions for this fragile forests of Anatolia. In our study Eurasian Otter (*Lutra lutra*), caracal (*Caracal caracal*) and wild cat (*Felis silvestris*) were chosen as indicator mammal species in terms of ecosystem integrity. These species needs untouched habitats, they avoid from anthropogenic effects, their populations are critical in Asia minor and herbivorous populations increase in the absence of their populations [16, 17, 18].

MATERIALS AND METHODS

Study Area. Field works were conducted in Fethiye, Dalaman, Köyceğiz, Gökova and Marmaris regions of Muğla province in Turkey where the Anatolian sweetgum forests cover from 30 to 250 hectares area/forest patches (Figure 1).

The close vicinity of the study area is surrounded by flat areas. The areas of sweetgum forests that are studied are observed as places where alluvial soils are accumulated before the water from the mountainous regions reaches the Mediterranean Sea. For this reason, there are agricultural areas of primary importance in the region. Citrus plantation is the most important agricultural activity in and around the sweetgum forests.

Forest patches were clustered into three groups to evaluate their ecological network status by using the GUIDOS-Version 1.3 (Graphical User Interface for the Description of image Objects and their Shapes) programme. These are defined as follows: non-isolated, semi-isolated and isolated. According to the network analyses; status of forest patches were determined by adjacency with human activities (settlement, agriculture, grazing, beekeeping, tourism etc.). Accordingly, connection value and anthropogenic pressures between 0% and 30% defined as non-isolated, 30% and 70% defined as semi-isolated and 70% and 100% defined as isolated. As a result, we revealed 3 non-isolated, 4 semi-isolated and 2 isolated forest patches (Figure 2).

Anatolian sweetgum forests are an uniform ecosystem in terms of ecological factors that affects local diversity. Fragmentation is the major factor to assess the diversity of mammals species because other ecological variables such as geology, hydrology, insolation, elevation, slope, temperature, moisture are almost same for our each forest patches.

Data collection and analyses. The mammal survey was conducted between March 2015 and March 2018 by using 9 camera traps for 9 forest patches. 1 camera trap is located in the middle of the each patch (Cuddeback Attack, Wisconsin, USA). To compute indices of community parameters camera trap detections were analyzed. We filtered the camera trap data based on the assumption that multiple photographs of a species taken at a single camera trap station during any 24- hour period represent only one individual. That is, if an Eurasian otter was photographed at a single site four times during a 24-hour period, then these four photographs were counted as a single event of the same otter. Also repeated photographs were counted as a single event of the species [19,20]. To compute abundance, camera traps were deployed for same periods in each forest patch and camera trap data normalise to 1 hectare.

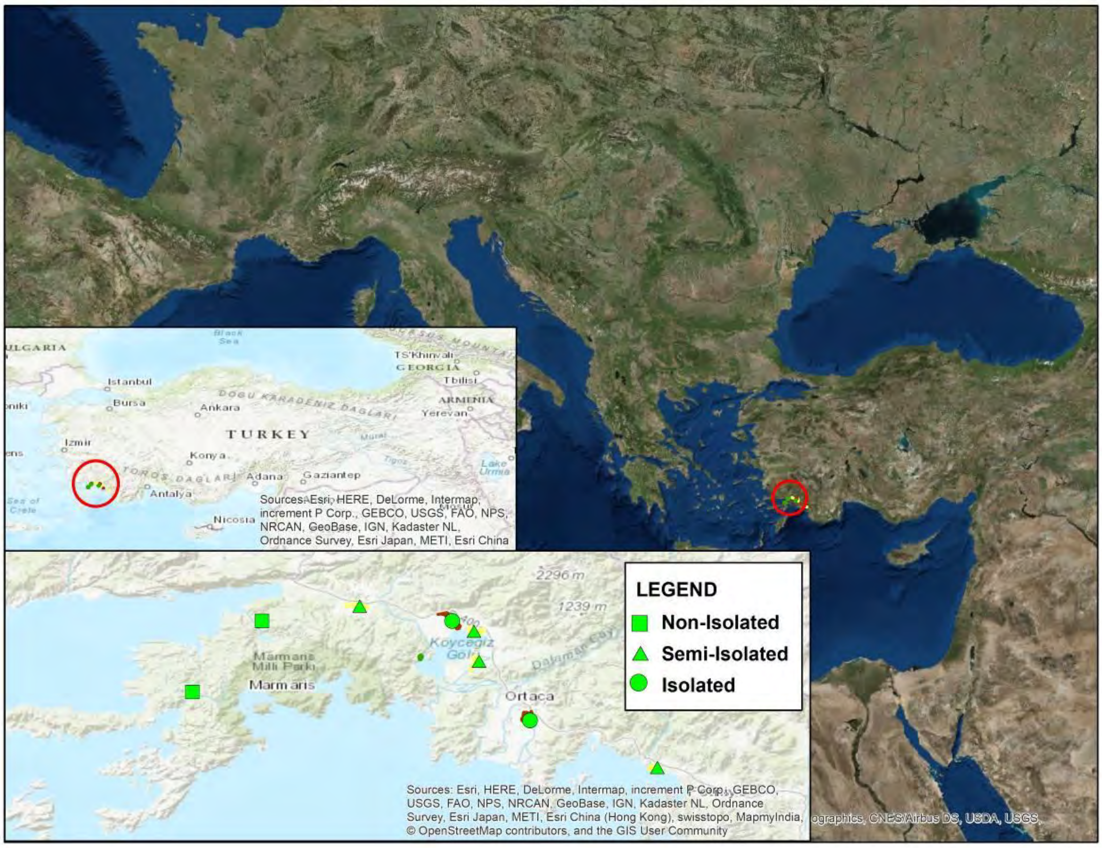

FIGURE 1
Location Map of the Study Area

Kersele, Non-isolated (Human activity 0%-30%) | Kavakarası, semi-isolated (Human activity 30%-70%) | Dalaman, isolated (Human activity 70%-100%)

FIGURE 2
Some examples related to the different ecological status of the forest patches.

TABLE 1
Total number of events in 2976 camera trap days and the number of events per 1 Hectare (Ha) for each mammal species in the study area.

Species	Total Number of Events			Events per 1 Ha		
	Non-isolated	Semi-isolated	isolated	Non-isolated	Semi-isolated	isolated
Otter (*Lutra lutra*)	10	7		0,14	0,01	
		17				
Caracal (*Caracal caracal*)	4			0,06		
		4				
Wild Cat (*Felis silvestris*)	3			0,04		
		3				
Badger (*Meles meles*)	17	36		0,24	0,05	
		53				
Beech marten (*Martes foina*)	2	9		0,03	0,01	
		11				
Red fox (*Vulpes vulpes*)	13	22	9	0,19	0,03	0,03
		44				
Golden jackcal (*Canis aureus*)			2			0,01
		2				
Wild boar (*Sus scrofa*)	242	435	56	3,46	0,62	0,19
		733				

TABLE 2
The results of the community parameters within the three different clustered forest patches.

Community Parameters	Non-isolated	Semi-isolated	Isolated
Dominancy	88,94	93,05	95,65
Diversity Index	1,03	0,81	0,24
Richness Index	0,87	0,57	0,29
Richness	7	5	3
Similarity	Non-isolated	Semi-isolated	Isolated
Non-isolated	*	0,83	0,4
Semi-isolated	0,83	*	0,5
Isolated	0,4	0,5	*

Also regular field observations were carried out to record findings such as traces, footprints and droppings of the mammal species.

Following indices of community properties [21] were used in this study; Sorensen's Similarity Index, Dominance Index, Shannon Diversity Index, Margalef Richness Index and Richness to assess ecological status of the three forest groups.

Sorensen's Similarity Index:

2a / (2a+b+c)

a: is the number of species shared by the two samples
b: the species numbers in sample 1
c: the species numbers in sample 2,

Dominance Index:

100*[(y1+y2)/Y]

y1: The number of first species that has highest frequency in transect
y2: The number of second species that has highest frequency in transect
Y: Total frequency,

Shannon Diversity Index:

$H' = -\sum (pi) (\log2\ pi)$

H: Diversity Index
S: total number of species in the community (richness)
*p*i: proportion of *S* made up of the *i*th species
i=1

Margalef Richness Index:

(S-1)/lnY

S: Richness
Y: Total frequency,
Richness: Total species number that had been saved during the camera-trap study.

RESULTS

During our 2976 camera trap days survey, we totally recorded eight different wild mammal species (Table 1). Camera traps were deployed at same time intervals (996 camera trap days non-isolated, 1012 semi-isolated and 968 isolated, respectively).

Three different clustered forest patches were also analysed and compared with each other by taken into account the Dominancy, Diversity, Richness and Similarity Indices. The related data is presented below (Table 2).

DISCUSSION

According to the results, three different forest patches display different ecological characteristics in terms of mammal community thus evaluating their ecological integrity is more explicit for us.

Eurasian Otter (*Lutra lutra*) is a top predator in aquatic systems and plays an important role in the ecosystem as a bioindicator [18]. Otters have been monitored in semi-isolated patches beside non-isolated patches. Because they easily reached semi-isolated patches by using waterways. Therefore we could reveal that semi-isolated forest patches still remained uncontaminated in the region. Caracal (*Caracal caracal*) and wild cat (*Felis silvestris*) are terrestrial mammals in sweetgum forests. These two felids has limited ecological tolerance especially in Mediterranean basin [16, 17]. In this study caracal and wild cat recorded at only in non-isolated sweetgum forests. This case could be explained by virgin status of non-isolated sweetgum forest patches. On the other hand, ecological tolerance of Eurasian badger and beech marten is broader than felid species [16]. In our study, we recorded them also in semi-isolated areas beside non-isolated areas.

Red fox and wild boar have a wide range of ecological tolerance compared to other species detected in this study [22, 23]. That's why, we determined both of them in three different forest patches. However, wild boar has mostly been detected in non-isolated forests. Wild boar has been detected at low numbers in isolated forests. On the other hand, red fox found at high numbers in non-isolated forests while it is determined at same numbers in two other forest patches. This can be explained by red foxes' wide ecological tolerance in urban areas [22]. One golden jackal has been detected only in an isolated forest. However, this random record is insignificant. With the exception of this wandering individual, there was no permanent golden jackal population during the last decade in the region.

According to the similarity index, the high similarity between non-isolated and semi-isolated (0,83) is due to their heterogeneous structure such as land use, property, stands and forest management properties etc. On the other hand, the less similarity between non-isolated and isolated (0,4) is because of the isolated forest parts are generally plantation and this condition is reducing the biodiversity in general.

Wild boar is the dominant species for all the forest parts due to its opportunistic properties. Isolated forest parts are more dominant areas than others (%95.65). The relationships between richness and dominance indices should be more focused. The results compatible with the literature because, theoretically, if the richness is low, dominancy is expected to be high [13]. The richness for all the forest parts that had been studied was as expected. While the non-isolated parts are richer than the others, isolated parts are identified as the poorest areas in terms of diversity and richness. This situation most probably arises from the homogenic characteristics of isolated forest parts, thus giving a chance of survival to opportunistic species such as Wild Boar which in turn increases the dominancy.

The findings of both richness and diversity indices are consistent with each other. According to the richness index results; as isolation and fragmentation increase, richness decrease relatively together with decreasing frequency (0,29<0,57<0,87). In accordance with the richness index, also the diversity is decreasing inversely with the isolation and fragmentation (0,24<0,81<1,03).

In addition to habitat fragmentation, several negative impacts exist on mammal communities of Sweetgum forests. Eurasian otter habitats and their water regime is manipulated by the hand of man for touristic and irrigation purposes. Agricultural spraying on adjacent citrus plantations to sweetgum forests is another negative impact on the habitat and mammal community. These pesticides are spread by groundwater and waterways of sweetgum forests to whole habitat and influence fragile species like Eurasian otter and badger. Stray dogs are another aspect affecting the mammal community and their negative impact is increased by habitat fragmentation.

CONCLUSIONS

In this study, we demonstrated the importance of large mammals as an indicator tool to evaluate forest ecosystems. According to the results, loss of biodiversity is expounded by fragmentation of the Anatolian (Oriental) Sweetgum forests.

Our results provide empirical evidence that fragmentations cause to increase the genetic bottleneck effects in the Anatolian (Oriental) Sweetgum forests [4]. We therefore recommend that any kind of seedling strategies such as making corridors between the fragmented parts and/or creating plantations in the new areas should be preferred for those forests. Second, we suggest that necessary conservation actions (such as less pesticide usage, stopping the corruptions of the water regimes, managing the street animals etc.) should be taken into account for the indicator mammals live inside those forests.

The results of our study have important implications for wildlife management of the Anatolian (Oriental) Sweetgum forests.

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