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First Results of Monitoring the New Invasive Species *Prunus serotina* Ehrh. Population inside the Regeneration Area of Common Oak-Hornbeam Forest in Western Croatia

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ABSTRACT

Black cherry (*Prunus serotina* Ehrh., Rosaceae) is a widespread invader of the European temperate forests and a significant component of the human-caused part of the global environmental changes. Its successful invasion results from a complex interaction between the species life traits and the recipient ecosystem attributes. While it has been recorded to develop spontaneously in numerous European countries, in Croatia information details on its population distribution, as well as its current status, are still missing. The individuals of *P. serotina* were found in the pedunculate oak (*Quercus robur* L.) forest regeneration area of Jastrebarsko forest management unit in 2018. This alerted us to start to monitor its spreading area, status and impact on the native plant species in a four-year period (2018-2021). In order to investigate the habitat characteristics, phytosociological approach was applied. In addition, the area was surveyed using an unmanned aerial vehicle (UAV) DJI Mavic 2 Pro and DJI Ground Station Pro. The results showed that *P. serotina* spread considerably in the regeneration area, which indicates its invasive character. It also caused alteration in current vegetation. Fast initial expansion of *P. serotina* in 2019 was slowed down in the next 2 years due to performed tending activities, suggesting mechanical measures could help to control its invasive spreading at an early stage of development. This research brought up the first record of the *Prunus serotina* species in pedunculate oak forest regeneration area of western Croatia with a recommendation to continue the monitoring survey in order to help prevent its spread in the future.

Keywords: regeneration area monitoring; invasiveness; Jastrebarsko; spreading control; phytosociology; forest management

INTRODUCTION

Alien invasive species, i.e. the species that are not native to a specific location (an introduced species), are nowadays recognized as the second most important cause of biodiversity loss (just after direct habitat destruction) and may have a strong wide-ranging environmental (on structure, function and stability of the ecosystem) and an economic impact (Starfinger 1991, Simberloff et al. 2013). From an extensive literature on biological invasions (e.g. Starfinger 1991, Starfinger 1997, Vitousek et al. 1997, Everett 2000, Kolar 2001, Vila and Weiner 2004, Godefroid 2005, Verheyen et al. 2007, Vila et al. 2010, Simberloff et al. 2013, Aerts et al. 2017), it can be seen that an organism introduction to areas where they were originally absent may have very different consequences. In the vast majority of cases the introduced species do not survive in the natural or near-natural vegetation and only a small percentage totally naturalizes. In other cases, new species do not only naturalize successfully, but also significantly change the whole ecosystem This happens mostly by establishing high abundance, affecting the regeneration of the native species by suppressing their growth (Huxel 1999, Godefroid 2005, Vanhellemont et al. 2010), indirectly changing the plant community composition and affecting belowground carbon pools (Ehrenfeld 2004, Koutika et al. 2007). They can also have a direct impact on human health, for instance by producing allergenic pollen that exacerbate respiratory diseases or just by serving as a novel habitat for disease vectors (Vitousek et al. 1997). Invasive species often affect larger areas and their impacts on plant communities and soil microbiota may accelerate or decelerate the local nutrient cycles (Ehrenfeld 2003, Vanderhoeven et al. 2005, Liao et al. 2007, Dassonville et al. 2008, Lazzaro et al. 2014), promoting losses or gains in local nutrient stocks and even have an impact on the greenhouse gas emissions from the soil (Wayne et al. 2002, Chen et al. 2015).

American bird cherry, black cherry or rum cherry (*Prunus serotina* Ehrh.) is a deciduous, single-stemmed, native forest tree originating from dry and warm parts of the North America, which was introduced and successfully spread across Europe. It typically forms large and straight branch-free boles and narrow crowns in the forest environment and an irregular crown type with short and broad trunks in the opening area. The bark of the young stems is thin, smooth and reddish-brown to nearly black, while the bark of the large trunks is fissured and scaly but remains thin. It develops simple, elliptic-ovate, thick and glossy leaves with serrated leaf margins, two green glands on the petiole and a brown tomentose center leaf vein. Its small, white and 5-petalled flowers with a pleasant smell form long, cylindrical inflorescences, while the incoming fruits are nearly globular, one-seeded, purplish-black to black, edible drupes (Muys et al. 1992, Starfinger 2010). *Prunus serotina* is highly resistant to some less favorable ecological factors for the majority of the plant species such as drought, frost, lack of light, and excess moisture. It prefers moderately acidic habitats of deep, humid soils with moderate nitrogen concentrations and can also grow on somewhat poorer soils such as sandy or salty ones. *Prunus serotina* shows resistance to various pollutions and even to the pesticide effects of the certain repellents. Its incredibly high hardiness ability and tendency to easily produce larger amount of seeds allows it to successfully expand and have an impact on various types of ecosystems (Muys et al. 1992, Starfinger 2010, Thijs et al. 2012). *P. serotina* disperses by seeds but has a very efficient asexual reproduction by suckering and sprouting. If it is sufficiently exposed to light, it produces an abundant quantity of seeds since the age of seven. Seeds are dispersed by birds and frugivorous mammals (Muys et al. 1992). While its growth rate and/or mass seed production is approximately proportional to light availability, *P. serotina* also holds competitive advantage of enabling its seedlings to persist as ageing juveniles in the dense shade conditions, giving itself the opportunity to disperse again in more favorable, open-gap conditions (Closset-Kopp et al. 2007).

Studies on the invasion of *P. serotina* and its effects have been published by many researchers (Bijak et al. 2014, Halarewicz et al. 2014, Aerts et al. 2017). According to the European alien species checklist database (Klotz 2007), *P. serotina* takes place as an invasive plant species with an existing evidence on various impacts (environmental, social and/or economic) in Europe (Klotz 2007, Kettunen et al. 2009, Sitzia et al. 2016). It covers large parts of the continental European lowlands, reaching high abundance and invasive status in Germany, especially the northern half of the country (Kowarik 1995), the Netherlands (Klotz 2007, Vanhellemont et al. 2010), Denmark (Andersen 1995), Poland (Bijak et al. 2014), Belgium (Godefroid et al. 2005, Vanhellemont 2009, Vanhellemont et al. 2010), Switzerland (Wittenberg 2005), the Czech Republic (Vanhellemont 2009, Pyšek et al. 2012) and Southern England (CABI Undated, EPPO Global Database 2020).

In accordance with the European regulation on Invasive Alien Species (IAS), the black cherry tree has recently been indicated as one of the 96 species proposed for the development of the national list of priority invasive alien species in Italy (Forte et al. 2019). In Slovenia, on the other hand, current status has not been yet extensively studied. As far as it is known, only few places are currently naturalized with an invasive tendencies (LIFE ARTEMIS, Undated).

Furthermore, the existing data from Nikolić 2005 (Flora Croatica Database) indicate the presence of *P. serotina* species in some parts of Croatia (Figure 1). *P. serotina* occurrence has been recorded in Arboretum Lisičine (Idžojtić et al. 2011) as well as in Đurđevački peski Arboretum (Ređep 2017). The data on its distribution within forest complexes and natural habitats are still missing. Unlike in many European countries, in Croatia *P. serotina* is still not on the invasive species list.

Also, according to the EPPO Global Database *P. serotina* observation point, the presence of *P. serotina* in Croatia still lacks the information details (https://gd.eppo.int/taxon/PRNSO/distribution/HR). Lack of national inventories of *P. serotina* populations emphasizes the importance of its further monitoring in our area.

This paper deals with the possible invasiveness of the black cherry in Croatia. Due to its fast growing capability and

Figure 1. Current data of *P. serotina*'s presence in Croatia (https://hirc.botanic.hr/fcd/).

the potential to establish dense shrub layer in sparse forests, it may outcompete some native plant species and become the source or decreasing biodiversity. Its significant spread in pedunculate oak forest regeneration area motivated us to find the most adequate way of tracking its further expansion and development.

The objectives are to determine its spreading area, status and its impact on the native plant species by monitoring over a certain period of time.

MATERIALS AND METHODS

A research area of the *P. serotina* distribution is located in the Jastrebarsko Forest Office as part of the management unit of "Jastrebarske prigorske šume" and subcompartment 19a with the total size of 11.73 ha (Figure 2).

The research area is a former forest culture that consisted of Weymouth pine (*Pinus strobus*) as main species together with Scots pine (*P. sylvestris*) and Norway spruce (*Picea abies*). The area was affected with two mayor windbreaks in 2014 and 2016, resulting with more openings in the canopy layer and degradation of forest structure and habitat. This ended up in 2017 with the replantation of pedunculate oak (*Quercus robur* L.) seedlings inside polypropylene tree shelters in the amount of 8000 seedlings per 4 ha.

According to Köppen climate classification, the area belongs to the "Cfwbx" type of climate. This indicates moderately warm, rainy climate where the mean temperature of the coldest month in the year is between -3°C and 18°C and the warmest is between 10°C and 22°C. The surrounding forest area belongs to *Carpino betuli-Quercetum roboris* (Anić 1959, Rauš 1971) with a typical pseudogley soil type. The first dissemination data of the *P. serotina* in this area date from 15th September 2018.

In order to perform area monitoring we did an areal recording four times in 2019-2021 period (3rd May and 7th June 2019, on 30th June 2020 and on 16th August 2021). It was performed with the use of the unmanned aerial vehicle (UAV) DJI Mavic 2 Pro equipped with standard RGB sensor. These images were used to determine the size of the affected area with *P. serotina* speciments. The mission was planned with DJI Ground Station Pro app for iOS. It was

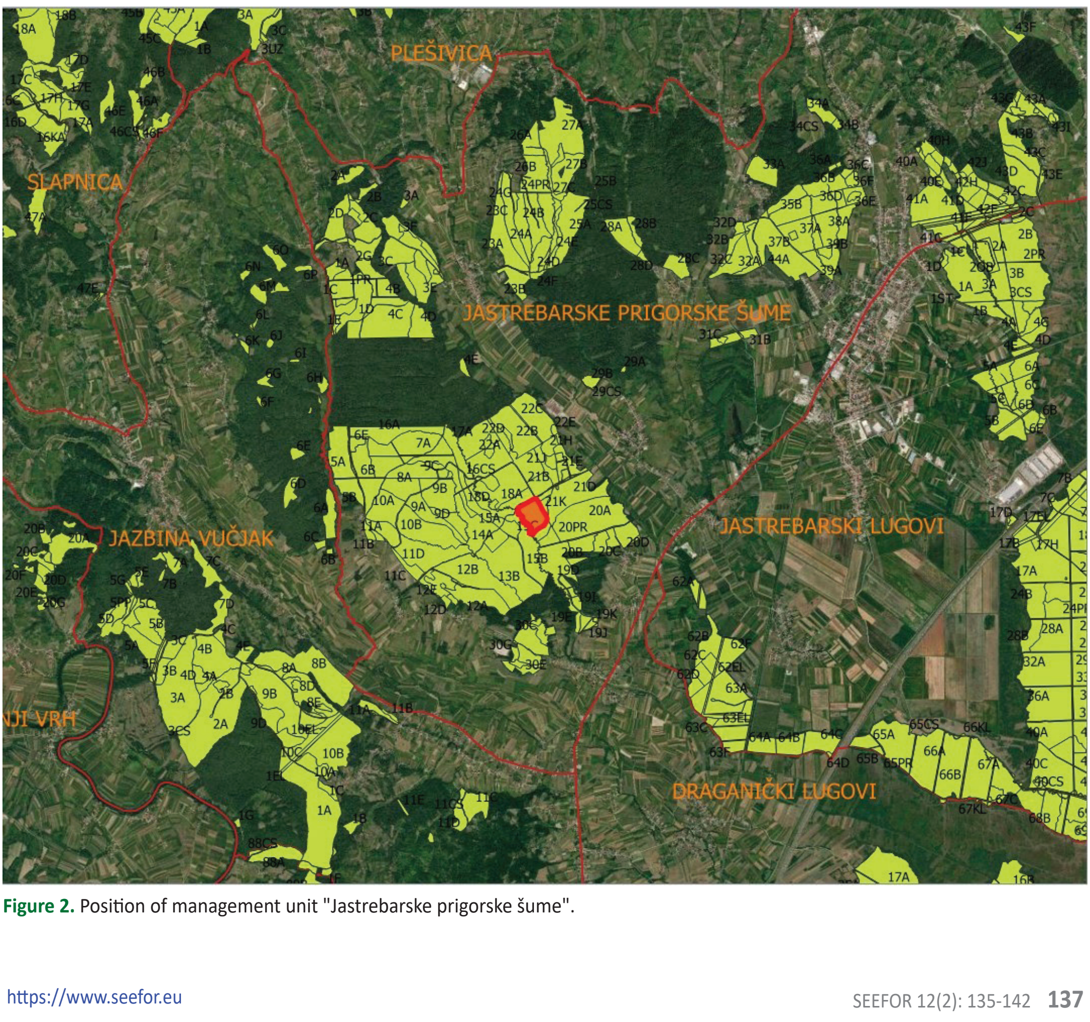

Figure 2. Position of management unit "Jastrebarske prigorske šume".

conducted with 80% front overlap ratio and 75% side overlap which allowed high quality of post flight image processing. The above ground flight was set to 90 meters, resulting with 2.1 cm pixel resolution. Post flight data processing, which included photos alignment, dense cloud build, mesh build and lastly orthomosaic build, was performed using AgiSoft PhotoScan Professional (Version 1.5.5) software. Map of the area was created using QGIS software (QGIS Development Team, http://qgis.osgeo.org). The size of the area affected by black cherry was calculated with QGIS geometry tools.

In order to research habitat characteristics of the area and possible *P. serotina* invasion, we performed vegetation survey according to the standard Brown-Blanquet method (1964) during the high vegetation season on 27th July 2020 and on 2nd August 2021.

RESULTS

Spreading Data

The first report of the *P. serotina* occurrence in forest ecosystem of western Croatia dates from September 2018, when spreading of the "unknown" woody species was detected by local foresters. Herbarium material was collected and brought to Croatian Forest Research Institute where it was identified as *P. serotina* species. The affected area of approximately 200 m^2 in 2018 was reported during the stand tending activities.

Based on the conducted research process, the estimated area of the black cherry expanded to 480.75 m^2 in 2019. It increased its distribution area considerably in comparison to the reported one in 2018.

After this significant spread, the interpretation of aerial images showed no change in the infested area in 2020 and 2021. Even though further spreading of *P. serotina* was successfully prevented by forest tending activities, mechanical measures did not manage to totally remove *P. serotina* off the regeneration area.

Vegetation Data

The results of phytosociological survey in the regeneration area affected with *P. serotina* showed that it mostly consists of pioneer and a fast growing, heliophilic flora. As it can be seen in Table 1, the high shrub is mostly overlaid by *P. serotina* (Figure 5).

The herb layer is mostly covered by *Solidago gigantea*, together with other invasive species such as *Phytolacca americana*, *Ambrosia artemisifolia*, *Erigeron annuus* and other stress-tolerant species: *Eupatorium cannabinum* and *Pteridium aquilinum*. In 2021 some species were missing, such as: *Abies alba, Calluna vulgaris, Angelica sylvestris, Asarum europaeum, Athyrium filix-femina*, *Centaurea jacea, Dryopteris filix-mas, Equisetum aquilinum, Fragaria vesca, Glechoma hederacea, Humulus lupulus, Pinus strobus* and *Pulmonaria officinalis*.

Vegetation survey of the surrounding forest area of *Carpino betuli-Quercetum roboris* community indicates typical floral composition for this community. We detected herbaceous invasive plant species such as *Phytolacca americana* and *Erigeron annuus*, but no presence of *Prunus serotina* specimens.

Table 1. Phytocenological recordings of both regeneration area.

		Regeneration area	
		2 August 2020	27 July 2021
Relevé area (m^2)		400	
Altitude (m)		155	
Slope (degrees)		<10	
Exposure		SW	
Cover tree layer (%)		.	.
Cover shrub layer (%)		70	70
Cover herb layer (%)		70	70
X-coordinate		45.64568	
Y-coordinate		15.58830	
Prunus serotina	s1	4	4
Rubus fructicosus	s1	2	2
Quercus robur	s1	1	1
Carpinus betulus	s1	1	1
Salix caprea	s1	1	1
Frangula alnus	s1	+	1
Populus alba	s1	+	1
Abies alba	s1	+	.
Pinus strobus	s1	+	+
Populus tremula	s1	+	+
Alnus glutinosa	s1	+	+
Solidago gigantea	hl	2	2
Eupatorium cannabinum	hl	2	2
Phytolacca maericana	hl	1	1
Pteridium aquilinum	hl	1	1
Calluna vulgaris	hl	1	.
Genista tinctoria	hl	1	+
Ambrosia artemisifolia	hl	+	+
Angelica sylvestris	hl	+	.
Asarum europaeum	hl	+	.
Athyrium filix-femina	hl	+	.
Calamagrostis epigejos	hl	+	+
Carpinus betulus	hl	.	+
Centaurea jacea	hl	+	.
Cirsium palustre	hl	+	+
Dryopteris filix-mas	hl	+	.
Equisetum sylvaticum	hl	+	.
Erigeron annuus	hl	+	+
Fragaria vesca	hl	+	.
Glechoma hederacea	hl	+	.
Humulus lupulus	hl	+	.
Juncus effusus	hl	+	+
Lycopus europaeus	hl	+	+
Lysimachia vulgaris	hl	+	+
Lythrum salicaria	hl	+	+
Pinus strobus	hl	.	.
Potentilla erecta	hl	+	+
Pulmonaria officinalis	hl	+	.
Salix caprea	hl	.	+
Scrophularia nodosa	hl	+	+
Tanacetum vulgare	hl	+	+
Viola reichenbachiana	hl	+	+

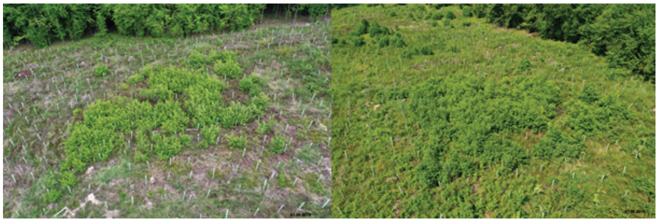

Figure 3. Black cherry group in subcompartment 19a in May and June 2019.

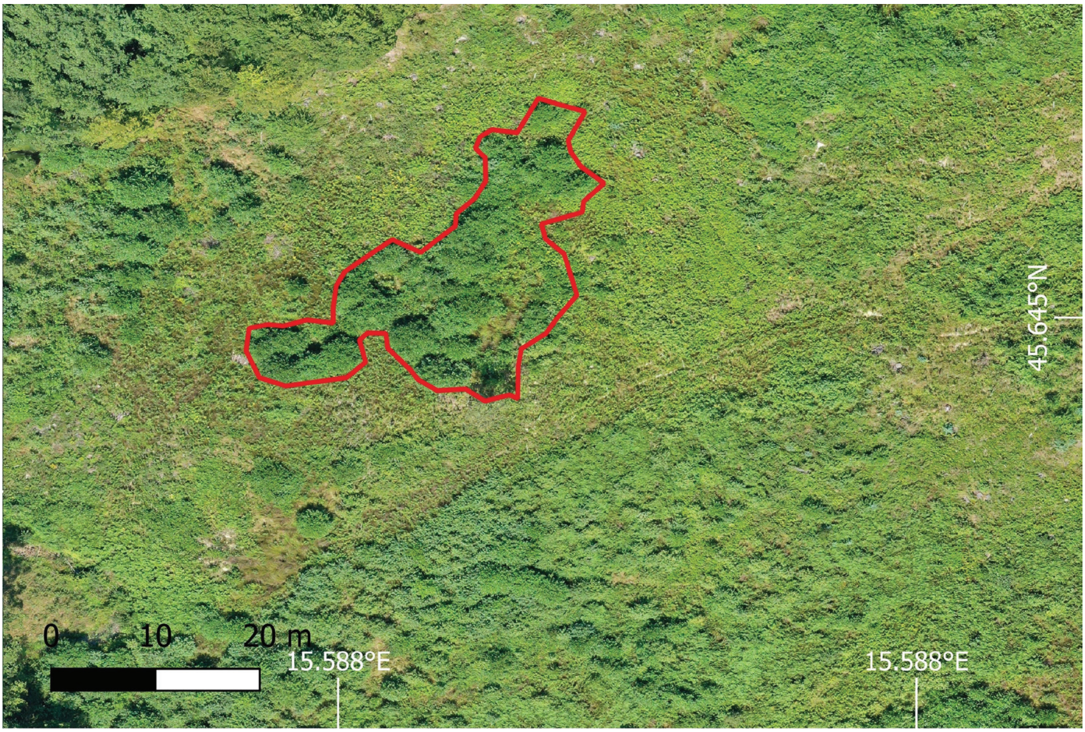

Figure 4. Size of the affected area by *P. serotina*.

Figure 5. Rapid *P. serotina* development suppresses growth of other species.

DISCUSSION

Structural complexity and continuous canopy cover represent one of the main characteristics that insure stability of the forest community. When, at some point, this stability is disrupted, both by anthropogenic and/or natural large-scale disturbances ending with a canopy cover fragmentation, the habitat becomes exposed to potential invasive species' development.

This highlights degradation issue which consequently, in the majority of cases, often leads to vitality disruption and invasive species settlement. Also, the ability of *P. serotina* to naturalize in less favourable environmental conditions, as well as not having direct competitors with a similar life strategy, contributes to its successful expansion and domination upon the native species regeneration process (Starfinger 1997). *P. serotina*'s tendency to easily produce abundant quantity of seed and disperse it by birds and frugivorous mammals can also allow its appearance and successfully expand in various types of ecosystems (Muys et al. 1992, Starfinger 2010), as well as in the regeneration area.

Although the first record of *P. serotina* in this area dates from 2018 we do not know exactly when the first specimen appeared, but we can assume, according to its spreading size, that it happened several years before, as part of the former forest culture. This has been also confirmed by many researches that presume pre-gap patterns in the understorey, rather than postgap partioning, largely determine gap composition. It refers to a fact that species that are present in the understorey at the time of gap creation (chance occupants) are the ones that fill the open area and not the best adapted species (Fraver et al. 1998, Brokaw 2000, Closset-Kopp et al. 2006). According to the Closset-Kopp et al. 2006, this 'sit-and wait' strategy is quite common among co-occurring tree species in *P. serotina*'s native range (e.g. *Fagus grandifolia, Quercus alba, Acer pensylvanicum, Tsuga canadensis*), but it is almost unknown for tree species of European temperate forests. This life plasticity greatly contributes to *P. serotina* invasiveness and explains its rapid spread in the regeneration area in the first year of monitoring.

After its significant spreading progression in the regeneration area in 2019, the use of visual image interpretation elements (Lillesan et al. 2008) in 2020 and 2021 showed no expansion or reduction in size covered with *P. serotina* specimens.

Since *P. serotina* was continuously subjected to the above-ground removal treatments (partial-cutting) of essentially all shrub and herb layer vegetation with a mulcher, twice a year (at the beginning of spring and in the late summer period), it contributed to stopping the spreading of the species in the last 2 years of our monitoring process.

Even though mechanical measures did not manage to totally remove *P. serotina* specimens off the regeneration area, they represent its spreading control method in the regeneration area. If we consider the number of other cases undergone *P. serotina*'s removal (Muys et al. 1992, Van Den Meersschaut et al. 1997, Oosterbann 2005, Annighöfer et al. 2012), when it comes to successful control measures, a combination of often mechanical and chemical methods is used. Mechanical suppression alone, especially by the above-ground biomass removal, has proven inadequate and it is questionable to what extent it would be considered sufficient for its effective suppression in the regeneration area in the future (Muys et al. 1992). Considering such results from different researches, it is also highly important to continue the monitoring of the spreading area in the pedunculate oak regeneration area.

Vegetation survey of the area affected by *P. serotina* showed the expected presence of regeneration area species such as *Rubus fruticosus, Salix caprea, Populus alba, Frangula alnus* and high abundance of *P. serotina* in the shrub layer in both 2020 and 2021. Although invasive species (*Phytolacca americana, Ambrosia artemisifolia, Erigeron annuus, Solidago gigantea*) did not increase their cover significantly, their population became denser and more vigorous after tending activities. Possibly, this lead to repression of some habitat-specific species (*Asarum europaeum, Athyrium filix-femina*, *Dryopteris filix-mas, Equisetum aquilinum, Fragaria vesca, Glechoma hederacea, Pulmonaria officinalis*), in just one year.

Vegetation survey of the surrounding *Carpino betuli-Quercetum roboris* forest community reflects the structural stability regarding canopy cover as well as the floristic composition, without the presence of *P. serotina* specimens. Although some researches suggest possibilities of *P. serotina* to invade the natural forest ecosystems (Closset-Kopp et al. 2007, Bijak et al. 2014), we assume that the stability of the forest ecosystem with continuous canopy cover layer is the first and crucial point in fighting invasive plant species.

CONCLUSIONS

This research brought up the first record of *Prunus serotina* species in pedunculate oak forest regeneration area of western Croatia. Initial significant expansion of the *P. serotina* specimens in the first year of monitoring process indicated its invasive character. *P. serotina* needs to be put on the Croatian National Invasive Species list. The other two-year vegetation survey monitoring showed no change in *P. serotina* spreading. This does not only relate to *P. serotina*, but to other invasive and non-invasive species as well. Mechanical measures, in this case, as a part of a regularly conducted tending activities, represent a potential spreading control method of *P. serotina.* This method of monitoring by using the unmanned aerial vehicle with basic RGB sensors showed the possibility for a fast and easy detection of species. This can also be used for fast on-site inspection of other large areas at a low cost. We recommend to continue the monitoring survey of *P. serotina* in order to prevent and control its spread in the future.

Author Contributions

JM and SP conceived and designed the research. JM, IS and NZ carried out the field activities, NZ processed the data and performed area surveying while JM and IS performed phytosociological approach. JM and SP secured the research funding and JM supervised the research. JM and IS and NZ wrote the manuscript. JM helped to draft the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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